The Twisted Documentation

The Twisted Development Team

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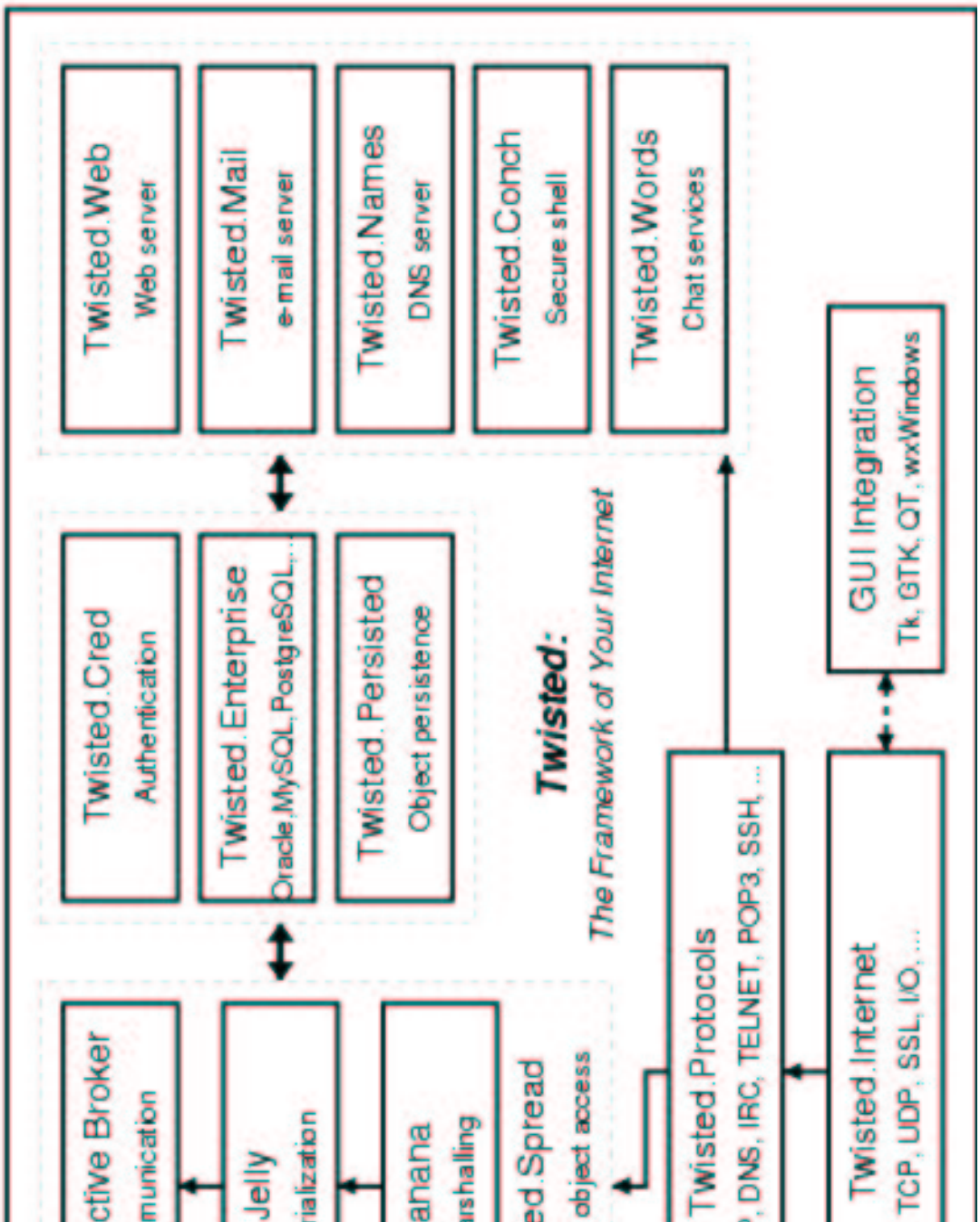
Chapter 1

Introduction

1.1 High-Level Overview of Twisted



1.2 The Vision For Twisted

Many other documents in this repository are dedicated to defining what Twisted is. Here, I will attempt to explain not what Twisted is, but what it should be, once I've met my goals with it.

First, Twisted should be fun. It began as a game, it is being used commercially in games, and it will be, I hope, an interactive and entertaining experience for the end-user.

Twisted is a platform for developing internet applications. While python, by itself, is a very powerful language, there are many facilities it lacks which other languages have spent great attention to adding. It can do this now; Twisted is a good (if somewhat idiosyncratic) pure-python framework or library, depending on how you treat it, and it continues to improve.

As a platform, Twisted should be focused on integration. Ideally, all functionality will be accessible through all protocols. Failing that, all functionality should be configurable through at least one protocol, with a seamless and consistent user-interface. The next phase of development will be focusing strongly on a configuration system which will unify many disparate pieces of the current infrastructure, and allow them to be tacked together by a non-programmer.

Twisted should be a collaboration application. The next major phase of development will also involve lots of chat, mail, and news functionality, both in clients and in servers.

Finally, Twisted should be a personal information space as well as a shared one. Twisted should unify all your messages and contacts for you across multiple machines and in multiple environments, through multiple modes of access, while also being industrial-strength enough to run the back end of an online sales service with millions of users.

1.3 Overview of Twisted Internet

Twisted Internet is a compatible collection of event-loops for Python. It contains the code to dispatch events to interested observers, and a portable API so that observers need not care about which event loop is running. Thus, it is possible to use the same code for different loops, from Twisted's basic, yet portable, `select`-based loop to the loops of various GUI toolkits like GTK+ or Tk. Twisted Internet also contains a powerful persistence API so that network programs can be shutdown and then resurrected with most of the code unaware of this.

Twisted Internet contains the various interfaces to the reactor API, whose usage is documented in the low-level chapter. Those APIs are `IReactorCore`, `IReactorTCP`, `IReactorSSL`, `IReactorUNIX`, `IReactorUDP`, `IReactorTime`, `IReactorProcess` and `IReactorThreads`. The reactor APIs allow non-persistent calls to be made.

Twisted Internet also covers the interfaces for the various transports, in `ITransport` and friends. These interfaces allow Twisted network code to be written without regard to the underlying implementation of the transport.

The `IProtocolFactory` dictates how factories, which are usually a large part of third party code, are written.

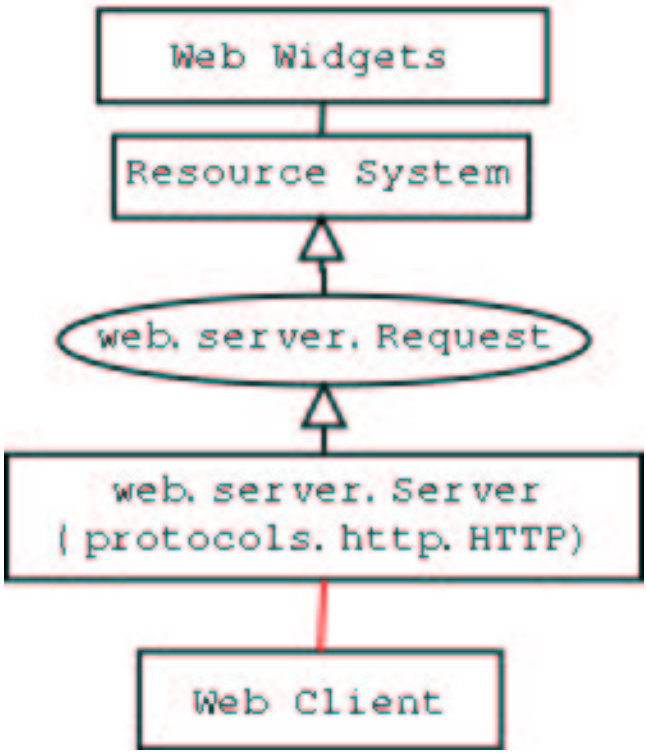
The `app.Application` class allows for a similar API to the reactor, which is automatically persistent. Applications usually persist and resurrect automatically, depending on the usage. See *the Application documentation* (page 38) for more information.

1.4 Overview of Twisted Web

1.4.1 Introduction

Twisted Web is a web application server written in pure Python, with APIs at multiple levels of abstraction to facilitate different kinds of web programming. The most useful for web application designers is *Woven* (page 160), a high-level MVC-and-template oriented system. There is also the Resource system, which Woven is built on.

1.4.2 Twisted Web's Structure



When the Web Server receives a request from a Client, it creates a Request object and passes it on to the Resource system. The Resource system dispatches to the appropriate Resource object based on what path was requested by the client. The Resource is asked to render itself, and the result is returned to the client.

1.4.3 Resources

Resources are the lowest-level abstraction for applications in the Twisted web server. Each Resource is a 1:1 mapping with a path that is requested: you can think of a Resource as a single "page" to be rendered. The interface for making Resources is very simple; they must have a method named `render` which takes a single argument, which is the Request object (an instance of `twisted.web.server.Request`). This render method must return a string, which will be returned to the web browser making the request. Alternatively, they can return a special constant,

`twisted.web.server.NOT_DONE_YET`, which tells the web server not to close the connection; you must then use `request.write(data)` to render the page, and call `request.finish()` whenever you're done.

1.4.4 Woven

Woven is an added layer of abstraction over Resources – it's much nicer for most sorts of web applications. For more information on Woven, see *Woven Overview* (page 160).

1.5 Overview of Twisted Spread

Perspective Broker (affectionately known as "PB") is an asynchronous, symmetric[1], network protocol for secure, remote method calls. PB is "translucent, not transparent", meaning that it is very visible and obvious to see the difference between local method calls and potentially remote method calls, but remote method calls are still extremely convenient to make, and it is easy to emulate them to have objects which work both locally and remotely.

PB supports user-defined serialized data in return values, which can be either copied each time the value is returned, or "cached": only copied once and updated by notifications.

PB gets its name from the fact that access to objects is through a "perspective". This means that when you are responding to a remote method call, you can establish who is making the call.

1.5.1 Rationale

No other currently existing protocols have all the properties of PB at the same time. The particularly interesting combination of attributes, though, is that PB is flexible and lightweight, allowing for rapid development, while still powerful enough to do two-way method calls and user-defined data types.

It is important to have these attributes in order to allow for a protocol which is extensible. One of the facets of this flexibility is that PB can integrate an arbitrary number of services could be aggregated over a single connection, as well as publish and call new methods on existing objects without restarting the server or client.

1.6 Introduction to Twisted Enterprise

1.6.1 Abstract

Twisted is an asynchronous networking framework, but most database API implementations unfortunately have blocking interfaces – for this reason, `twisted.enterprise.adbapi` was created. It is a non-blocking interface to the standardized DB-API 2.0 API, which allows you to access a number of different RDBMSes.

1.6.2 What you should already know

- Python :-)
- How to write a simple Twisted Server (see *this tutorial* (page 68) to learn how)

[1] There is a negotiation phase for banana with particular roles for listener and initiator, so it's not *completely* symmetric, but after the connection is fully established, the protocol is completely symmetrical.

- Familiarity with using database interfaces (see the documentation for DBAPI 2.0[2] or this article[3] by Andrew Kuchling)

1.6.3 Quick Overview

Twisted is an asynchronous framework. This means standard database modules cannot be used directly, as they typically work something like:

```
# Create connection...
db = dbmodule.connect('mydb', 'andrew', 'password')
# ...which blocks for an unknown amount of time

# Create a cursor
cursor = db.cursor()

# Do a query...
resultset = cursor.query('SELECT * FROM table WHERE ...')
# ...which could take a long time, perhaps even minutes.
```

Those delays are unacceptable when using an asynchronous framework such as Twisted. For this reason, twisted provides `twisted.enterprise.adbapi`, an asynchronous wrapper for any DB-API 2.0[4]-compliant module. It is currently best tested with the pyPgSQL[5] module for PostgreSQL[6].

`enterprise.adbapi` will do blocking database operations in seperate threads, which trigger callbacks in the originating thread when they complete. In the meantime, the original thread can continue doing normal work, like servicing other requests.

1.6.4 How do I use adbapi?

Rather than creating a database connection directly, use the `adbapi.ConnectionPool` class to manage a connections for you. This allows `enterprise.adbapi` to use multiple connections, one per thread. This is easy:

```
# Using the "dbmodule" from the previous example, create a ConnectionPool
from twisted.enterprise import adbapi
dbpool = adbapi.ConnectionPool("dbmodule", 'mydb', 'andrew', 'password')
```

Things to note about doing this:

- There is no need to import dbmodule directly. You just pass the name to `adbapi.ConnectionPool`'s constructor.
- The parameters you would pass to dbmodule.connect are passed as extra arguments to `adbapi.ConnectionPool`'s constructor. Keyword parameters work as well.

[2] http://www.python.org/topics/database/DatabaseAPI-2.0.html
[3] http://www.amk.ca/python/writing/DB-API.html
[4] http://www.python.org/topics/database/DatabaseAPI-2.0.html
[5] http://pypgsql.sourceforge.net/
[6] http://www.postgresql.org/

- You may also control the size of the connection pool with the keyword parameters `cp_min` and `cp_max`. The default minimum and maximum values are 3 and 5.

So, now you need to be able to dispatch queries to your ConnectionPool. We do this by subclassing `adbapi.Augmentation`. Here's an example:

```
class AgeDatabase(adbapi.Augmentation):
    """A simple example that can retrieve an age from the database"""
    def getAge(self, name):
        # Define the query
        sql = """SELECT Age FROM People WHERE name = ?"""
        # Run the query, and return a Deferred to the caller to add
        # callbacks to.
        return self.runQuery(sql, name)


def gotAge(resultlist, name):
    """Callback for handling the result of the query"""
    age = resultlist[0][0]          # First field of first record
    print "%s is %d years old" % (name, age)

db = AgeDatabase(dbpool)

# These will *not* block.  Hooray!
db.getAge("Andrew").addCallbacks(gotAge, db.operationError,
                                 callbackArgs=("Andrew",))
db.getAge("Glyph").addCallbacks(gotAge, db.operationError,
                                callbackArgs=("Glyph",))

# Of course, nothing will happen until the reactor is started
from twisted.internet import reactor
reactor.run()
```

This is straightforward, except perhaps for the return value of `getAge`. It returns a `twisted.internet.defer.Deferred`, which allows arbitrary callbacks to be called upon completion (or upon failure). More documentation on Deferred is available *here* (page 82).

Also worth noting is that this example assumes that dbmodule uses the "qmarks" paramstyle (see the DB-API specification). If your dbmodule uses a different paramstyle (e.g. pyformat) then use that. Twisted doesn't attempt to offer any sort of magic paramater munging – `runQuery(query, params, ...)` maps directly onto `cursor.execute(query, params, ...)`.

1.6.5 And that's it!

That's all you need to know to use a database from within Twisted. You probably should read the adbapi module's documentation to get an idea of the other functions it has, but hopefully this document presents the core ideas.

1.7 Why and How to use Twisted.Cred

1.7.1 Authentication and Account Management in Twisted

(This document is a work in progress. Later it will include some examples but for now a brief explanation is better than nothing!)

Twisted unifies authentication and account management of multiple services in the Twisted.Cred package. Although this authentication model was originally designed to integrate services in the *Perspective Broker* (page 14) remote method invocation protocol, it is useful in many kinds of servers, and work is underway to move all systems that require log-in in Twisted to use twisted.cred.

In order to use twisted.cred, your code has to be structured around a subclass of `Service`. A service is a particular unit of functionality which has a way to request `Perspective` objects. You will probably have to subclass both of these.

In order to simplify integration of services that come from lots of different places, Twisted.Cred presents user-account related information in two different ways. Application-independent user information, such as passwords, public keys, and other things related to the existence and authentication of a particular person should reside in an `Identity`. Information related to a particular service, such as e-mail messages, high scores, or to-do lists should be represented by a `Perspective`.

In support of these two basic abstractions is the `Authorizer`. An authorizer serves primarily as the storage mechanism for a collection of identities. Its usage varies depending on whether the services it is providing authentication for can support multiple services on one port. `Authorizer` is an abstract class, but you don't need to implement your own; the simplest authorizer to get started with is `DefaultAuthorizer`.

At this point, there are basically 2 ways that an authorizer can be used. It is either the root of a PB object hierarchy, or simply the authorizer for some number of non-PB services.

Setting Up a Service

```
from twisted.internet.app import MultiService
# A service which collects other services.
from twisted.cred.authorizer import DefaultAuthorizer
# A simple in-memory Authorizer implementation.
from my.service import MyService, OtherService
# Two sample user-written services.

multiserv = MultiService("pb")
# multiservice named "pb" to hold other services
auth = DefaultAuthorizer()
auth.setApplication(multiserv)
# the authorizer for both of our other services
myserv = MyService("my service", multiserv, auth)
otherserv = OtherService("another service", multiserv, auth)
# create both of our services pointing to their authorizer

from twisted.internet import reactor
from twisted.spread import pb
reactor.listenTCP(pb.portno, pb.AuthRoot(auth))
```

```
# If the services are all pb.Service subclasses, we can connect them to a
# network like this.  It will look up services through the serviceCollection
# passed to the Authorizer; which in this case was a MultiService but could
# also be an Application.
```

1.8 Overview of Twisted IM

Twisted IM (Instance Messenger) is a multi-protocol chat framework, based on the Twisted framework we've all come to know and love. It's fairly simple and extensible in two directions - it's pretty easy to add new protocols, and it's also quite easy to add new front-ends.

1.8.1 Code flow

Twisted IM is usually started from the file `twisted/scripts/im.py` (maybe with a shell-script wrapper or similar). Twisted currently comes with two interfaces for Twisted IM - one written in GTK for Python under Linux, and one written in Swing for Jython. `im.py` picks an implementation and starts it - if you want to write your own interface, you can modify `im.py` to start it under appropriate conditions.

Once started, both interfaces behave in a very similar fashion, so I won't be getting into differences here.

AccountManager

Control flow starts at the relevant subclass of `baseaccount.AccountManager`. The AccountManager is responsible for, well, managing accounts - remembering what accounts are available, their settings, adding and removal of accounts, and making accounts log on at startup.

This would be a good place to start your interface, load a list of accounts from disk and tell them to login. Most of the method names in `AccountManager` are pretty self-explanatory, and your subclass can override whatever it wants, but you *need* to override `__init__`. Something like this:

```
def __init__(self):
self.chatui = ... # Your subclass of basechat.ChatUI
self.accounts = ... # Load account list
for a in self.accounts:
a.logOn(self.chatui)
```

ChatUI

Account objects talk to the user via a subclass of `basechat.ChatUI`. This class keeps track of all the various conversations that are currently active, so that when an account receives and incoming message, it can put that message in its correct context.

How much of this class you need to override depends on what you need to do. You will need to override `getConversation` (a one-on-one conversation, like an IRC DCC chat) and `getGroupConversation` (a multiple user conversation, like an IRC channel). You might want to override `getGroup` and `getPerson`.

The main problem with the default versions of the above routines is that they take a parameter, `Class`, which defaults to an abstract implementation of that class - for example, `getConversation` has a `Class` parameter that

defaults to `basechat.Conversation` which raises a lot of `NotImplementedError`s. In your subclass, override the method with a new method whose Class parameter defaults to your own implementation of `Conversation`, that simply calls the parent class' implementation.

Conversation and GroupConversation

These classes are where your interface meets the chat protocol. Chat protocols get a message, find the appropriate `Conversation` or `GroupConversation` object, and call its methods when various interesting things happen.

Override whatever methods you want to get the information you want to display. You must override the `hide` and `show` methods, however - they are called frequently and the default implementation raises `NotImplemented Error`.

Accounts

An account is an instance of a subclass of `basesupport.AbstractAccount`. For more details and sample code, see the various `*support` files in `twisted.im`.

Chapter 2

The Basics

2.1 Installing Twisted

2.1.1 Installation

If you are on Windows, you may want to skip this and simply get the Windows Installer version of Twisted from the download page[1].

If you are on Debian. you may want to use the Debian packages. The last stable release of Twisted is at "deb http://twistedmatrix.com/users/moshez/apt ./", and the last prerelease of Twisted is at "deb http://twistedmatrix.com/users/moshez/snapshot ./"

To install Twisted, just make sure the `Twisted-$VERSION/` directory is in the `PYTHONPATH` environment variable. For example, if you extracted Twisted-1.0.5.tar.gz to /home/bob/, then you would have something like:

```
export PYTHONPATH=$PYTHONPATH:/home/bob/Twisted-1.0.5/
```

in your `~/.bash_profile`, `~/.zshrc`, `~/.cshrc`, etc. If you use Windows NT, 2000, or XP, then set your environment variables by right-clicking on My Computer and selecting Properties, then the Advanced tab, and click on the "Environment Variables" button. If you use some other version of windows, you'll need to set the variable at a command prompt, or in autoexec.bat, with the 'set' command.

If you'd like to install Twisted system-wide on your machine and into the default `PYTHONPATH`, you can use `setup.py` to do so:

```
# python ./setup.py install
```

Be sure to run `setup.py` with appropriate privileges (root under Unix).

2.1.2 Optional Compilation

There are a couple of small optional alternative implementations of pieces of Twisted that are in C for increased performance. If you don't run the installer, and you need these modules, you'll need to perform a couple of extra steps:

[1] http://www.twistedmatrix.com/products/download

```
$ python ./setup.py build_ext
```

This will (eventually) generate some shared libraries (cBanana.so, cReactor.so) within a directory tree called 'build' under the Twisted directory.

If you don't go on to install the build results into a directory on the `$PYTHONPATH`, then you will need to create a couple of symlinks:

```
$ cd twisted/spread
$ ln -s ../../build/lib.linux-i686-2.1/twisted/spread/cBanana.so cBanana.so
$ cd ../internet
$ ln -s ../../build/lib.linux-i686-2.1/twisted/internet/cReactor.so cReactor.so
```

The exact details of the symlinks may vary based on your system.

2.1.3 Running Tests

See our unit tests run, proving that the software is BugFree(TM):

```
% admin/runtests
```

(From the directory where Twisted was originally untarred/unzipped to.)

Some of these tests will fail if you don't have the Crypto packages installed on your system.

2.2 The Basics

2.2.1 Application

Twisted programs usually work with `twisted.internet.app.Application`. This class usually holds all persistent configuration of a running server – ports to bind to, places where connections to must be kept or attempted, periodic actions to do and almost everything else.

Other HOWTOs describe how to write custom code for Applications, but this one describes how to use already written code (which can be part of Twisted or from a third-party Twisted plugin developer). The Twisted distribution comes with an assortment of tools to create and manipulate `Application`s.

`Application`s are just Python objects, which can be created and manipulated in the same ways as any other object. In particular, they can be serialized to files. Twisted supports several serialization formats.

2.2.2 Serialization

TAP A Twisted Application Pickle. This format is supported by the native Python pickle support. While not being human readable, this format is the fastest to load and save.

TAX Twisted contains `twisted.persisted.marmalade`, a module that supports serializing and deserializing from a format which follows the XML standard. This format is human readable and editable.

TAS Twisted contains `twisted.persisted.aot`, a module that supports serializing into Python source. This has the advantage of using Python's own parser and being able to later manually add Python code to the file.

2.2.3 mktap and tapconvert

The `mktap(1)` utility is the main way to create a TAP (or TAX or TAS) file. It can be used to create an Application for all of the major Twisted server types like web, ftp or IRC. It also supports plugins, so when you install a Twisted plugin (that is, unpack it into a directory on your `PYTHONPATH`) it will automatically detect it and use any Twisted Application support in it. It can create any of the above Application formats.

In order to see which server types are available, use `mktap --help`. For a given server, `mktap --help <name>` shows the possible configuration options. `mktap` supports a number of generic options to configure the application – for full details, read the man page.

One important option is `--append <filename>`. This is used when there is already a Twisted application serialized to which a server should be added. For example, it can be used to add a telnet server, which would let you probe and reconfigure the application by telnetting into it.

Another useful utility is `tapconvert(1)`, which converts between all three Application formats.

2.2.4 twistd

Having an `Application` in a variety of formats, aesthetically pleasing as it may be, does not actually cause anything to happen. For that, we need a program which takes a "dead" Application and brings life to it. For UNIX systems (and, until there are are alternatives, for other operating systems too), this program is `twistd(1)`. Strictly speaking, `twistd` is not necessary – unserializing the application and calling its `.run` method could be done manually. `twistd(1)`, however, supplies many options which are highly useful for program set up.

`twistd` supports choosing a reactor (for more on reactors, see *Choosing a Reactor* (page 96)), logging to a logfile, daemonizing and more. `twistd` supports all Applications mentioned above – and an additional one. Sometimes is is convenient to write the code for building a class in straight Python. One big source of such Python files is the `doc/examples` directory. When a straight Python file which defines an `Application` object called `application` is used, use the `-y` option.

When `twistd` runs, it records its process id in a `twistd.pid` file (this can be configured via a command line switch). In order to shutdown the `twistd` process, kill that pid (usually you would do `kill 'cat twisted.pid'`). When the process is killed in an orderly fashion it will leave behind the "shutdown Application" which is named the same as the original file with a `-shutdown` added to its base name. This contains the new configuration information, as changed in the application.

As always, the gory details are in the manual page.

2.2.5 tap2deb

For Twisted-based server application developers who want to deploy on Debian, Twisted supplies the `tap2deb` program. This program wraps a Twisted Application file (of any of the supported formats – Python, source, xml or pickle) in a Debian package, including correct installation and removal scripts and `init.d` scripts. This frees the installer from manually stopping or starting the service, and will make sure it goes properly up on startup and down on shutdown and that it obeys the init levels.

For the more savvy Debian users, the `tap2deb` also generates the source package, allowing her to modify and polish things which automated software cannot detect (such as dependencies or relationships to virtual packages). In addition, the Twisted team itself intends to produce Debian packages for some common services, such as web servers and an inetd replacement. Those packages will enjoy the best of all worlds – both the consistency which comes from being based on the `tap2deb` and the delicate manual tweaking of a Debian maintainer, insuring perfect integration with Debian.

Right now, there is a beta Debian archive of a web server available at Moshe's archive[2].

2.3 Configuring and Using the Twisted.Web Server

2.3.1 Installation

To install the Twisted.Web server, you'll need to have *installed Twisted* (page 20).

Twisted servers, like the web server, do not have configuration files. Instead, you instantiate the server and store it into a 'Pickle' file, `web.tap`. This file will then be loaded by the Twisted Daemon.

```
% mktap web --path /path/to/web/content
```

If you just want to serve content from your own home directory, the following will do:

```
% mktap web --path ~/public_html/
```

Some other configuration options are available as well:

- `--port`: Specify the port for the web server to listen on. This defaults to 8080.
- `--logfile`: Specify the path to the log file.

The full set of options that are available can be seen with:

```
% mktap web --help
```

2.3.2 Using Twisted.Web

Stopping and Starting the Server

Once you've created your `web.tap` file and done any configuration, you can start the server:

```
% twistd -f web.tap
```

You can stop the server at any time by going back to the directory you started it in and running the command:

```
% kill `cat twistd.pid`
```

Serving Flat HTML

Twisted.Web serves flat HTML files just as it does any other flat file.

[2] http://twistedmatrix.com/users/moshez/debian

Resource Scripts

A Resource script is a Python file ending with the extension `.rpy`, which is required to create an instance of a (subclass of a) `twisted.web.resource.Resource`.

Resource scripts have 3 special variables:

- `__file__`: The name of the .rpy file, including the full path. This variable is automatically defined and present within the namespace.
- `registry`: An object of class `static.Registry`. It can be used to access and set persistent data keyed by a class.
- `resource`: The variable which must be defined by the script and set to the resource instance that will be used to render the page.

A very simple Resource Script might look like:

```
from twisted.web import resource
class MyGreatResource(resource.Resource):
    def render(self, request):
        return "<html>foo</html>"

resource = MyGreatResource()
```

A slightly more complicated resource script, which accesses some persistent data, might look like:

```
from twisted.web import resource
from SillyWeb import Counter

counter = registry.getComponent(Counter)
if not counter:
   registry.setComponent(Counter, Counter())
counter = registry.getComponent(Counter)

class MyResource(resource.Resource):
    def render(self, request):
        counter.increment()
        return "you are visitor %d" % counter.getValue()

resource = MyResource()
```

This is assuming you have the `SillyWeb.Counter` module, implemented something like the following:

```
class Counter:

    def __init__(self):
        self.value = 0

    def increment(self):
```

```
        self.value += 1

    def getValue(self):
        return self.value
```

Woven

The Woven API is an advanced system for giving web UIs to your application with something resembling MVC and templates. See *its documentation* (page 160) for more details.

Spreadable Web Servers

One of the most interesting applications of Twisted.Web is the distributed webserver; multiple servers can all answer requests on the same port, using the `twisted.spread` package for "spreadable" computing. In two different directories, run the commands:

```
% mktap web --user
% mktap web --personal [other options, if you desire]
```

Both of these create a `web.tap`; you need to run both at the same time. Once you have, go to `http://localhost:8080/your_username.twistd/` – you will see the front page from the server you created with the `--personal` option. What's happening here is that the request you've sent is being relayed from the central (User) server to your own (Personal) server, over a PB connection. This technique can be highly useful for small "community" sites; using the code that makes this demo work, you can connect one HTTP port to multiple resources running with different permissions on the same machine, on different local machines, or even over the internet to a remote site.

Serving PHP/Perl/CGI

Everything related to CGI is located in the `twisted.web.twcgi`, and it's here you'll find the classes that you need to subclass in order to support the language of your (or somebody elses) taste. You'll also need to create your own kind of resource if you are using a non-unix operatingsystem (such as Windows), or if the default resources has wrong pathnames to the parsers.

The following snippet is a .rpy that serves perl-files. Look at `twisted.web.twcgi` for more examples regarding twisted.web and CGI.

```
from twisted.web import static, twcgi

class PerlScript(twcgi.FilteredScript):
    filter = '/usr/bin/perl' # Points to the perl parser

resource = static.File("/perlsite") # Points to the perl website
resource.processors = {".pl": PerlScript} # Files that end with .pl will be
                                          # processed by PerlScript
resource.indexNames = ['index.pl']
```

Using VHostMonster

It is common to use one server (for example, Apache) on a site with multiple names which then uses reverse proxy (in Apache, via `mod_proxy`) to different internal web servers, possibly on different machines. However, naive configuration causes miscommunication: the internal server firmly believes it is running on "internal-name:port", and will generate URLs to that effect, which will be completely wrong when received by the client.

While Apache has the ProxyPassReverse directive, it is really a hack and is nowhere near comprehensive enough. Instead, the recommended practice in case the internal web server is Twisted.Web is to use VHostMonster.

From the Twisted side, using VHostMonster is easy: just drop a file named (for example) `vhost.rpy` containing the following:

```
from twisted.web import vhost
resource = vhost.VHostMonsterResource()
```

Of course, an equivalent `.trp` can also be used. Make sure the web server is configured with the correct processors for the `rpy` or `trp` extensions (the web server `mktap web --path` generates by default is so configured).

From the Apache side, instead of using the following ProxyPass directive:

```
<VirtualHost ip-addr>
ProxyPass / http://localhost:8538/
ServerName example.com
</VirtualHost>
```

Use the following directive:

```
<VirtualHost ip-addr>
ProxyPass / http://localhost:8538/vhost.rpy/http/example.com:80/
ServerName example.com
</VirtualHost>
```

Here is an example for Twisted.Web's reverse proxy:

```
from twisted.internet import app
from twisted.web import proxy, server, vhost
vhostName = 'example.com'
reverseProxy = proxy.ReverseProxyResource('internal', 8538,
                                          '/vhost.rpy/http/'+vhostName+'/')
root = vhost.NamedVirtualHost()
root.addHost(vhostName, reverseProxy)
site = server.Site(root)
application = app.Application('web-proxy')
application.listenTCP(80, site)
```

2.3.3 Rewriting URLs

Sometimes it is convenient to modify the content of the `Request` object before passing it on. Because this is most often used to rewrite either the URL, the similarity to Apache's `mod_rewrite` has inspired the `twisted.web.rewrite` module. Using this module is done via wrapping a resource with a `twisted.web.rewrite.RewriterResource` which then has rewrite rules. Rewrite rules are functions which accept a request object, and

possible modify it. After all rewrite rules run, the child resolution chain continues as if the wrapped resource, rather than the `RewriterResource`, was the child.

Here is an example, using the only rule currently supplied by Twisted itself:

```
default_root = rewrite.RewriterResource(default, rewrite.tildeToUsers)
```

This causes the URL `/~foo/bar.html` to be treated like `/users/foo/bar.html`. If done after setting default's `users` child to a `distrib.UserDirectory`, it gives a configuration similar to the classical configuration of web server, common since the first NCSA servers.

2.3.4 Knowing When We're Not Wanted

Sometimes it is useful to know when the other side has broken the connection. Here is an example which does that:

```
from twisted.web.resource import Resource
from twisted.web import server
from twisted.internet import reactor
from twisted.python.util import println


class ExampleResource(Resource):

    def render(self, request):
        request.write("hello world")
        d = request.notifyFinish()
        d.addCallback(lambda _: println("finished normally"))
        d.addErrback(println, "error")
        reactor.callLater(10, request.finish)
        return server.NOT_DONE_YET

resource = ExampleResource()
```

This will allow us to run statistics on the log-file to see how many users are frustrated after merely 10 seconds.

2.3.5 As-Is Serving

Sometimes, you want to be able to send headers and status directly. While you can do this with a `ResourceScript`, an easier way is to use `AsIsProcessor`. Use it by, for example, addding it as a processor for the `.asis` extension. Here is a sample file:

```
HTTP/1.0 200 OK
Content-Type: text/html

Hello world
```

2.3.6 Twisted Web Development

Twisted Web serves python objects that implement the interface IResource.

Main Concepts

- *Site Objects* (page 28) are responsible for creating `HTTPChannel` instances to parse the HTTP request, and begin the object lookup process. They contain the root Resource, the resource which represents the URL `/` on the site.
- *Resource* (this page) objects represent a single URL segment. The `IResource` interface describes the methods a Resource object must implement in order to participate in the object publishing process.
- *Resource trees* (page 29) are arrangements of Resource objects into a Resource tree. Starting at the root Resource object, the tree of Resource objects defines the URLs which will be valid.
- *.rpy scripts* (page 29) are python scripts which the twisted.web static file server will execute, much like a CGI. However, unlike CGI they must create a Resource object which will be rendered when the URL is visited.
- *Resource rendering* (page 30) occurs when Twisted Web locates a leaf Resource object. A Resource can either return an html string or write to the request object.
- *Session* (page 30) objects allow you to store information across multiple requests. Each individual browser using the system has a unique Session instance.

Site Objects

Site objects serve as the glue between a port to listen for HTTP requests on, and a root Resource object.

When using `mktap web --path /foo/bar/baz`, a Site object is created with a root Resource that serves files out of the given path.

You can also create a `Site` instance by hand, passing it a `Resource` object which will serve as the root of the site:

```
from twisted.web import server, resource
from twisted.internet import reactor

class Simple(resource.Resource):
    isLeaf = True
    def render(self, request):
        return "<html>Hello, world!</html>"

site = server.Site(Simple())
reactor.listenTCP(8080, site)
reactor.run()
```

Resource objects

`Resource` objects represent a single URL segment of a site. During URL parsing, `getChild` is called on the current `Resource` to produce the next `Resource` object.

When the leaf Resource is reached, either because there were no more URL segments or a Resource had isLeaf set to True, the leaf Resource is rendered by calling `render(request)`.

During the Resource location process, the URL segments which have already been processed and those which have not yet been processed are available in `request.prepath` and `request.postpath`.

A Resource can know where it is in the URL tree by looking at `request.prepath`, a list of URL segment strings.

A Resource can know which path segments will be processed after it by looking at `request.postpath`.

If the URL ends in a slash, for example `http://example.com/foo/bar/`, the final URL segment will be an empty string. Resources can thus know if they were requested with or without a final slash.

Here is a simple Resource object:

```
from twisted.web.resource import Resource

class Hello(Resource):
    def getChild(self, name, request):
        if name == '':
            return self
        return Resource.getChild(
            self, name, request)

        def render(self, request):
            return """<html>
      Hello, world! I am located at %r.
    </html>""" % (request.prepath)

resource = Hello()
```

Resource Trees

Resources can be arranged in trees using `putChild`. `putChild` puts a Resource instance into another Resource instance, making it available at the given path segment name:

```
root = Hello()
root.putChild('fred', Hello())
root.putChild('bob', Hello())
```

If this root resource is served as the root of a Site instance, the following URLs will all be valid:

- `http://example.com/`
- `http://example.com/fred`
- `http://example.com/bob`
- `http://example.com/fred/`
- `http://example.com/bob/`

.rpy scripts

Files with the extension `.rpy` are python scripts which, when placed in a directory served by Twisted Web, will be executed when visited through the web.

An `.rpy` script must define a variable, `resource`, which is the Resource object that will render the request.

`.rpy` files are very convenient for rapid development and prototyping. Since they are executed on every web request, defining a Resource subclass in an `.rpy` will make viewing the results of changes to your class visible simply by refreshing the page:

```
class MyResource(resource.Resource):
    def render(self, request):
        return "<html>Hello, world!</html>"

resource = MyResource()
```

However, it is often a better idea to define Resource subclasses in Python modules. In order for changes in modules to be visible, you must either restart the Python process, or reload the module:

```
import myresource

## Comment out this line when finished debugging
reload(myresource)

resource = myresource.MyResource()
```

Creating a Twisted Web server which serves a directory is easy:

```
% mktap web --path /Users/dsp/Sites
% twistd -nf web.tap
```

Resource rendering

Resource rendering occurs when Twisted Web locates a leaf Resource object to handle a web request. A Resource object may do various things to produce output which will be sent back to the browser:

- Return a string
- Call `request.write("stuff")` as many times as desired, then call `request.finish()` and return `server.NOT_DONE_YET` (This is deceptive, since you are in fact done with the request, but is the correct way to do this)
- Request a `Deferred`, return `server.NOT_DONE_YET`, and call `request.write("stuff")` and `request.finish()` later, in a callback on the `Deferred`.

Session

HTTP is a stateless protocol; every request-response is treated as an individual unit, distinguishable from any other request only by the URL requested. With the advent of Cookies in the mid nineties, dynamic web servers gained the ability to distinguish between requests coming from different *browser sessions* by sending a Cookie to a browser. The browser then sends this cookie whenever it makes a request to a web server, allowing the server to track which requests come from which browser session.

Twisted Web provides an abstraction of this browser-tracking behavior called the *Session object*. Calling `request.getSession()` checks to see if a session cookie has been set; if not, it creates a unique session id, creates a Session object, stores it in the Site, and returns it. If a session object already exists, the same session object is returned. In this way, you can store data specific to the session in the session object.

2.4 Debugging with Manhole

2.4.1 Creating the Manhole Service

In order to create a manhole server, use a command like `mktap manhole -u [username] -w [password]`. If you've already got a "TAP" for a server, you can use the argument `--append [tapname]` to `mktap` to add a manhole service to that "TAP".

2.4.2 Using the Manhole PB Client

The second service offered by twisted.manhole is a Perspective Broker -based server. This gives the client a remote reference to a `twisted.manhole.service.Service` object, which offers remotely-callable methods to evaluate Python code.

With this in place and running, you're ready to connect with the manhole client. This is a Gtk+-based GUI application named `manhole` that gets installed along with the rest of twisted. Execute the command `manhole` to start the client, and it will bring up a dialog that asks for hostname, port number, Service name, username, and password (and also "Perspective" but don't worry about that for now). Use the default host/port of localhost/8787 to indicate where the `twisted.manhole` service is listening, and use boss/sekrit for the username and password. Use the default Service name "twisted.manhole", and leave the Perspective blank.

Click the "Log In" button to establish the connection, and you will be greeted with a short message in a window with an output area in the top, and an input area at the bottom. This is just like the python interpreter accessed through the telnet shell, but with a different GUI. You can type arbitrary python code into the input area and get the results in the output area. Note that multi-line sequences are all sent together, so if you define a function (or anything else that uses indentation to tell the interpreter that you aren't finished yet), you'll need to type one additional Return to tell the client to send off the code.

At this point, you can get access to the main `Application` object just like you did before with the telnet-based shell. You can use that to obtain the `Service` objects inside it, or references to the `Factory` objects that are listening on TCP or UDP ports, by doing:

```
from twisted.internet import app
a = app.theApplication
service = a.getServiceNamed("twisted.manhole")
(port, factory, backlog, interface) = a.tcpPorts[0]
```

After that, you can do anything you want with those objects.

2.4.3 Special Commands

> **Note:**
> At this time, not all commands are available in all manhole clients. `/browse` is currently only implemented in the GTK 1.x client, the "Spelunking" view is only available with GTK 1.x + GNOME.

There are a few special commands so far that make debugging Twisted objects really nice. Well, just one at the moment, really: `/browse`. You can `/browse` any type of object, and it will give you some nice information about that object in the "Spelunking" window that pops up when `manhole` establishes a connection to the `manhole` Service. Try the following in the `manhole` window and watch what happens in the "Spelunking" box (word wrapped for clarity):

```
/browse ["hello", "there"]
 <ObjectLink of ["hello", "there"] type list>:
  ['hello',
   'there',]


class A:
    def foo(self):
        self.x = 1

x = A()
/browse x
<ObjectLink of x type instance>:
  {members: {}
   class: 'A'
   methods: {}}
```

TODO: Add an example using `twisted.python.rebuild.rebuild`. This lets you tell your application (remotely) to reload its classes, allowing you to upgrade a running server without missing a beat.

Have fun!

2.5 Creating and working with a telnet server

2.5.1 Simple Configuration

To start things off, we're going to create a simple server that just gives you remote access to a Python interpreter. We will use a telnet client to access this server.

Run `mktap telnet -p 4040 -u admin -w admin` at your shell prompt. If you list the contents of your current directory, you'll notice a new file – `telnet.tap`. After you do this, run `twistd -f telnet.tap`. Since the Application has a telnet server that you specified to be on port 4040, it will start listening for connections on this port. Try connecting with your favorite telnet utility to 127.0.0.1 port 4040.

```
$ telnet localhost 4040
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.

twisted.manhole.telnet.ShellFactory
Twisted 1.0.4
username: admin
password: admin
>>>
```

Now, you should see a Python prompt – `>>>`. You can type any valid Python code here. Let's try looking around.

```
>>> dir()
['__builtins__']
```

Ok, not much. let's play a little more:

```
>>> import __main__
>>> dir(__main__)
['__builtins__', '__doc__', '__name__', 'os', 'run', 'string', 'sys']

>>> from twisted.internet import app
>>> app.theApplication
<'telnet' app>
>>> app.theApplication.tcpPorts
[(4040, <twisted.manhole.telnet.ShellFactory instance at 0x8268edc>,5,'')]
```

From this session we learned that there is an application object stored in `twisted.internet.app.theApplication` that's a telnet app, and that it is listening on port 4040 with something called a `ShellFactory`. There are lots of other attributes in `theApplication`, which we're not going to worry about for now.

Alright, so now you've decided that you hate Twisted and want to shut it down. Or you just want to go to bed. Either way, I'll tell you what to do. First, disconnect from your telnet server. Then, back at your system's shell prompt, type `kill 'cat twistd.pid'` (the quotes around `cat twistd.pid` are backticks, not single-quotes). If you list the contents of your current directory again, you'll notice that there will be a file named telnet-shutdown.tap. If you wanted to restart the server with exactly the same state as you left it, you could just run `twistd -f telnet-shutdown.tap`. This is why Twisted doesn't need any sort of configuration files – all the configuration data is stored right in the objects!

Now that you've learned how to create a telnet server with 'mktap telnet', we'll delve a little deeper and learn how one is created behind the scenes. Start up a python interpreter and make sure that the 'twisted' directory is in your module search path.

```
Python 2.2.2 (#1, Mar 21 2003, 23:01:54)
[GCC 3.2.3 20030316 (Debian prerelease)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> import sys
>>> sys.path.append('/twisted/Twisted')
```

I installed Twisted in /twisted, so the place where my 'twisted' package directory is at is /twisted/Twisted/twisted (confusing, I know). For Python to find the 'twisted' package, it must have the directory *containing* the package in sys.path – which is why I added /twisted/Twisted.

```
>>> from twisted.internet import app
>>> from twisted.manhole import telnet
>>> application = app.Application('telnet')
>>> ts = telnet.ShellFactory()
>>> application.listenTCP(4040, ts)
```

The above is basically what `mktap telnet` does. First we create a new Twisted Application, we create a new telnet Shell Factory, and we tell the application to listen on TCP port 4040 with the ShellFactory we've created.

Now let's start the application. This causes all ports on the application to start listening for incoming connections. This step is basically what the 'twistd' utility does.

```
>>> application.run()
twisted.protocols.telnet.ShellFactory starting on 4040
```

You now have a functioning telnet server! You can connect with your telnet program and work with it just the same as you did before. The username and password both default to "admin", but you can change those by modifying the attributes of the `ShellFactory` object you created earlier. When you're done using the telnet server, you can switch back to your python console and hit ctrl-C. The following should appear:

```
Starting Shutdown Sequence.
Stopping main loop.
Main loop terminated.
Saving telnet application to telnet-shutdown.tap...
Saved.
>>>
```

Your server was pickled up again and saved to the telnet-shutdown.tap file, just like when you did `kill ‘cat twistd.pid‘`.

2.5.2 More Complicated Configuration

Let's suppose that we have the following application:

```
#! /usr/bin/python

from twisted.internet.app import Application
from twisted.internet.protocol import Factory
from twisted.protocols.wire import QOTD

app = Application("demo")

# add QOTD server
f = Factory()
f.protocol = QOTD
app.listenTCP(8123, f)

app.run()
```

Source listing — *manhole1.py*

This will give us a basic quote-of-the-day server: running `telnet localhost 8123` will give us a quote. However, once this is running, it would be nice to poke around inside it. We can add the manhole-shell by adding a few lines to create a new server (a Factory) listening on a different point:

```
#! /usr/bin/python

from twisted.internet.app import Application
from twisted.internet.protocol import Factory
from twisted.protocols.wire import QOTD
import twisted.manhole.telnet
```

```
app = Application("demo")

# add QOTD server
f = Factory()
f.protocol = QOTD
app.listenTCP(8123, f)

# Add a manhole shell
f = twisted.manhole.telnet.ShellFactory()
f.username = "boss"
f.password = "sekrit"
f.namespace['foo'] = 12
app.listenTCP(8007, f)

app.run()
```

Source listing — *manhole2.py*

With this in place, you can telnet to port 8007, give the username "boss" and password "sekrit", and you'll end up with a shell that behaves very much like the Python interpreter that you get by running `python` all by itself, with lines you type prefixed with `>>>`.

```
% telnet localhost 8007
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.

twisted.manhole.telnet.ShellFactory
Twisted 0.99.2
username: boss
password: *****
>>>
```

Note that the original Quote-Of-The-Day server is still running on port 8123 by using `nc localhost 8123` (or `telnet localhost 8123` if you don't have netcat installed).

```
% nc localhost 8123
An apple a day keeps the doctor away.
```

The initial namespace of the manhole interpreter is defined by a dictionary stored in the '`namespace`' attribute of the ShellFactory. For convenience, you can put references to any objects you like in that dict (`f.namespace['foo'] = 12`), and then retrieve them by name from the telnet session.

```
>>> foo
12
```

Of course we can change that namespace by evaluating expressions in the interpreter. To be a useful debugging tool, however, we want to get access to our servers (the protocol `Factory` instances and everything hanging off of

them). We start by gaining access to the main `Application` instance through a global variable stored in the `app` module (assuming we ran using an Application and not the reactor directly):

```
>>> import twisted.internet.app
>>> a = twisted.internet.app.theApplication
>>> a
<'demo' app>
```

This object holds a number of things of interest: the list of Services (subclasses of ApplicationService that have been added to the application, most notably Perspective Broker services), and the list of ports on which protocol Factories are listening. The ports are kept in a number of lists, and the Factory object itself is available inside those lists (word wrapped for clarity):

```
>>> a.tcpPorts
[(8123, <twisted.internet.protocol.Factory instance at 0x8249b8c>, 5, ''),
(8007, <twisted.manhole.telnet.ShellFactory instance at 0x824aefc>, 5, '')
]
>>> f = a.tcpPorts[0][1]
>>> f
<twisted.internet.protocol.Factory instance at 0x8249b8c>
```

Now that we have access to that QOTD Factory, what can we do? We can modify any attribute of the object, or call functions on it. Remember that the Factory stores a reference to a subclass of Protocol, and it uses that reference to create new Protocol instances for each new connection. We can change that reference to make the Factory create something else:

```
>>> f.protocol
<class twisted.protocols.wire.QOTD at 0x824a66c>
>>> from twisted.protocols.wire import Daytime
>>> f.protocol = Daytime
```

Congratulations, you've just changed the Factory to use the `Daytime` protocol instead of the `QOTD` protocol. You have just transformed the QOTD server into a Daytime server. Connect to port 8123 now and see the difference: you get a timestamp instead of a quote:

```
% nc localhost 8123
Sat Sep 28 09:11:37 2002
```

From here, you can do anything you want to your application. It is a good idea to check the source for the `Application` and `Service` classes to see what else you can extract from them.

Note: to terminate your session, you'll need to exit the telnet or netcat program (the usual control-D that works in the Python interpreter won't work here). Try control-] for telnet. Also note that any exceptions caused by your manhole session will be displayed both in the telnet session *and* in the stderr on the application side.

Chapter 3

High-Level Twisted

3.1 Asynchronous Programming

3.1.1 Introduction

There are many ways to write network programs. The main ones are:

1. Handle each connection in a separate process
2. Handle each connection in a separate thread[1]
3. Use non-blocking system calls to handle all connections in one thread.

When dealing with many connections in one thread, the scheduling is the responsibility of the application, not the operating system, and is usually implemented by calling a registered function when each connection is ready to for reading or writing – commonly known as asynchronous, event-driven or callback-based programming.

Multi-threaded programming is tricky, even with high level abstractions, and Python's Global Interpreter Lock[2] limits the potential performance gain. Forking Python processes also has many disadvantages, such as Python's reference counting not playing well with copy-on-write and problems with shared state. Consequently, it was felt the best option was an event-driven framework. A benefit of such an approach is that by letting other event-driven frameworks take over the main loop, server and client code are essentially the same – making peer-to-peer a reality.

However, event-driven programming still contains some tricky aspects. As each callback must be finished as soon as possible, it is not possible to keep persistent state in function-local variables. In addition, some programming techniques, such as recursion, are impossible to use – for example, this rules out protocol handlers being recursive-descent parsers. Event-driven programming has a reputation of being hard to use due to the frequent need to write state machines. Twisted was built with the assumption that with the right library, event-driven programming is easier than multi-threaded programming.

Note that Twisted still allows the use of threads if you really need them, usually to interface with synchronous legacy code. See *Using Threads* (page 94) for details.

[1] There are variations on this method, such as a limited-size pool of threads servicing all connections, which are essentially just optimizations of the same idea.

[2] http://www.python.org/doc/current/api/threads.html

3.1.2 Async Design Issues

In Python, code is often divided into a generic class calling overridable methods which subclasses implement. In that, and similar, cases, it is important to think about likely implementations. If it is conceivable that an implementation might perform an action which takes a long time (either because of network or CPU issues), then one should design that method to be asynchronous. In general, this means to transform the method to be callback based. In Twisted, it usually means returning a *Deferred* (page 82).

Since non-volatile state cannot be kept in local variables, because each method must return quickly, it is usually kept in instance variables. In cases where recursion would have been tempting, it is usually necessary to keep stacks manually, using Python's list and the `.append` and `.pop` method. Because those state machines frequently get non-trivial, it is better to layer them such that each one state machine does one thing – converting events from one level of abstraction to the next higher level of abstraction. This allows the code to be clearer, as well as easier to debug.

3.1.3 Using Reflection

One consequence of using the callback style of programming is the need to name small chunks of code. While this may seem like a trivial issue, used correctly it can prove to be an advantage. If strictly consistent naming is used, then much of the common code in parsers of the form of if/else rules or long cases can be avoided. For example, the SMTP client code has an instance variable which signifies what it is trying to do. When receiving a response from the server, it just calls the method `"do_%s_%s" % (self.state, responseCode)`. This eliminates the requirement for registering the callback or adding to large if/else chains. In addition, subclasses can easily override or change the actions when receiving some responses, with no additional harness code. The SMTP client implementation can be found in `twisted/protocols/smtp.py`.

3.2 Using app.Application

3.2.1 Motivation

Calling reactor methods (like `.listenTCP` and `.run`) directly, as in the examples in *Writing Servers* (page 68), is a good way to immediately demonstrate the use of Factories and Protocols. But you would ask for more from a fully-fledged, easy-to-run, easy-to-configure Internet Server. Twisted provides many of these features as a partnership between its Application object and the `twistd` administrator's program.

What more could we want? Well:

- *starting as a daemon*:

  One of the important aspects of a server program is that it can be run in the background, with output detached from the terminal, run in a chroot jail or under a different user id.

- *configuration arguments*:

  suppose your quote of the day ('QOTD') server behaves a bit more like the normal port 17 server and pulls a random line from `/usr/share/fortunes`. Your QOTDFactory() might take a filename to indicate where the QOTD protocols should pull these lines. It would be nice if the person installing your quote server didn't have to modify any Python code to change where this file should be found.

  Likewise, what if they want it to listen on some other port? That shouldn't require editing the code.

- *basic persistence*:

  If your protocol demands that you keep some state from one invocation of the server to the next, you'll need to save some information before the server shuts down, and to restore it again when you start back up.

  Suppose your protocol's purpose in life is to generate one-time keys, and that people can connect to it to retrieve a single-use key. (Don't ask me why they might want to do this. Security is such a weird big thing that chances are somebody out there will want to do something that's probably pretty dumb when you think about it carefully). The important thing is that you never give out the same key twice. So you have to remember a sequence number, and each time you give out a key, you bump up the number. Before you shut down, you save the number to a file somewhere; at start up, if the file exists you read the number from it, if it doesn't exist, you start at 0. (an example is included below)

  This kind of persistent data is a common need, and many kinds of servers require it. Hence Twisted provides an easy way to record and reload this data.

This functionality is provided by the Application class (defined in twisted/internet/app.py). You create an Application with a constructor like any other object. Then you tell the app to listen to ports (just like you told the reactor to in the previous example), providing a Factory on each one. The difference is that the App won't starting listening on those ports right away, but will wait until it starts to run.

When you're done setting up an Application object, there are three options. You can run it directly by calling the application's `.run()` method. You can use `twistd -y app.py` to run your application directly from python source code. Or you can save the Application out to a file by calling the `.save()` method. The saved application can then be started later by using `twistd -f app-start.tap`.

3.2.2 Example Application

Here is a short example of the first option, running the server immediately. This example uses the pre-defined Daytime protocol, which simply sends the current time to each client.:

```
#! /usr/bin/python

from twisted.internet.app import Application
from twisted.protocols.wire import Daytime
from twisted.internet.protocol import Factory

application = Application("daytimer")
f = Factory()
f.protocol = Daytime
application.listenTCP(8813, f)

if '__main__' == __name__:
    application.run()
```

Source listing — *app1.py*

This program will start listening to port 8813 in the `app.run()` call, and won't return from that call until the server is terminated (probably when you send it SIGINT via ^C on the keyboard).

To use the second option, the same source file can be used, but using the `twistd -y` command to start the application as a daemon. If persistence is not required, then use the `--no_save` option.

```
$ twistd --no_save --python=app1.py
$ tail -f twistd.log
04/04/2003 23:45 [-] Log opened.
04/04/2003 23:45 [-] twistd 1.0.4alpha1 (/usr/local/bin/python 2.2.2)
starting up
04/04/2003 23:45 [-] license user: Nobody <>
04/04/2003 23:45 [-] organization: No Organization
04/04/2003 23:45 [-] reactor class: twisted.internet.default.SelectReactor
04/04/2003 23:45 [-] Loading
/home/cce/work/Twisted/doc/howto/listings/application/app1.py...
04/04/2003 23:45 [-] Loaded.
04/04/2003 23:45 [*daytimer*] twisted.internet.protocol.Factory starting on
8813
04/04/2003 23:45 [*daytimer*] Starting factory
<twisted.internet.protocol.Factory instance at 0x835dcac>
```

To use the third option and launch the server later, just use `.save()` instead of `.run()`. The `.save()` method takes a base name for the generated `.tap` file:

```
...
app.listenTCP(8813, f)

app.save("start")
```

When you run this program, it will create a file called `daytime-start.tap`, and then exit. (The name is obtained by combining the application name with the argument to `.save()`). To start the server from the "freeze-dried" `.tap` file, use `twistd` (text wrapped to be more readable):

```
% ./app2.py
Saving daytimer application to daytimer-start.tap...
Saved.
% twistd -f daytimer-start.tap
% tail twistd.log
30/09/2002 01:38 [-] Log opened.
30/09/2002 01:38 [-] twistd 0.99.2 (/usr/bin/python2.2 2.2.1) starting up
30/09/2002 01:38 [-] license user: Nobody <>
30/09/2002 01:38 [-] organization: No Organization
30/09/2002 01:38 [-] reactor class: twisted.internet.default.SelectReactor
30/09/2002 01:38 [-] Loading daytimer-start.tap...
30/09/2002 01:38 [-] Loaded.
30/09/2002 01:38 [*daytimer*] twisted.internet.protocol.Factory starting on 8813
30/09/2002 01:38 [*daytimer*] Starting factory
<twisted.internet.protocol.Factory instance at 0x81ac9fc>
%
```

That will "thaw out" the `.tap` file, create the Application, and then run it just as if you'd invoked app.run() yourself. It forks the new server off into the background (so twistd itself completes instead of waiting for the server to die), writes the server's process ID to a file called `twistd.pid`, and directs all the server's stdout messages to a file called `twistd.log` (these file names can be changed by appropriate arguments to `twistd`: see `twistd -h` for a list).

When you try this example, be aware that `twistd` returns right away, but it takes a second or two for the server to actually start. The `twistd.pid` file won't be created until it does. Wait a moment before doing `ls` or `netstat`, or you'll think that the server failed to start. If it persists in failing, look in `twistd.log` for details. Remember that trying to bind to a reserved port will fail unless you're root, and the exception will be listed at the end of the log file.

To kill the server, just do:

```
% kill ‘cat twistd.pid‘
```

When the server is shut down, you'll notice that it creates a file called `daytimer-shutdown.tap` in the directory it was run from (again, the name is derived from the application name and the word "shutdown"). This `.tap` file is just like the `daytimer-start.tap` created by your original setup program, except that it represents the state of the Application object as it existed just before shutdown, rather than when it was freshly created by your code.

Also note that the `twistd.pid` file is automatically deleted when the application shuts down.

3.2.3 Saving State Across Sessions: Adding Persistent Data

You can add persistent data (like that sequence number described above) to the protocol Factory object, and it will get saved in the `-shutdown.tap` file. Then, if you restart the server with `twistd -f daytimer-shutdown.tap`, the new server will get the data saved by the old server, and it can pick up where the old one left off, as if the server had been running continuously the whole time.

To take advantage of this, simply add the attributes you want to the Factory, or to your subclass of Service (see the docs on Perspective Broker for details about Services). When the application terminates, it simply pickles up the whole Application (and everything it references, including Factories and Services). Any attributes or objects you have added will be saved and later restored.

Here is an example:

```
#! /usr/bin/python

from twisted.internet.protocol import Protocol, Factory

class OneTimeKey(Protocol):
    def connectionMade(self):
        key = self.factory.nextkey
        print "giving key", key
        self.factory.nextkey += 1
        self.transport.write("%d\n" % key)
        self.transport.loseConnection()

def main():
    # namespaces are weird. if we used OneTimeKey directly, it would
    # pickle the instance as __main__.OneTimeKey, since we run this
```

```
    # module directly. So we reimport this module so the pickle refers
    # to it by its real name.
    import app3
    from twisted.internet.app import Application
    f = Factory()
    f.protocol = app3.OneTimeKey
    f.nextkey = 0
    app = Application("otk")
    app.listenTCP(8123, f)
    app.save("start")


if __name__ == '__main__':
    main()
```

Source listing — *app3.py*

To demonstrate this, do the following:

```
% ./app3.py
Saving otk application to otk-start.tap...
Saved.
% twistd -f otk-start.tap
%
% nc localhost 8123
0
% nc localhost 8123
1
% nc localhost 8123
2
%
```

Note that the stdout of the process is being directed into the log file, contained in `twistd.log`. Now stop the server, verify that it is no longer running, then restart it from the saved-at-shutdown `.tap` file:

```
% kill `cat twistd.pid `
% nc localhost 8123
localhost [127.0.0.1] 8123 (?) : Connection refused
% twistd -f otk-shutdown.tap
% nc localhost 8123
3
%
```

Notice how the saved `.nextkey` attribute was restored, and the application picks up where it left off.

3.2.4 Configuration arguments

To do this right, you'll want to follow the sequence described by the *writing plugins* (page 43) document. Instead of writing a short program that creates a `.tap` file (by creating an Application, doing various .listenTCPs on it, then calling .save), you will write a subroutine called updateApplication(). This subroutine should take a bunch of config arguments (using the usage.Options class described in the plugins document) and use them to create Factories and feed them to .listenTCP on an *existing* Application instance.

With that in place, and a few files to register this new server you've created, a utility program called '`mktap`' can relieve you of the business of gathering user arguments and creating the app instance. `mktap` can use the Options subclass you define in your build-a-tap class to figure out what arguments are legal (`--port` taking a number, `--quotes` taking a filename, etc), provide `--help` with a list of valid arguments, and parse everything the user passes in `argv[]`. It creates the Application, then passes the app and the parsed options to your `updateApplication()` method, where you do the server-specific creation of a Factory and the various `listenTCP` calls. Then `mktap` saves out the `.tap` file, ready for starting by `twistd`.

The end result is that installing your new server is simplified to the following steps:

- Unpack your server module (including the classes and plugin glue files) into somewhere on your PYTHONPATH, perhaps `/usr/local/lib/python`.
- Run the standard `mktap` program, giving it the name of your module and whatever configuration arguments it requires. Watch it create a `.tap` file.
- Use `twistd` to start the server contained in the `.tap` file.

Pretty easy. At least your users will think so.

And, once your application is defined by the `.tap` file, there are other tools that can be used to configure it. `tap2deb` is a tool that creates installable Debian `.deb` packages from your `.tap` file, making installation even easier.

The Application object has some other features designed to solve common server needs:

- logging is controlled, through the log.Logger class
- the process can switch to a different uid/gid after binding reserved ports
- styles.Versioned allows old saved copies of an object to be upgraded when new versions of the class are available
- Applications have Authorizers, used to authenticate client connections
- Applications have Services, which can be accessed by PB clients

3.3 Writing a New Plug-In for Twisted

3.3.1 Getting Started

Twisted is a very general and powerful tool. It can power anything connected to a network, from your corporate message-broadcasting network to your desktop IRC client. This is great for integrating lots of different tools, but can make it very difficult to document and understand how the whole platform is supposed to work. A side effect of this is that it's hard to get started with a project using Twisted, because it's hard to find out where to start.

This guide is to help you understand the "right way" to get started working on a Twisted application. It probably won't answer your specific questions about how to do things like *schedule functions to call in the future* (page 93) or *listen on a socket* (page 68); there are other documents that address these concerns and you can read them later. *Although there are other ways for Twisted to call your code, all Twisted projects should start as a plug-in of some kind.*

3.3.2 Twisted and You: Where Does Your Code Fit In?

If you're like most people that have asked me questions about this, you've probably come to Twisted thinking of it as a library of code to help you write an application. It can be, but it is much more useful to think of *your code as the library*. Twisted is a framework.

The difference between a framework and a library is that a developer's code will run a library's functions; a framework runs the developer's functions, instead. The difference is subtle, but significant; there are a range of resources which have to be allocated and managed regarding start-up and shut-down of an process, such as spawning of threads and handling events. You don't have to use Twisted this way. It is quite possible to write applications that use Twisted almost exclusively as a library. If you use it as a framework, though, Twisted will help you by managing these resources itself.

The central framework class that you will deal with, both as a Twisted developer and administrator, is `twisted.internet.app.Application`. There is one `Application` instance per Twisted process, and it is the top-level manager of resources and handler of events in the Twisted framework. (Unlike some other frameworks, developers do not subclass `Application`; rather than defining methods on it, you register event handlers to be called by it.) To store configuration data, as well as other information, Twisted serializes `Application` instances, storing all event handlers that have been registered with them. Since the whole `Application` instance is serialized, Twisted "configuration" files are significantly more comprehensive than those for other systems. These files store everything related to a running `Application` instance; in essence the full state of a running process.

The central concept that a Twisted system administrator will work with are files that contain `Application` instances serialized in various formats optimized for different uses. `.TAP` files are optimized for speed of loading and saving, `.TAX` files are editable by administrators familiar with XML syntax, and `.TAS` files are generated Python source code, most useful for developers. The two command-line programs which work with these files are `mktap` and `twistd`. The `mktap` utility create `.TA*` files from simple command-line arguments, and the `twistd` daemon will load and run those files.

There are many ways in which your code will be called by various parts of the Twisted framework by the time you're done. The initial one we're going to focus on here is a plug-in for the `mktap` utility. `mktap` produces complete, runnable `Application` instances, so no additional work is necessary to make your code work with `twistd`. First we will go through the process of creating a plug-in that Twisted can find, then we make it adhere to the `mktap` interface. Finally we will load that plug-in with a server.

3.3.3 What is a Plug-In?

Python makes it very easy to dynamically load and evaluate programs. The plug-in system for Twisted, `twisted.python.plugin`, is a way to find (without loading) and then load plug-ins for particular systems.

Unlike other "plug-in" systems, like the well known ones associated with The Gimp, Photoshop, and Apache `twisted.python.plugin` is generic. Any one of the Twisted "dot-products"[3] can define mechanisms for extensibility using plug-ins. Two Twisted dot-products already load such plug-ins. The `twisted.tap`package loads

[3] http://twistedmatrix.com/products/dot-products

Twisted Application builder modules (TAP plug-ins) and the `twisted.coil` package loads configuration modules (COIL plug-ins).

Twisted finds its plug-ins by using pre-existing Python concepts; the load path, and packages. Every top-level Python package[4] (that is, a directory whose parent is on sys.path and which contains an `__init__.py`) can potentially contain some number of plug-ins. Packages which contain plug-ins are called "drop-ins", because you "drop" them into your `sys.path`. The only difference between a package and a drop-in is the existence of a file named `plugins.tml` (TML for Twisted Module List) that contains some special Python expressions to identify the location of sub-packages or modules which can be loaded.

If you look at `twisted/plugins.tml`, you will notice that Twisted is a drop-in for itself! You can browse through it for lots of examples of plug-ins being registered.

The most prevalent kind of plug-in is the `TAP` (Twisted Application builder) type. These are relatively simple to get started with. Let's look at an excerpt from Twisted's own plugins.tml for an example of registering one:

```
# ...

register("Twisted Web Automated TAP builder",
         "twisted.tap.web",
         description="""
         Builds a Twisted Application instance that contains a general-purpose
         web server, which can serve from a filesystem or application resource.
         """,
         type="tap",
         tapname="web")

# ...
```

`plugins.tml` will be a list of calls to one function:

```
register(name, module, type=plugin_type,
         description=user_description
         [, **plugin_specific_data])
```

- `name` is a free-form string, to be displayed to the user in presentation contexts (like a web page, or a list-box in a GUI).
- `module` is a string which must be the fully-qualified name of a Python module.
- `type` is the name of the system you are plugging in to. Be sure to spell this right, or Twisted won't find your plug-in at all!
- `**plugin_specific_data` is a dictionary of information associated with the plug-in, specific to the `type` of plug-in it is. Note that some plug-in types may require a specific bit of data in order to work.

Note the `tapname` parameter given in the example above. This parameter is an example of `**plugin_specific_data`. The parameter `tapname` is only used by `"tap"`-type modules. It indicates what name to use on the `mktap` command line. In English, this particular call to `register` means "When the user types `mktap web`, it selects the module `twisted.tap.web` to handle the rest of the arguments".

Now that you understand how to register a plug-in, let's move along to writing your first one.

[4] http://www.python.org/doc/current/tut/node8.html#SECTION008400000000000000000

3.3.4 Twisted Quotes: A Case Study

As an example, we are going to work on a Quote of the Day application, `TwistedQuotes`. Aspects of this application will be explored in more depth throughout in the Twisted documentation.

`TwistedQuotes` is a very simple plugin which is a great demonstration of Twisted's power. It will export a small kernel of functionality – Quote of the Day – which can be accessed through every interface that Twisted supports: web pages, e-mail, instant messaging, a specific Quote of the Day protocol, and more.

Before you Begin

First, make a directory, `TwistedQuotes`, where you're going to keep your code. If you installed Twisted from source, the path of least resistance is probably just to make a directory inside your `Twisted-X.X.X` directory, which will already be in your `sys.path`. If you want to put it elsewhere, make sure that your `TwistedQuotes` directory is a package on your python path.

> **Note:**
> The directory you add to your PYTHONPATH needs to be the directory *containing* your package's directory! For example, if your TwistedQuotes directory is /my/stuff/TwistedQuotes, you can `export PYTHONPATH=/my/stuff:$PYTHONPATH` in UNIX, or edit the `PYTHONPATH` environment variable to add `/my/stuff;` at the beginning through the System Properties dialog on Windows.

You will then need to add an `__init__.py` to this directory, to mark it as a package. (For more information on exactly how Python packages work, read this section[5] of the Python tutorial.) In order to test that everything is working, start up the Python interactive interpreter, or your favorite IDE, and verify that the package imports properly.

```
Python 2.1.3 (#1, Apr 20 2002, 22:45:31)
[GCC 2.95.4 20011002 (Debian prerelease)] on linux2
Type "copyright", "credits" or "license" for more information.
>>> import TwistedQuotes
>>> # No traceback means you're fine.
```

A Look at the Heart of the Application

(You'll need to put this code into a file called `quoters.py` in your `TwistedQuotes` directory.)

```
from twisted.python import components

from random import choice


class IQuoter(components.Interface):
    """An object that returns quotes."""

    def getQuote(self):
        """Return a quote."""
```

[5] http://www.python.org/doc/current/tut/node8.html#SECTION008400000000000000000

```
class StaticQuoter:
    """Return a static quote."""

    __implements__ = IQuoter

    def __init__(self, quote):
        self.quote = quote

    def getQuote(self):
        return self.quote


class FortuneQuoter:
    """Load quotes from a fortune-format file."""

    __implements__ = IQuoter

    def __init__(self, filenames):
        self.filenames = filenames

    def getQuote(self):
        return choice(open(choice(self.filenames)).read().split('\n%\n'))
```

Twisted Quotes Central Abstraction — *quoters.py*

This code listing shows us what the Twisted Quotes system is all about. The code doesn't have any way of talking to the outside world, but it provides a library which is a clear and uncluttered abstraction: "give me the quote of the day".

Note that this module does not import any Twisted functionality at all! The reason for doing things this way is integration. If your "business objects" are not stuck to your user interface, you can make a module that can integrate those objects with different protocols, GUIs, and file formats. Having such classes provides a way to decouple your components from each other, by allowing each to be used independently.

In this manner, Twisted itself has minimal impact on the logic of your program. Although the Twisted "dot products" are highly interoperable, they also follow this approach. You can use them independently because they are not stuck to each other. They communicate in well-defined ways, and only when that communication provides some additional feature. Thus, you can use `twisted.web` with `twisted.enterprise`, but neither requires the other, because they are integrated around the concept of *Deferreds* (page 82). (Don't worry we'll get to each of those features in later documentation.)

Your Twisted applications should follow this style as much as possible. Have (at least) one module which implements your specific functionality, independant of any user-interface code.

Next, we're going to need to associate this abstract logic with some way of displaying it to the user. We'll do this by writing a Twisted server protocol, which will respond to the clients that connect to it by sending a quote to the client and then closing the connection. Note: don't get too focused on the details of this – different ways to interface with the user are 90% of what Twisted does, and there are lots of documents describing the different ways to do it.

(You'll need to put this code into a file called `quoteproto.py` in your `TwistedQuotes` directory.)

```
from twisted.internet.protocol import Factory, Protocol
from twisted.internet.app import Application

class QOTD(Protocol):

    def connectionMade(self):
        self.transport.write(self.factory.quoter.getQuote()+'\r\n')
        self.transport.loseConnection()

class QOTDFactory(Factory):

    protocol = QOTD

    def __init__(self, quoter):
        self.quoter = quoter
```

Twisted Quotes Protocol Implementation — *quoteproto.py*

This is a very straightforward `Protocol` implementation, and the pattern described above is repeated here. The Protocol contains essentially no logic of its own, just enough to tie together an object which can generate quotes (a `Quoter`) and an object which can relay bytes to a TCP connection (a `Transport`). When a client connects to this server, a `QOTD` instance is created, and its `connectionMade` method is called.

The `QOTDFactory`'s role is to specify to the Twisted framework how to create a `Protocol` instance that will handle the connection. Twisted will not instantiate a `QOTDFactory`; you will do that yourself later, in the `mktap` plug-in below.

Note: you can read more specifics of `Protocol` and `Factory` in the *Writing Servers* (page 68) HOWTO.

Once we have an abstraction – a `Quoter` – and we have a mechanism to connect it to the network – the `QOTD` protocol – the next thing to do is to put the last link in the chain of functionality between abstraction and user. This last link will allow a user to choose a `Quoter` and configure the protocol.

Practically speaking, this link is an interface for a savvy user who will run the server. (In this case, you; when you have more users, a system administrator.) For the purposes of this example we will first implement a `mktap` interface. Like most system administrator tools, this is command-line oriented. (It is possible to implement a graphical front-end to mktap, using the same plug-in structure, but this has not been done yet.)

Creating the extension to `mktap` is done through implementing a module that follows the `mktap` plug-in interface, and then registering it to be found and loaded by `twisted.python.plugin`. As described above, registration is done by adding a call to `register` in the file `TwistedQuotes/plugins.tml`

(You'll need to put this code into a file called `quotetap.py` in your `TwistedQuotes` directory.)

```
from TwistedQuotes import quoteproto    # Protocol and Factory
from TwistedQuotes import quoters       # "give me a quote" code

from twisted.python import usage        # twisted command-line processing

class Options(usage.Options):
    optParameters = [["port", "p", 8007,
                      "Port number to listen on for QOTD protocol."],
```

```
                    ["static", "s", "An apple a day keeps the doctor away.",
                     "A static quote to display."],
                    ["file", "f", None,
                     "A fortune-format text file to read quotes from."]]

def updateApplication(app, config):
    if config["file"]:                  # If I was given a "file" option...
        # Read quotes from a file, selecting a random one each time,
        quoter = quoters.FortuneQuoter([config['file']])
    else:                               # otherwise,
        # read a single quote from the command line (or use the default).
        quoter = quoters.StaticQuoter(config['static'])
    port = int(config["port"])          # TCP port to listen on
    factory = quoteproto.QOTDFactory(quoter) # here we create a QOTDFactory
    # Finally, set up our factory, with its custom quoter, to create QOTD
    # protocol instances when events arrive on the specified port.
    app.listenTCP(port, factory)
```

Twisted Quotes TAP construction module — *quotetap.py*

This module has to conform to a fairly simple interface. It must have a class called `Options` which is a subclass of `twisted.python.usage.Options`. It must also have a function `updateApplication(app, config)`, which will be passed an instance of a `twisted.internet.app.Application` and an instance of the `Options` class defined in the module itself, `TwistedQuotes.quotetap.Options`. Command-line options given on the `mktap` command line fill in the values in `Options` and are used in `updateApplication` to make the actual connections between objects.

A more detailed discussion of `twisted.python.usage.Options` can be found in the document *Using `usage.Options`* (page 54).

Now that we've implemented all the necessary pieces, we can finish putting them together by writing a TML file which allows the `mktap` utility to find our protocol module.

```
register("Quote of the Day TAP Builder",
         "TwistedQuotes.quotetap",
         description="""
         Example of a TAP builder module.
         """,
         type="tap",
         tapname="qotd")
```

Twisted Quotes Plug-in registration — *plugins.tml*

Now the QOTD server is ready to be instantiated! Let's start up a server and get a quote from it.

```
% mktap qotd
Saving qotd application to qotd.tap...
Saved.
```

```
% twistd -f qotd.tap
% nc localhost 8007
An apple a day keeps the doctor away.
% kill ‘cat twistd.pid‘
```

Let’s walk through the above example. First, we run `mktap` specifying the Application type (`qotd`) to create. `mktap` reads in our `plugins.tml` file, instantiates an `Application` object, fills in the appropriate data, and serializes it out to a `qotd.tap` file. Next, we launch the server using the twistd daemon, passing `qotd.tap` as a command line option. The server launches, listens on the default port from `quotetap.py`. Next, we run `nc` to connect to the running server. In this step, the `QOTDFactory` creates a `Quoter` instance, which responds to our network connection by sending a quote string (in this case, the default quote) over our connection, and then closes the connection. Finally, we shutdown the server by killing it via a saved out process id file.

(`nc` is the netcat[6] utility, which no UNIX system should be without.)

So we just saw Twisted in action as a framework. With relatively little code, we’ve got a server that can respond to a request over a network, with two potential alternative back-ends (fortune files and static text).

After reading this (and following along with your own example, of course), you should be familiar with the process of getting your own Twisted code with unique functionality in it running inside of a server. You should be familiar with the concept of a drop-in and a plug-in, and understand both how to create them and how to install them from other people on your system.

By following the rules set out at the beginning of this HOWTO, we have accidentally implemented another piece of useful functionality.

```
% mktap
Usage:    mktap [options] <command> [command options]

Options:
  -x, --xml      DEPRECATED: same as --type=xml
  -s, --source   DEPRECATED: same as --type=source
  -e, --encrypted  Encrypt file before writing
  -p, --progress   Show progress of plugin loading
  -d, --debug      Show debug information for plugin loading
  -u, --uid=     [default: 1000]
  -g, --gid=     [default: 1000]
  -a, --append=  An existing .tap file to append the plugin to, rather than
                 creating a new one.
  -t, --type=    The output format to use; this can be ’pickle’, ’xml’, or
                 ’source’. [default: pickle]
      --help     display this message
Commands:
    coil             A web-based configuration manager.
    ftp              An FTP server.
    im               A multi-protocol chat client.
    inetd
    issues           Bug reporting/tracking service.
    mail             An email service.
```

[6] http://www.atstake.com/research/tools/index.html#network_utilities

```
manhole          An interactive remote debugger service.
news             News Server
parent           Parent service.
pinger           Zoot Pinger TAP builder module
ponger           Zoot Ponger TAP builder module
portforward      A simple port-forwarder.
qotd             Example of a TAP builder module.
sibling          Sibling service.
socks            A SOCKSv4 proxy service.
ssh
telnet           A simple, telnet-based remote debugging service.
toc              An AIM TOC service.
web              A general-purpose web server which can serve from a
                 filesystem or application resource.
words            A chat service.
zoot             Zoot TAP builder module
```

Not only does our `Options` class get instantiated by `mktap` directly, the user can query mktap for interactive help! This is just one small benefit to using Twisted as it was designed. As more tools that use the `tap` style of plug-in, more useful functionality will become available from Twisted Quotes. For example, a graphical tool could provide not just help messages at the command line, but a listing of all available TAP types and forms for each, for the user to enter information.

It is this kind of power that results from using a dynamic, powerful framework like Twisted. I hope that you take your newfound knowledge and discover all kinds of cool things like this that you get for free just by using it!

The plug-in system is a relatively new part of Twisted, and not as many things use it as they should yet. Watch this space for new developments regarding plug-ins, other systems that you can plug your code into, and more documentation for people wanting to write systems that can be plugged in to!

3.4 Twisted Enterprise Row Objects

The `twisted.enterprise.row` module is a method of interfacing simple python objects with rows in relational database tables. It has two components: the `RowObject` class which developers sub-class for each relational table that their code interacts with, and the `Reflector` which is responsible for updates, inserts, queries and deletes against the database.

The row module is intended for applications such as on-line games, and web-site that require a back-end database interface. It is not a full functioned object-relational mapper for python - it deals best with simple data types structured in ways that can be easily represented in a relational database. It is well suited to building a python interface to an existing relational database, and slightly less suited to added database persistance to an existing python application.

3.4.1 Class Definitions

To interface to relational database tables, the developer must create a class derived from the `twisted.enterprise.row.RowObject` class for each table. These derived classes must define a number of class attributes which contains information about the database table that class corresponds to. The required class attributes are:

- rowColumns - list of the column names and types in the table with the correct case
- rowKeyColumns - list of key columns in form: `[(columnName, typeName)]`
- rowTableName - the name of the database table

There are also two optional class attributes that can be specified:

- rowForeignKeys - list of foreign keys to other database tables in the form: `[(tableName, [(childColumnName, childColumnType), ...], [(parentColumnName, parentColumnType), ...], containerMethodName, autoLoad]`
- rowFactoryMethod - a method that creates instances of this class

For example:

```
class RoomRow(row.RowObject):
    rowColumns       = [("roomId",  "int"),
                        ("town_id", "int"),
                        ("name",    "varchar"),
                        ("owner",   "varchar"),
                        ("posx",    "int"),
                        ("posy",    "int"),
                        ("width",   "int"),
                        ("height",  "int")]
    rowKeyColumns    = [("roomId",  "int4")]
    rowTableName     = "testrooms"
    rowFactoryMethod = [testRoomFactory]
```

The items in the rowColumns list will become data members of classes of this type when they are created by the Reflector.

3.4.2 Initialization

The initialization phase builds the SQL for the database interactions. It uses the system catalogs of the database to do this, but requires some basic information to get started. The class attributes of the classes derived from RowClass are used for this. Those classes are passed to a Reflector when it is created.

There are currently two available reflectors in Twisted Enterprise, the SQL Reflector for relational databases which uses the python DB API, and the XML Reflector which uses a file system containing XML files. The XML reflector is currently extremely slow.

An example class list for the RoomRow class we specified above using the SQLReflector:

```
from twisted.enterprise.sqlreflector import SQLReflector

dbpool = adbapi.ConnectionPool("pyPgSQL.PgSQL")
reflector = SQLReflector( dbpool, [RoomRow] )
```

3.4.3 Creating Row Objects

There are two methods of creating RowObjects - loading from the database, and creating a new instance ready to be inserted.

To load rows from the database and create RowObject instances for each of the rows, use the loadObjectsFrom method of the Reflector. This takes a tableName, an optional "user data" parameter, and an optional "where clause". The where clause may be omitted which will retrieve all the rows from the table. For example:

```
def gotRooms(rooms):
    for room in rooms:
        print "Got room:", room.id

d = reflector.loadObjectsFrom("testrooms",
                              whereClause=[("id", reflector.EQUAL, 5)])
d.addCallback(gotRooms)
```

For more advanced RowObject construction, loadObjectsFrom may use a factoryMethod that was specified as a class attribute for the RowClass derived class. This method will be called for each of the rows with the class object, the userData parameter, and a dictionary of data from the database keyed by column name. This factory method should return a fully populated RowObject instance and may be used to do pre-processing, lookups, and data transformations before exposing the data to user code. An example factory method:

```
def testRoomFactory(roomClass, userData, kw):
    newRoom = roomClass(userData)
    newRoom.__dict__.update(kw)
    return newRoom
```

The last method of creating a row object is for new instances that do not already exist in the database table. In this case, create a new instance and assign its primary key attributes and all of its member data attributes, then pass it to the `insertRow` method of the Reflector. For example:

```
    newRoom = RoomRow()
    newRoom.assignKeyAttr("roomI", 11)
    newRoom.town_id = 20
    newRoom.name = 'newRoom1'
    newRoom.owner = 'fred'
    newRoom.posx = 100
    newRoom.posy = 100
    newRoom.width = 15
    newRoom.height = 20
    reflector.insertRow(newRoom).addCallback(onInsert)
```

This will insert a new row into the database table for this new RowObject instance. Note that the `assignKeyAttr` method must be used to set primary key attributes - regular attribute assignment of a primary key attribute of a rowObject will raise an exception. This prevents the database identity of RowObject from being changed by mistake.

3.4.4 Relationships Between Tables

Specifying a foreign key for a RowClass creates a relationship between database tables. When `loadObjectsFrom` is called for a table, it will automatically load all the children rows for the rows from the specified table. The child rows

will be put into a list member variable of the rowObject instance with the name `childRows` or if a *containerMethod* is specified for the foreign key relationship, that method will be called on the parent row object for each row that is being added to it as a child.

The *autoLoad* member of the foreign key definition is a flag that specifies whether child rows should be auto-loaded for that relationship when a parent row is loaded.

3.4.5 Duplicate Row Objects

If a reflector tries to load an instance of a rowObject that is already loaded, it will return a reference to the existing rowObject rather than creating a new instance. The reflector maintains a cache of weak references to all loaded row objects by their unique keys for this purpose.

3.4.6 Updating Row Objects

RowObjects have a `dirty` member attribute that is set to 1 when any of the member attributes of the instance that map to database columns are changed. This dirty flag can be used to tell when RowObjects need to be updated back to the database. In addition, the `setDirty` method can be overridden to provide more complex automated handling such as dirty lists (be sure to call the base class setDirty though!).

When it is determined that a RowObject instance is dirty and need to have its state updated into the database, pass that object to the `updateRow` method of the Reflector. For example:

```
reflector.updateRow(room).addCallback(onUpdated)
```

For more complex behavior, the reflector can generate the SQL for the update but not perform the update. This can be useful for batching up multiple updates into single requests. For example:

```
updateSQL = reflector.updateRowSQL(room)
```

3.4.7 Deleting Row Objects

To delete a row from a database pass the RowObject instance for that row to the Reflector `deleteRow` method. Deleting the python Rowobject instance does *not* automatically delete the row from the database. For example:

```
reflector.deleteRow(room)
```

3.5 Using usage.Options

3.5.1 Introduction

There is frequently a need for programs to parse a UNIX-like command line program: options preceded by `-` or `--`, sometimes followed by a parameter, followed by a list of arguments. The `twisted.python.usage` provides a class, `Options`, to facilitate such parsing.

While Python has the `getopt` module for doing this, it provides a very low level of abstraction for options. Twisted has a higher level of abstraction, in the class `twisted.python.usage.Options`. It uses Python's reflection facilities to provide an easy to use yet flexible interface to the command line. While most command line processors either force the application writer to write her own loops, or have arbitrary limitations on the command line

(the most common one being not being able to have more then one instance of a specific option, thus rendering the idiom `program -v -v -v` impossible), Twisted allows the programmer to decide how much control she wants.

The `Options` class is used by subclassing. Since a lot of time it will be used in the `twisted.tap` package, where the local conventions require the specific options parsing class to also be called `Options`, it is usually imported with

```
from twisted.python import usage
```

3.5.2 Boolean Options

For simple boolean options, define the attribute `optFlags` like this:

```
class Options(usage.Options):

    optFlags = [["fast", "f", "Act quickly"], ["safe", "s", "Act safely"]]
```

`optFlags` should be a list of 3-lists. The first element is the long name, and will be used on the command line as `--fast`. The second one is the short name, and will be used on the command line as `-f`. The last element is a description of the flag and will be used to generate the usage information text. The long name also determines the name of the key that will be set on the Options instance. Its value will be 1 if the option was seen, 0 otherwise. Here is an example for usage:

```
class Options(usage.Options):

    optFlags = [
        ["fast", "f", "Act quickly"],
        ["good", "g", "Act well"],
        ["cheap", "c", "Act cheaply"]
    ]

command_line = ["-g", "--fast"]

options = Options()
try:
    options.parseOptions(command_line)
except usage.UsageError, errortext:
    print '%s: %s' % (sys.argv[0], errortext)
    print '%s: Try --help for usage details.' % (sys.argv[0])
    sys.exit(1)
if options['fast']:
    print "fast",
if options['good']:
    print "good",
if options['cheap']:
    print "cheap",
print
```

The above will print `fast good`.

Note here that Options fully supports the mapping interface. You can access it mostly just like you can access any other dict. Options are stored as mapping items in the Options instance: parameters as 'paramname': 'value' and flags as 'flagname': 1 or 0.

Inheritance, Or: How I Learned to Stop Worrying and Love the Superclass

Sometimes there is a need for several option processors with a unifying core. Perhaps you want all your commands to understand `-q`/`--quiet` means to be quiet, or something similar. On the face of it, this looks impossible: in Python, the subclass's `optFlags` would shadow the superclass's. However, `usage.Options` uses special reflection code to get all of the `optFlags` defined in the hierarchy. So the following:

```
class BaseOptions(usage.Options):

    optFlags = [["quiet", "q"], None]

class SpecificOptions(BaseOptions):

    optFlags = [
        ["fast", "f", None], ["good", "g", None], ["cheap", "c", None]
    ]
```

Is the same as:

```
class SpecificOptions(BaseOptions):

    optFlags = [
        ["quiet", "q", "Silence output"],
        ["fast", "f", "Run quickly"],
        ["good", "g", "Don't validate input"],
        ["cheap", "c", "Use cheap resources"]
    ]
```

3.5.3 Parameters

Parameters are specified using the attribute `optParameters`. They *must* be given a default. If you want to make sure you got the parameter from the command line, give a non-string default. Since the command line only has strings, this is completely reliable.

Here is an example:

```
from twisted.python import usage

class Options(usage.Options):

    optFlags = [
        ["fast", "f", "Run quickly"],
        ["good", "g", "Don't validate input"],
```

```
        ["cheap", "c", "Use cheap resources"]
    ]
    optParameters = [["user", "u", None, "The user name"]]

config = Options()
try:
    config.parseOptions() # When given no argument, parses sys.argv[1:]
except usage.UsageError, errortext:
    print '%s: %s' % (sys.argv[0], errortext)
    print '%s: Try --help for usage details.' % (sys.argv[0])
    sys.exit(1)

if config['user'] is not None:
    print "Hello", config['user']
print "So, you want it:"

if config['fast']:
    print "fast",
if config['good']:
    print "good",
if config['cheap']:
    print "cheap",
print
```

Like `optFlags`, `optParameters` works smoothly with inheritance.

3.5.4 Option Subcommands

It is useful, on occassion, to group a set of options together based on the logical "action" to which they belong. For this, the `usage.Options` class allows you to define a set of "subcommands", each of which can provide its own `usage.Options` instance to handle its particular options.

Here is an example for an Options class that might parse options like those the cvs program takes

```
from twisted.python import usage

class ImportOptions(usage.Options):
    optParameters = [
        ['module', 'm', None, None], ['vendor', 'v', None, None],
        ['release', 'r', None]
    ]

class CheckoutOptions(usage.Options):
    optParameters = [['module', 'm', None, None], ['tag', 'r', None, None]]

class Options(usage.Options):
    subCommands = [['import', None, ImportOptions, "Do an Import"],
                   ['checkout', None, CheckoutOptions, "Do a Checkout"]]
```

```
    optParameters = [
        ['compression', 'z', 0, 'Use compression'],
        ['repository', 'r', None, 'Specify an alternate repository']
    ]

config = Options(); config.parseOptions()
if config.subCommand == 'import':
    doImport(config.subOptions)
elif config.subCommand == 'checkout':
    doCheckout(config.subOptions)
```

The `subCommands` attribute of `Options` directs the parser to the two other `Options` subclasses when the strings `"import"` or `"checkout"` are present on the command line. All options after the given command string are passed to the specified Options subclass for further parsing. Only one subcommand may be specified at a time. After parsing has completed, the Options instance has two new attributes - `subCommand` and `subOptions` - which hold the command string and the Options instance used to parse the remaining options.

3.5.5 Generic Code For Options

Sometimes, just setting an attribute on the basis of the options is not flexible enough. In those cases, Twisted does not even attempt to provide abstractions such as "counts" or "lists", but rathers lets you call your own method, which will be called whenever the option is encountered.

Here is an example of counting verbosity

```
from twisted.python import usage

class Options(usage.Options):

    def __init__(self):
        usage.Options.__init__(self)
        self['verbosity'] = 0 # default

    def opt_verbose(self):
        self['verbosity'] = self['verbosity']+1

    def opt_quiet(self):
        self['verbosity'] = self['verbosity']-1

    opt_v = opt_verbose
    opt_q = opt_quiet
```

Command lines that look like `command -v -v -v -v` will increase verbosity to 4, while `command -q -q -q` will decrease verbosity to -3.

The `usage.Options` class knows that these are parameter-less options, since the methods do not receive an argument. Here is an example for a method with a parameter:

```
from twisted.python import usage

class Options(usage.Options):

    def __init__(self):
        usage.Options.__init__(self)
        self['symbols'] = []

    def opt_define(self, symbol):
        self['symbols'].append(symbol)

    opt_D = opt_define
```

This example is useful for the common idiom of having `command -DFOO -DBAR` to define symbols.

3.5.6 Parsing Arguments

`usage.Options` does not stop helping when the last parameter is gone. All the other arguments are sent into a function which should deal with them. Here is an example for a `cmp` like command.

```
from twisted.python import usage

class Options(usage.Options):

    optParameters = [["max_differences", "d", 1, None]]

    def parseArgs(self, origin, changed):
        self['origin'] = origin
        self['changed'] = changed
```

The command should look like `command origin changed`.

If you want to have a variable number of left-over arguments, just use `def parseArgs(self, *args):`. This is useful for commands like the UNIX `cat(1)`.

3.5.7 Post Processing

Sometimes, you want to perform post processing of options to patch up inconsistencies, and the like. Here is an example:

```
from twisted.python import usage

class Options(usage.Options):

    optFlags = [
        ["fast", "f", "Run quickly"],
        ["good", "g", "Don't validate input"],
        ["cheap", "c", "Use cheap resources"]
```

```
    ]

    def postOptions(self):
        if self['fast'] and self['good'] and self['cheap']:
            raise usage.UsageError, "can't have it all, brother"
```

3.6 DirDBM: Directory-based Storage

3.6.1 dirdbm.DirDBM

`twisted.persisted.dirdbm.DirDBM` is a DBM-like storage system. That is, it stores mappings between keys and values, like a Python dictionary, except that it stores the values in files in a directory - each entry is a different file. The keys must always be strings, as are the values. Other than that, `DirDBM` objects act just like Python dictionaries.

`DirDBM` is useful for cases when you want to store small amounts of data in an organized fashion, without having to deal with the complexity of a RDBMS or other sophisticated database. It is simple, easy to use, cross-platform, and doesn't require any external C libraries, unlike Python's built-in DBM modules.

```
>>> from twisted.persisted import dirdbm
>>> d = dirdbm.DirDBM("/tmp/dir")
>>> d["librarian"] = "ook"
>>> d["librarian"]
'ook'
>>> d.keys()
['librarian']
>>> del d["librarian"]
>>> d.items()
[]
```

3.6.2 dirdbm.Shelf

Sometimes it is neccessary to persist more complicated objects than strings. With some care, `dirdbm.Shelf` can transparently persist them. `Shelf` works exactly like `DirDBM`, except that the values (but not the keys) can be arbitrary picklable objects. However, notice that mutating an object after it has been stored in the `Shelf` has no effect on the Shelf. When mutating objects, it is neccessary to explictly store them back in the `Shelf` afterwards:

```
>>> from twisted.persisted import dirdbm
>>> d = dirdbm.Shelf("/tmp/dir2")
>>> d["key"] = [1, 2]
>>> d["key"]
[1, 2]
>>> l = d["key"]
>>> l.append(3)
>>> d["key"]
[1, 2]
>>> d["key"] = l
>>> d["key"]
[1, 2, 3]
```

3.7 Twisted Components: Interfaces and Adapters

Object oriented programming languages allow programmers to reuse portions of existing code by creating new "classes" of objects which subclass another class. When a class subclasses another, it is said to *inherit* all of its behaviour. The subclass can then "override" and "extend" the behavior provided to it by the superclass. Inheritance is very useful in many situations, but because it is so convenient to use, often becomes abused in large software systems, especially when multiple inheritance is involved. One solution is to use *delegation* instead of "inheritance" where appropriate. Delegation is simply the act of asking *another* object to perform a task for an object. To support this design pattern, which is often referred to as the *components* pattern because it involves many small interacting components, *interfaces* and *adapters* were created by the Zope 3 team.

"Interfaces" are simply markers which objects can use to say "I implement this interface". Other objects may then make requests like "Please give me an object which implements interface X for object type Y". Objects which implement an interface for another object type are called "adapters".

The superclass-subclass relationship is said to be an *is-a* relationship. When designing object hierarchies, object modellers use subclassing when they can say that the subclass *is* the same class as the superclass. For example:

```
class Shape:
    sideLength = 0
    def getSideLength(self):
        return self.sideLength

    def setSideLength(self, sideLength):
        self.sideLength = sideLength

    def area(self):
        raise NotImplementedError, "Subclasses must implement area"

class Triangle(Shape):
    def area(self):
        return (self.sideLength * self.sideLength) / 2

class Square(Shape):
    def area(self):
        return self.sideLength * self.sideLength
```

In the above example, a Triangle *is-a* Shape, so it subclasses Shape, and a Square *is-a* Shape, so it also subclasses Shape.

However, subclassing can get complicated, especially when Multiple Inheritance enters the picture. Multiple Inheritance allows a class to inherit from more than one base class. Software which relies heavily on inheritance often ends up having both very wide and very deep inheritance trees, meaning that one class inherits from many superclasses spread throughout the system. Since subclassing with Multiple Inheritance means *implementation inheritance*, locating a method's actual implementation and ensuring the correct method is actually being invoked becomes a challenge. For example:

```
class Area:
    sideLength = 0
    def getSideLength(self):
```

```
        return self.sideLength

    def setSideLength(self, sideLength):
        self.sideLength = sideLength

    def area(self):
        raise NotImplementedError, "Subclasses must implement area"

class Color:
    color = None
    def setColor(self, color):
      self.color = color

    def getColor(self):
      return self.color

class Square(Area, Color):
    def area(self):
        return self.sizeLength * self.sideLength
```

The reason programmers like using implementation inheritance is because it makes code easier to read since the implementation details of Area are in a separate place than the implementation details of Color. This is nice, because conceivably an object could have a color but not an area, or an area but not a color. The problem, though, is that Square is not really an Area or a Color, but has an area and color. Thus, we should really be using another object oriented technique called *composition*, which relies on delegation rather than inheritance to break code into small reusable chunks. Let us continue with the Multiple Inheritance example, though, because it is often used in practice.

What if both the Color and the Area base class defined the same method, perhaps `calculate`? Where would the implementation come from? The implementation that is located for `Square().calculate()` depends on the method resolution order, or MRO, and can change when programmers change seemingly unrelated things by refactoring classes in other parts of the system, causing obscure bugs. Our first thought might be to change the calculate method name to avoid name clashes, to perhaps `calculateArea` and `calculateColor`. While explicit, this change could potentially require a large number of changes throughout a system, and is error-prone, especially when attempting to integrate two systems which you didn't write.

Let's imagine another example. We have an electric appliance, say a hair dryer. The hair dryer is american voltage. We have two electric sockets, one of them an american 110 Volt socket, and one of them a foreign 220 Volt socket. If we plug the hair dryer into the 220 Volt socket, it is going to expect 110 Volt current and errors will result. Going back and changing the hair dryer to support both `plug110Volt` and `plug220Volt` methods would be tedious, and what if we decided we needed to plug the hair dryer into yet another type of socket? For example:

```
class HairDryer:
    def plug(self, socket):
        if socket.voltage() == 110:
            print "I was plugged in properly and am operating."
        else:
            print "I was plugged in improperly and "
    print "now you have no hair dryer any more."
```

```
class AmericanSocket:
    def voltage(self):
        return 110

class ForeignSocket:
    def voltage(self):
        return 220
```

Given these classes, the following operations can be performed:

```
>>> hd = HairDryer()
>>> am = AmericanSocket()
>>> hd.plug(am)
I was plugged in properly and am operating.
>>> fs = ForeignSocket()
>>> hd.plug(fs)
I was plugged in improperly and
now you have no hair dryer any more.
```

We are going to attempt to solve this problem by writing an Adapter for the `ForeignSocket` which converts the voltage for use with an American hair dryer. An Adapter is a class which is constructed with one and only one argument, the "adaptee" or "original" object. There is a simple implementation in `twisted.python.components.Adapter` which defines the `__init__` shown below, so you can subclass it if you desire. In this example, we will show all code involved for clarity:

```
class AdaptToAmericanSocket:
    def __init__(self, original):
        self.original = original

    def voltage(self):
        return self.original.voltage() / 2
```

Now, we can use it as so:

```
>>> hd = HairDryer()
>>> fs = ForeignSocket()
>>> adapted = AdaptToAmericanSocket(fs)
>>> hd.plug(adapted)
I was plugged in properly and am operating.
```

So, as you can see, an adapter can 'override' the original implementation. It can also 'extend' the interface of the original object by providing methods the original object did not have. Note that an Adapter must explicitly delegate any method calls it does not wish to modify to the original, otherwise the Adapter cannot be used in places where the original is expected. Usually this is not a problem, as an Adapter is created to conform an object to a particular interface and then discarded.

3.7.1 twisted.python.components: Twisted's implementation of Interfaces and Components

Adapters are a useful way of using multiple classes to factor code into discrete chunks. However, they are not very interesting without some more infrastructure. If each piece of code which wished to use an adapted object had to

explicitly construct the adapter itself, the coupling between components would be too tight. We would like to achieve "loose coupling", and this is where `twisted.python.components` comes in.

First, we need to discuss Interfaces in more detail. As we mentioned earlier, an Interface is nothing more than a class which is used as a marker. Interfaces should be subclasses of `twisted.python.components.Interface`, and have a very odd look to python programmers not used to them:

```
from twisted.python import components

class IAmericanSocket(components.Interface):
    def voltage():
      """Return the voltage produced by this socket object, as an integer.
      """
```

Notice how it looks just like a regular class definition, other than inheriting from `components.Interface`. However, the method definitions inside the class block do not have any self parameters, and also do not have any method body! Since Python does not have any native language-level support for Interfaces like Java does, this is what distinguishes an Interface definition from a Class.

Now that we have a defined Interface, we can talk about objects using terms like this: "The `AmericanSocket` class implements the `IAmericanSocket` interface" and "Please give me an object which adapts `ForeignSocket` to the `IAmericanSocket` interface". We can make *declarations* about what interfaces a certain class implements, and we can request adapters which implement a certain interface for a specific class.

Let's look at how we declare that a class implements an interface:

```
class AmericanSocket:
    __implements__ = (IAmericanSocket, )
    def voltage(self):
        return 110
```

So, to declare that a class implements an interface, we simply set the `__implements__` class variable to a tuple of interfaces. A single item tuple in Python is created by enclosing an item in parentheses and placing a single trailing comma after it.

Now, let's say we want to rewrite the `AdaptToAmericanSocket` class as a real adapter. We simply subclass `components.Adapter` and provide implementations of the methods in the `IAmericanSocket` interface:

```
class AdaptToAmericanSocket(components.Adapter):
    __implements__ = (IAmericanSocket, )
    def voltage(self):
        return self.original.voltage() / 2
```

Notice how we placed the implements declaration on this adapter class. So far, we have not achieved anything by using components other than requiring us to type more. In order for components to be useful, we must use the *component registry*. Since `AdaptToAmericanSocket` implements `IAmericanSocket` and regulates the voltage of a `ForeignSocket` object, we can *register `AdaptToAmericanSocket` as an `IAmericanSocket` adapter for the `ForeignSocket` class*. It is easier to see how this is done in code than to describe it:

```
from twisted.python import components

class IAmericanSocket(components.Interface):
```

```
    def voltage():
      """Return the voltage produced by this socket object, as an integer.
      """

class AmericanSocket:
    __implements__ = (IAmericanSocket, )
    def voltage(self):
        return 110

class ForeignSocket:
    def voltage(self):
        return 220

class AdaptToAmericanSocket(components.Adapter):
    __implements__ = (IAmericanSocket, )
    def voltage(self):
        return self.original.voltage() / 2

components.registerAdapter(
    AdaptToAmericanSocket,
    ForeignSocket,
    IAmericanSocket)
```

Now, if we run this script in the interactive interpreter, we can discover a little more about how to use components. The first thing we can do is discover whether an object implements an interface or not:

```
>>> as = AmericanSocket()
>>> fs = ForeignSocket()
>>> components.implements(as, IAmericanSocket)
1
>>> components.implements(fs, IAmericanSocket)
0
```

As you can see, the `AmericanSocket` instance claims to implement `IAmericanSocket`, but the `ForeignSocket` does not. If we wanted to use the `HairDryer` with the `AmericanSocket`, we could know that it would be safe to do so by checking whether it implements `IAmericanSocket`. However, if we decide we want to use `HairDryer` with a `ForeignSocket` instance, we must *adapt* it to `IAmericanSocket` before doing so. We use the interface object to do this:

```
>>> IAmericanSocket(fs)
<__main__.AdaptToAmericanSocket instance at 0x1a5120>
```

When calling an interface with an object as an argument, the interface looks in the adapter registry for an adapter which implements the interface for the given instance's class. If it finds one, it constructs an instance of the Adapter class, passing the constructor the original instance, and returns it. Now the `HairDryer` can safely be used with the adapted `ForeignSocket`. But what happens if we attempt to adapt an object which already implements `IAmericanSocket`? We simply get back the original instance:

```
>>> IAmericanSocket(as)
<__main__.AmericanSocket instance at 0x36bff0>
```

So, we could write a new "smart"`HairDryer` which automatically looked up an adapter for the socket you tried to plug it into:

```
class HairDryer:
    def plug(self, socket):
        adapted = IAmericanSocket(socket)
        assert socket.voltage() == 110, "BOOM"
        print "I was plugged in properly and am operating"
```

Now, if we create an instance of our new "smart"`HairDryer` and attempt to plug it in to various sockets, the `HairDryer` will adapt itself automatically depending on the type of socket it is plugged in to:

```
>>> as = AmericanSocket()
>>> fs = ForeignSocket()
>>> hd = HairDryer()
>>> hd.plug(as)
I was plugged in properly and am operating
>>> hd.plug(fs)
I was plugged in properly and am operating
```

Voila; the magic of components.

Chapter 4

Low-Level Twisted

4.1 Reactor Basics

The reactor is the core of the event loop within Twisted and provides a basic interface to a number of services, including network communications, threading, and event dispatching.

There are multiple implementations of the reactor, each modified to provide better support for specialized features over the default implementation. More information about these and how to use a particular implementation is available via *Choosing a Reactor* (page 96).

You can get to the reactor object using the following code:

```
from twisted.internet import reactor
```

The reactor usually implements a set of interfaces, but depending on the chosen reactor and the platform, some of the interfaces may not be implemented:

- `IReactorCore`: Core (required) functionality.
- `IReactorFDSet`: Use FileDescriptor objects.
- `IReactorProcess`: Process management. Read the *Using Processes* (page 76) document for more information.
- `IReactorSSL`: SSL networking support.
- `IReactorTCP`: TCP networking support. More information can be found in the *Writing Servers* (page 68) and *Writing Clients* (page 72) documents.
- `IReactorThreads`: Threading use and management. More information can be found within *Threading In Twisted* (page 94).
- `IReactorTime`: Scheduling interface. More information can be found within *Scheduling Tasks* (page 93).
- `IReactorUDP`: UDP networking support. More information can be found within *UDP Networking* (page 75).
- `IReactorUNIX`: UNIX socket support.

4.2 Writing Servers

4.2.1 Overview

Twisted is a framework designed to be very flexible and let you write powerful servers. The cost of this flexibility is a few layers in the way to writing your server.

This document describes the `Protocol` layer, where you implement protocol parsing and handling. If you are implementing an application then you should read this document second, after first reading the top level overview of how to begin writing your Twisted application, in *Writing Plug-Ins for Twisted* (page 43). This document is only relevant to TCP, SSL and Unix socket servers, there is a *separate document* (page 75) for UDP.

Your protocol handling class will usually subclass `twisted.internet.protocol.Protocol`. Most protocol handlers inherit either from this class or from one of its convenience children. An instance of the protocol class might be instantiated per-connection, on demand, and might go away when the connection is finished. This means that persistent configuration is not saved in the `Protocol`.

The persistent configuration is kept in a Factory class, which usually inherits from `twisted.internet.protocol.Factory`. The default factory class just instantiates each `Protocol`, and then sets on it an attribute called `factory` which points to itself. This lets every `Protocol` access, and possibly modify, the persistent configuration.

It is usually useful to be able to offer the same service on multiple ports or network addresses. This is why the `Factory` does not listen to connections, and in fact does not know anything about the network. See `twisted.internet.interfaces.IReactorTCP.listenTCP`, and the other `IReactor*.listen*` APIs for more information.

This document will explain each step of the way.

4.2.2 Protocols

As mentioned above, this, along with auxiliary classes and functions, is where most of the code is. A Twisted protocol handles data in an asynchronous manner. What this means is that the protocol never waits for an event, but rather responds to events as they arrive from the network.

Here is a simple example:

```
from twisted.internet.protocol import Protocol

class Echo(Protocol):

    def dataReceived(self, data):
        self.transport.write(data)
```

This is one of the simplest protocols. It simply writes back whatever is written to it, and does not respond to all events. Here is an example of a Protocol responding to another event:

```
from twisted.internet.protocol import Protocol

class QOTD(Protocol):

    def connectionMade(self):
        self.transport.write("An apple a day keeps the doctor away\r\n")
        self.transport.loseConnection()
```

This protocol responds to the initial connection with a well known quote, and then terminates the connection.

The connectionMade event is usually where set up of the connection object happens, as well as any initial greetings (as in the QOTD protocol above, which is actually based on RFC 865). The `connectionLost` event is where tearing down of any connection-specific objects is done. Here is an example:

```
from twisted.internet.protocol import Protocol

class Echo(Protocol):

    def connectionMade(self):
        self.factory.numProtocols = self.factory.numProtocols+1
        if self.factory.numProtocols > 100:
            self.transport.write("Too many connections, try later")
            self.transport.loseConnection()

    def connectionLost(self, reason):
        self.factory.numProtocols = self.factory.numProtocols-1

    def dataReceived(self, data):
        self.transport.write(data)
```

Here `connectionMade` and `connectionLost` cooperate to keep a count of the active protocols in the factory. `connectionMade` immediately closes the connection if there are too many active protocols.

Using the Protocol

In this section, I will explain how to test your protocol easily. (In order to see how you should write a production-grade Twisted server, though, you should read the *Writing Plug-Ins for Twisted* (page 43) HOWTO as well).

Here is code that will run the QOTD server discussed earlier

```
from twisted.internet.protocol import Protocol, Factory
from twisted.internet import reactor

class QOTD(Protocol):

    def connectionMade(self):
        self.transport.write("An apple a day keeps the doctor away\r\n")
        self.transport.loseConnection()

# Next lines are magic:
factory = Factory()
factory.protocol = QOTD

# 8007 is the port you want to run under. Choose something >1024
reactor.listenTCP(8007, factory)
reactor.run()
```

Don’t worry about the last 6 magic lines – you will understand what they do later in the document.

Helper Protocols

Many protocols build upon similar lower-level abstraction. The most popular in internet protocols is being line-based. Lines are usually terminated with a CR-LF combinations.

However, quite a few protocols are mixed - they have line-based sections and then raw data sections. Examples include HTTP/1.1 and the Freenet protocol.

For those cases, there is the `LineReceiver` protocol. This protocol dispatches to two different event handlers - `lineReceived` and `rawDataReceived`. By default, only `lineReceived` will be called, once for each line. However, if `setRawMode` is called, the protocol will call `rawDataReceived` until `setLineMode` is called again.

Here is an example for a simple use of the line receiver:

```
from twisted.protocols.basic import LineReceiver

class Answer(LineReceiver):

    answers = {'How are you?': 'Fine', None : "I don't know what you mean"}

    def lineReceived(self, line):
        if self.answers.has_key(line):
            self.sendLine(self.answers[line])
        else:
            self.sendLine(self.answers[None])
```

Note that the delimiter is not part of the line.

Several other, less popular, helpers exist, such as a netstring based protocol and a prefixed-message-length protocol.

State Machines

Many Twisted protocol handlers need to write a state machine to record the state they are at. Here are some pieces of advice which help to write state machines:

- Don't write big state machines. Prefer to write a state machine which deals with one level of abstraction at a time.
- Use Python's dynamicity to create open ended state machines. See, for example, the code for the SMTP client.
- Don't mix application-specific code with Protocol handling code. When the protocol handler has to make an application-specific call, keep it as a method call.

4.2.3 Factories

As mentioned before, usually the class `twisted.internet.protocol.Factory` works, and there is no need to subclass it. However, sometimes there can be factory-specific configuration of the protocols, or other considerations. In those cases, there is a need to subclass `Factory`.

For a factory which simply instantiates instances of a specific protocol class, simply instantiate `Factory`, and sets its `protocol` attribute:

```
from twisted.internet.protocol import Factory
from twisted.protocols.wire import Echo

myFactory = Factory()
myFactory.protocol = Echo
```

If there is a need to easily construct factories for a specific configuration, a factory function is often useful:

```
from twisted.internet.protocol import Factory, Protocol

class QOTD(Protocol):

    def connectionMade(self):
        self.transport.write(self.factory.quote+'\r\n')
        self.transport.loseConnection()


def makeQOTDFactory(quote=None):
    factory = Factory()
    factory.protocol = QOTD
    factory.quote = quote or 'An apple a day keeps the doctor away'
    return factory
```

A Factory has two methods to perform application-specific building up and tearing down (since a Factory is frequently persisted, it is often not appropriate to do them in `__init__` or `__del__`, and would frequently be too early or too late).

Here is an example of a factory which allows its Protocols to write to a special log-file:

```
from twisted.internet.protocol import Factory
from twisted.protocols.basic import LineReceiver


class LoggingProtocol(LineReceiver):

    def lineReceived(self, line):
        self.factory.fp.write(line+'\n')


class LogfileFactory(Factory):

    protocol = LoggingProtocol

    def __init__(self, fileName):
        self.file = fileName

    def startFactory(self):
        self.fp = open(file, 'a')
```

```
    def stopFactory(self):
        self.fp.close()
```

Putting it All Together

So, you know what factories are, and want to run the QOTD with configurable quote server, do you? No problems, here is an example.

```
from twisted.internet.protocol import Factory, Protocol
from twisted.internet import reactor

class QOTD(Protocol):

    def connectionMade(self):
        self.transport.write(self.factory.quote+'\r\n')
        self.transport.loseConnection()


class QOTDFactory(Factory):

    protocol = QOTD

    def __init__(self, quote=None):
        self.quote = quote or 'An apple a day keeps the doctor away'

reactor.listenTCP(8007, QOTDFactory("configurable quote"))
reactor.run()
```

The only lines you might not understand are the last two.

`listenTCP` is the method which connects a `Factory` to the network. It uses the reactor interface, which lets many different loops handle the networking code, without modifying end-user code, like this. As mentioned above, if you want to write your code to be a production-grade Twisted server, and not a mere 20-line hack, you will want to use *the Application object* (page 38).

4.3 Writing Clients

4.3.1 Overview

Twisted is a framework designed to be very flexible, and let you write powerful clients. The cost of this flexibility is a few layers in the way to writing your client. This document covers creating clients that can be used for TCP, SSL and Unix sockets, UDP is covered *in a different document* (page 75).

At the base, the place where you actually implement the protocol parsing and handling, is the Protocol class. This class will usually be decended from `twisted.internet.protocol.Protocol`. Most protocol handlers inherit either from this class or from one of its convenience children. An instance of the protocol class will be instantiated when you connect to the server, and will go away when the connection is finished. This means that persistent configuration is not saved in the Protocol.

The persistent configuration is kept in a Factory class, which usually inherits from `twisted.internet.protocol.ClientFactory`. The default factory class just instantiate the Protocol, and then sets on it an attribute called `factory` which points to itself. This let the Protocol access, and possibly modify, the persistent configuration.

4.3.2 Protocol

As mentioned above, this, and auxiliary classes and functions, is where most of the code is. A Twisted protocol handles data in an asynchronous manner. What this means is that the protocol never waits for an event, but rather responds to events as they arrive from the network.

Here is a simple example:

```
from twisted.internet.protocol import Protocol
from sys import stdout
class Echo(Protocol):

    def dataReceived(self, data):
        stdout.write(data)
```

This is one of the simplest protocols. It simply writes to standard output whatever it reads from the connection. There are many events it does not respond to. Here is an example of a Protocol responding to another event.

```
from twisted.internet.protocol import Protocol
class WelcomeMessage(Protocol):

    def connectionMade(self):
        self.transport.write("Hello server, I am the client!\r\n")
        self.transport.loseConnection()
```

This protocol connects to the server, sends it a welcome message, and then terminates the connection.

The connectionMade event is usually where set up of the Protocol object happens, as well as any initial greetings (as in the WelcomeMessage protocol above). Any tearing down of Protocol-specific objects is done in connectionLost.

4.3.3 ClientFactory

With the new API, Protocols no longer connect directly using reactor.client*. Instead, we use reactor.connect* and a ClientFactory. The ClientFactory is in charge of creating the Protocol, and also receives events relating to the connection state. This allows it to do things like reconnect on the event of a connection error. Here is an example of a simple ClientFactory that uses the Echo protocol (above) and also prints what state the connection is in.

```
from twisted.internet.protocol import Protocol, ClientFactory
from sys import stdout
class Echo(Protocol):

    def dataReceived(self, data):
            stdout.write(data)

class EchoClientFactory(ClientFactory):
```

```
    def startedConnection(self, connector):
        print 'Started to connect.'

    def buildProtocol(self, addr):
        print 'Connected.'
        return Echo()

    def clientConnectionLost(self, connector, reason):
        print 'Lost connection.  Reason:', reason

    def clientConnectionFailed(self, connector, reason):
        print 'Connection failed. Reason:', reason
```

To connect this EchoClientFactory to a server, you could use this code:

```
from twisted.internet import reactor
reactor.connectTCP(host, port, EchoClientFactory())
reactor.run()
```

4.3.4 A Higher-Level Example: ircLogBot

Overview of ircLogBot

The clients so far have been fairly simple. A more complicated example comes with Twisted in the doc/examples directory. ircLogBot.py connects to an IRC server, joins a channel, and logs all traffic on it to a file. It demonstrates some of the connection-level logic of reconnecting on a lost connection, as well as storing persistent data in the Factory.

Reconnection

Many times, the connection of a client will be lost unintentionally due to network errors. In the case of the ircLogBot, leaving the bot disconnected will result in the loss of the log data until the administrator reconnects the bot. However, with the new API this can be automated. The relevant part of ircLogBot.py follows:

```
from twisted.internet import protocol
class LogBotFactory(protocol.ClientFactory):

    def clientConnectionLost(self, connector, reason):
        connector.connect()
```

That last line is the most important. The connector passed as the first argument is the interface between a connection and a protocol. When the connection fails and the factory receives the clientConnectionLost event, the factory can call `connector.connect()` to start the connection over again from scratch.

Persistent Data in the Factory

Since the Protocol instance is recreated each time the connection is made, the client needs some way to keep track of data that should be persisted. In the case of ircLogBot.py: (`LogBot.log()` just logs the data to the file object stored in `LogBot.file`)

```
from twisted.internet import protocol
from twisted.protocols import irc
class LogBot(irc.IRCClient):

    def connectionMade(self):
        irc.IRCClient.connectionMade(self)
        self.file = open(self.factory.filename, "a")
        self.log("[connected at %s]" %
                 time.asctime(time.localtime(time.time())))

    def signedOn(self):
        self.join(self.factory.channel)

class LogBotFactory(protocol.ClientFactory):

    def __init__(self, channel, filename):
        self.channel = channel
        self.filename = filename
```

When the protocol is created, it gets a reference to the factory as self.factory. It can then access attributes of the factory in its logic. In the case of LogBot, it opens the file and connects to the channel stored in the factory.

4.4 UDP Networking

4.4.1 Overview

Unlike TCP, UDP has no notion of connections. A UDP socket can receive datagrams from any server on the network, and send datagrams to any host on the network. In addition, datagrams may arrive in any order, never arrive at all, or be duplicated in transit.

Since there are no multiple connections, we only use a single object, a protocol, for each UDP socket. We then use the reactor to connect this protocol to a UDP transport, using the `twisted.internet.interfaces.IReactorUDP` reactor API.

4.4.2 DatagramProtocol

At the base, the place where you actually implement the protocol parsing and handling, is the DatagramProtocol class. This class will usually be decended from `twisted.internet.protocol.DatagramProtocol`. Most protocol handlers inherit either from this class or from one of its convenience children. The DatagramProtocol class receives datagrams, and can send them out over the network. Received datagrams include the address they were sent from, and when sending datagrams the address to send to must be specified.

Here is a simple example:

```
from twisted.internet.protocol import DatagramProtocol
from twisted.internet import reactor

class Echo(DatagramProtocol):
```

```
    def datagramReceived(self, data, (host, port)):
        print "received %r from %s:%d" % (data, host, port)
        self.transport.write(data, (host, port))

reactor.listenUDP(9999, Echo())
reactor.run()
```

As you can see, the protocol is registed with the reactor. This means it may be persisted if it's added to an application, and thus it has `twisted.internet.protocol.DatagramProtocol.startProtocol` and `twisted.internet.protocol.DatagramProtocol.stopProtocol` methods that will get called when the protocol is connected and disconnected from a UDP socket.

The protocol's `transport` attribute will implement the `twisted.internet.interfaces.IUDPTransport` interface.

4.4.3 Connected UDP

A connected UDP socket is slighly different from a standard one - it can only send and receive datagrams to/from a single address, but this does not in any way imply a connection. Datagrams may still arrive in any order, and the port on the other side may have no one listening. The benefit of the connected UDP socket is that it is faster.

Unlike a regular UDP protocol, we do not need to specify where to send datagrams to, and are not told where they came from since they can only come from address the socket is 'connected' to.

The protocol's `transport` attribute will implement the `twisted.internet.interfaces.IUDPConnectedTransport` interface.

```
from twisted.internet.protocol import ConnectedDatagramProtocol
from twisted.internet import reactor

class Echo(ConnectedDatagramProtocol):

    def datagramReceived(self, data):
        self.transport.write(data)

reactor.connectUDP("www.example.com", 9999, Echo())
reactor.run()
```

4.5 Using Processes

4.5.1 Overview

Along with connection to servers across the internet, Twisted also connects to local processes with much the same API. The API is described in more detail in the documentation of:

- `twisted.internet.interfaces.IReactorProcess`
- `twisted.internet.interfaces.IProcessTransport`
- `twisted.internet.protocol.ProcessProtocol`

4.5.2 Running Another Process

Processes are run through the reactor, using `reactor.spawnProcess()`. Pipes are created to the child process, and added to the reactor core so that the application will not block while sending data into or pulling data out of the new process. `reactor.spawnProcess()` requires two arguments, processProtocol and executable, and optionally takes six more: arguments, environment, path, userID, groupID, and usePTY.

```
from twisted.internet import reactor

mypp = MyProcessProtocol()
reactor.spawnProcess(processProtocol, executable, args=[program, arg1, arg2],
                     env={'HOME': os.environ['HOME']}, path,
                     uid, gid, usePTY)
```

- `processProtocol` should be an instance of a subclass of `twisted.internet.protocol.ProcessProtocol`. The interface is described below.
- `executable` is the full path of the program to run. It will be connected to processProtocol.
- `args` is a list of command line arguments to be passed to the process. `args[0]` should be the name of the process.
- `env` is a dictionary containing the environment to pass through to the process.
- `path` is the directory to run the process in. The child will switch to the given directory just before starting the new program. The default is to stay in the current directory.
- `uid` and `gid` are the user ID and group ID to run the subprocess as. Of course, changing identities will be more likely to succeed if you start as root.
- `usePTY` specifies whether the child process should be run with a pty, or if it should just get a pair of pipes. Interactive programs (where you don't know when it may read or write) need to be run with ptys.

`args` and `env` have empty default values, but many programs depend upon them to be set correctly. At the very least, `args[0]` should probably be the same as `executable`. If you just provide `os.environ` for `env`, the child program will inherit the environment from the current process, which is usually the civilized thing to do (unless you want to explicitly clean the environment as a security precaution).

`reactor.spawnProcess()` returns an instance that implements the `twisted.internet.interfaces.IProcessTransport`.

4.5.3 Writing a ProcessProtocol

The ProcessProtocol you pass to spawnProcess is your interaction with the process. It has a very similar signature to a regular Protocol, but it has several extra methods to deal with events specific to a process. In our example, we will interface with 'wc' to create a word count of user-given text. First, we'll start by importing the required modules, and writing the initialization for our ProcessProtocol.

```
from twisted.internet import protocol
class WCProcessProtocol(protocol.ProcessProtocol):
```

```
    def __init__(self, text):
        self.text = text
```

When the ProcessProtocol is connected to the protocol, it has the connectionMade method called. In our protocol, we will write our text to the standard input of our process and then close standard input, to the let the process know we are done writing to it.

```
    def connectionMade(self):
        self.transport.write(self.text)
        self.transport.closeStdin()
```

At this point, the process has receieved the data, and it's time for us to read the results. Instead of being receieved in dataReceived, data from standard output is receieve in outReceived. This is to distinguish it from data on standard error.

```
    def outReceived(self, data):
        fieldLength = len(data) / 3
        lines = int(data[:fieldLength])
        words = int(data[fieldLength:fieldLength*2])
        chars = int(data[fieldLength*2:])
        self.transport.loseConnection()
        self.receiveCounts(lines, words, chars)
```

Now, the process has parsed the output, and ended the connection to the process. Then it sends the results on to the final method, receiveCounts. This is for users of the class to override, so as to do other things with the data. For our demonstration, we will just print the results.

```
    def receiveCounts(self, lines, words, chars):
        print 'Received counts from wc.'
        print 'Lines:', lines
        print 'Words:', words
        print 'Characters:', chars
```

We're done! To use our WCProcessProtocol, we create an instance, and pass it to spawnProcess.

```
from twisted.internet import reactor
wcProcess = WCProcessProtocol("accessing protocols through Twisted is fun!\n")
reactor.spawnProcess(wcProcess, 'wc', ['wc'])
reactor.run()
```

4.5.4 Things that can happen to your ProcessProtocol

These are the methods that you can usefully override in your subclass of `ProcessProtocol`:

- `.connectionMade`: This is called when the program is started, and makes a good place to write data into the stdin pipe (using `self.transport.write()`).

- `.outReceived(data)`: This is called with data that was received from the process' stdout pipe. Pipes tend to provide data in larger chunks than sockets (one kilobyte is a common buffer size), so you may not experience the "random dribs and drabs" behavior typical of network sockets, but regardless you should be prepared to deal if you don't get all your data in a single call. To do it properly, `outReceived` ought to simply accumulate the data and put off doing anything with it until the process has finished.
- `.errReceived(data)`: This is called with data from the process' stderr pipe. It behaves just like `outReceived`.
- `.inConnectionLost`: This is called when the reactor notices that the process' stdin pipe has closed. Programs don't typically close their own stdin, so this will probably get called when your ProcessProtocol has shut down the write side with `self.transport.loseConnection()`.
- `.outConnectionLost`: This is called when the program closes its stdout pipe. This usually happens when the program terminates.
- `.errConnectionLost`: Same as `outConnectionLost`, but for stderr instead of stdout.
- `.processEnded(status)`: This is called when the child process has been reaped, and receives information about the process' exit status. The status is passed in the form of a `Failure` instance, created with a `.value` that either holds a `ProcessDone` object if the process terminated normally (it died of natural causes instead of receiving a signal, and if the exit code was 0), or a `ProcessTerminated` object (with an `.exitCode` attribute) if something went wrong. This scheme may seem a bit weird, but I trust that it proves useful when dealing with exceptions that occur in asynchronous code.

  This will always be called *after* `inConnectionLost`, `outConnectionLost`, and `errConnectionLost` are called.

The base-class definitions of these functions are all no-ops. This will result in all stdout and stderr being thrown away. Note that it is important for data you don't care about to be thrown away: if the pipe were not read, the child process would eventually block as it tried to write to a full pipe.

4.5.5 Things you can do from your ProcessProtocol

The following are the basic ways to control the child process:

- `self.transport.write(data)`: Stuff some data in the stdin pipe. Note that this `write` method will queue any data that can't be written immediately. Writing will resume in the future when the pipe becomes writable again.
- `self.transport.closeStdin`: Close the stdin pipe. Programs which act as filters (reading from stdin, modifying the data, writing to stdout) usually take this as a sign that they should finish their job and terminate. For these programs, it is important to close stdin when you're done with it, otherwise the child process will never quit.
- `self.transport.closeStdout`: Not usually called, since you're putting the process into a state where any attempt to write to stdout will cause a SIGPIPE error. This isn't a nice thing to do to the poor process.
- `self.transport.closeStderr`: Not usually called, same reason as `closeStdout`.
- `self.transport.loseConnection`: Close all three pipes.

- `os.kill(self.transport.pid, signal.SIGKILL)`: Kill the child process. This will eventually result in `processEnded` being called.

4.5.6 Verbose Example

Here is an example that is rather verbose about exactly when all the methods are called. It writes a number of lines into the `wc` program and then parses the output.

```
#! /usr/bin/python

from twisted.internet import protocol
from twisted.internet import reactor
import re

class MyPP(protocol.ProcessProtocol):
    def __init__(self, verses):
        self.verses = verses
        self.data = ""
    def connectionMade(self):
        print "connectionMade!"
        for i in range(self.verses):
            self.transport.write("Aleph-null bottles of beer on the wall,\n" +
                                 "Aleph-null bottles of beer,\n" +
                                 "Take on down and pass it around,\n" +
                                 "Aleph-null bottles of beer on the wall.\n")
        self.transport.closeStdin() # tell them we're done
    def outReceived(self, data):
        print "outReceived! with %d bytes!" % len(data)
        self.data = self.data + data
    def errReceived(self, data):
        print "errReceived! with %d bytes!" % len(data)
    def inConnectionLost(self):
        print "inConnectionLost! stdin is closed! (we probably did it)"
    def outConnectionLost(self):
        print "outConnectionLost! The child closed their stdout!"
        # now is the time to examine what they wrote
        #print "I saw them write:", self.data
        (dummy, lines, words, chars, file) = re.split(r'\s+', self.data)
        print "I saw %s lines" % lines
    def errConnectionLost(self):
        print "errConnectionLost! The child closed their stderr."
    def processEnded(self, status_object):
        print "processEnded, status %d" % status_object.value.exitCode
        print "quitting"
        reactor.stop()
```

```
pp = MyPP(10)
reactor.spawnProcess(pp, "wc", ["wc"], {})
reactor.run()
```

Source listing — *process.py*

The exact output of this program depends upon the relative timing of some un-synchronized events. In particular, the program may observe the child process close its stderr pipe before or after it reads data from the stdout pipe. One possible transcript would look like this:

```
% ./process.py
connectionMade!
inConnectionLost! stdin is closed! (we probably did it)
errConnectionLost! The child closed their stderr.
outReceived! with 24 bytes!
outConnectionLost! The child closed their stdout!
I saw 40 lines
processEnded, status 0
quitting
Main loop terminated.
%
```

4.5.7 Doing it the Easy Way

Frequently, one just need a simple way to get all the output from a program. For those cases, the `twisted.internet.utils.getProcessOutput` function can be used. Here is a simple example:

```
from twisted.internet import protocol, utils, reactor
from twisted.python import failure
from cStringIO import StringIO

class FortuneQuoter(protocol.Protocol):

    fortune = '/usr/games/fortune'

    def connectionMade(self):
        output = utils.getProcessOutput(self.fortune)
        output.addCallbacks(self.writeResponse, self.noResponse)

    def writeResponse(self, resp):
        self.transport.write(resp)
        self.transport.loseConnection()

    def noResponse(self, err):
        self.transport.loseConnection()
```

```
if __name__ == '__main__':
    f = protocol.Factory()
    f.protocol = FortuneQuoter
    reactor.listenTCP(10999, f)
    reactor.run()
```

Source listing — *quotes.py*

If you need to get just the final exit code, the `twisted.internet.utils.getProcessValue` function is useful. Here is an example:

```
from twisted.internet import utils, reactor

def printTrueValue(val):
    print val
    output = utils.getProcessValue('false')
    output.addCallback(printFalseValue)

def printFalseValue(val):
    print val
    reactor.stop()

output = utils.getProcessValue('true')
output.addCallback(printTrueValue)
reactor.run()
```

Source listing — *trueandfalse.py*

4.6 Deferring Execution

4.6.1 The Context

Dealing with Blocking Code

When coding I/O based programs - networking code, databases, file access - there are many APIs that are blocking, and many methods where the common idiom is to block until a result is gotten.

```
class Getter:
    def getData(self, x):
        # imagine I/O blocking code here
        print "blocking"
        import time
        time.sleep(4)
```

```
        return x * 3

g = Getter()
print g.getData(3)
```

Don't Call Us, We'll Call You

Twisted can not support blocking calls in most of its code, since it is single threaded, and event based. The solution for this issue is to refactor the code, so that instead of blocking until data is available, we return immediately, and use a callback to notify the requester once the data eventually arrives.

```
from twisted.internet import reactor

class Getter:
    def getData(self, x, callback):
        # this won't block
        reactor.callLater(2, callback, x * 3)

def printData(d):
    print d

g = Getter()
g.getData(3, printData)

# startup the event loop, exiting after 4 seconds
reactor.callLater(4, reactor.stop);
reactor.run()
```

There are several things missing in this simple example. There is no way to know if the data never comes back; no mechanism for handling errors. The example does not handle a multiple callback functions, nor does it give a method to merge arguments before and after execution. Further, there is no way to distinguish between different calls to gotData from different producer objects. `Deferred` solves these problems, by creating a single, unified way to handle callbacks and errors from deferred execution.

4.6.2 Deferreds

A `twisted.internet.defer.Deferred` is a promise that a function will at some point have a result. We can attach callback functions to a Deferred, and once it gets a result these callbacks will be called. In addition Deferreds allow the developer to register a callback for an error, with the default behavior of logging the error. The deferred mechanism standardizes the application programmer's interface with all sorts of blocking or delayed operations.

```
from twisted.internet import reactor, defer

class Getter:
    def getData(self, x):
        # this won't block
        d = defer.Deferred()
```

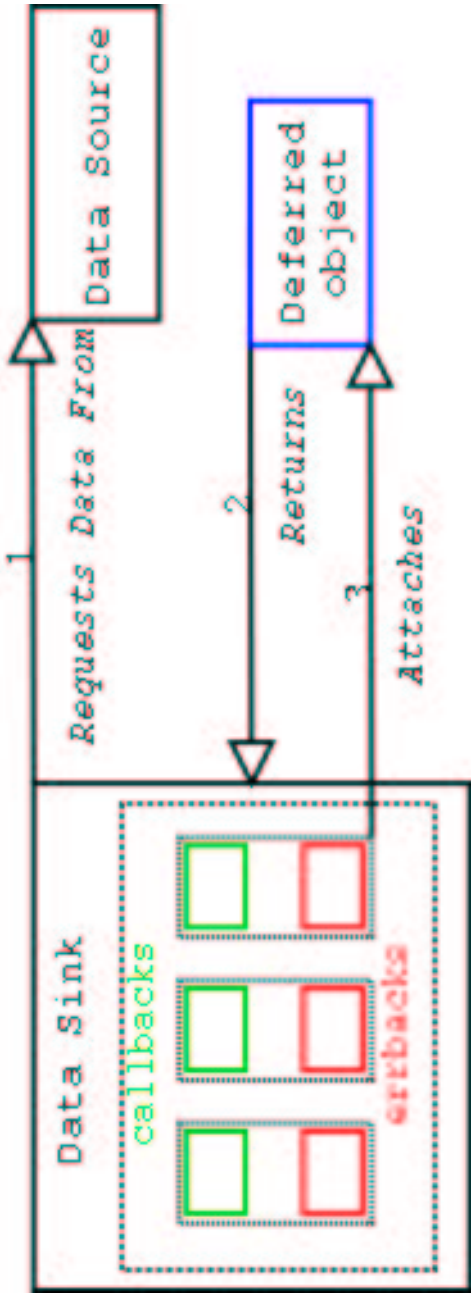
```
        reactor.callLater(2, d.callback, x * 3)
        return d

def printData(d):
    print d

g = Getter()
d = g.getData(3)
d.addCallback(printData)

reactor.callLater(4, reactor.stop); reactor.run()
```

As we said, multiple callbacks can be added to a Deferred. The first callback in the Deferred's callback chain will be called with the result, the second with the result of the first callback, and so on. Why do we need this? Well, consider a Deferred returned by twisted.enterprise.adbapi - the result of a SQL query. A web widget might add a callback that converts this result into HTML, and pass the Deferred onwards, where the callback will be used by twisted to return the result to the HTTP client. The callback chain will be bypassed in case of errors or exceptions.

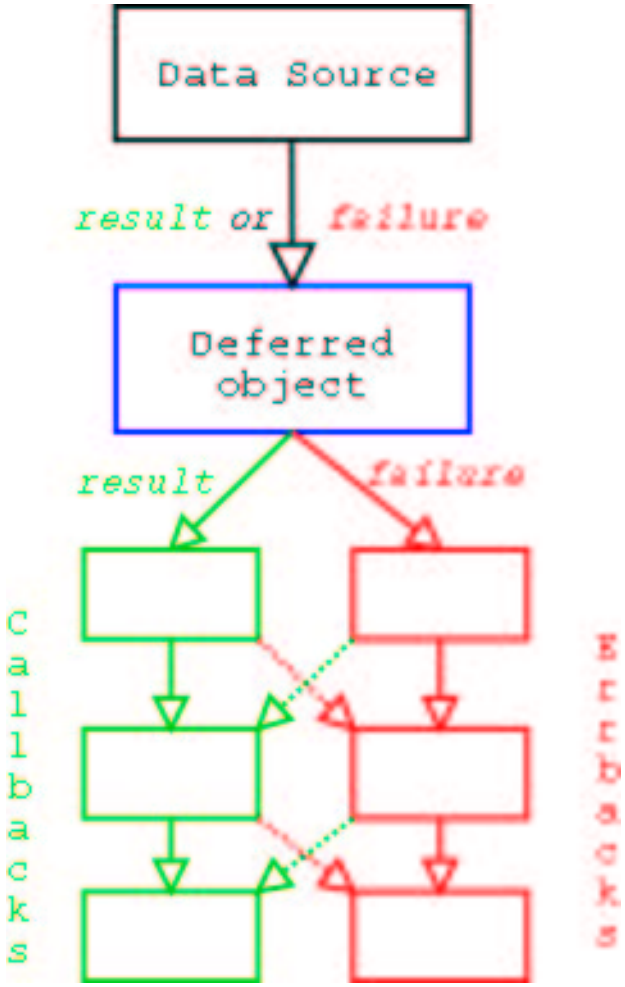
```
from twisted.internet import reactor, defer

class Getter:
    def gotResults(self, x):
        """The Deferred mechanism provides a mechanism to signal error
           conditions.  In this case, even numbers are bad.
        """
        if x % 2:
            self.d.callback(x*3)
        else:
            self.d.errback(ValueError("You used an even number!"))

    def _toHTML(self, r):
        return "Result: %s" % r

    def getData(self, x):
        """The Deferred mechanism allows for chained callbacks.
           In this example, the output of gotResults is first
           passed through _toHTML on its way to printData.
        """
        self.d = defer.Deferred()
        reactor.callLater(2, self.gotResults, x)
        self.d.addCallback(self._toHTML)
        return self.d

def printData(d):
    print d

def printError(failure):
```

```
    import sys
    sys.stderr.write(str(failure))

# this will print an error message
g = Getter()
d = g.getData(3)
d.addCallback(printData)
d.addErrback(printError)

# this will print "Result: 12"
g = Getter()
d = g.getData(4)
d.addCallback(printData)
d.addErrback(printError)

reactor.callLater(4, reactor.stop); reactor.run()
```

Visual Explanation



1. Requesting method (data sink) requests data, gets Deferred object.
2. Requesting method attaches callbacks to Deferred object.



1. When the result is ready, give it to the Deferred object. `.callback(result)` if the operation succeeded, `.errback(failure)` if it failed. Note that `failure` is typically an instance of a `twisted.python.failure.Failure` instance.

2. Deferred object triggers previously-added (call/err)back with the `result` or `failure`. Execution then follows the following rules, going down the chain of callbacks to be processed.

   - Result of the callback is always passed as the first argument to the next callback, creating a chain of processors.
   - If a callback raises an exception, switch to errback.
   - An unhandled failure gets passed down the line of errbacks, this creating an asynchronous analog to a series to a series of `except:` statements.
   - If an errback doesn't raise an exception or return a `twisted.python.failure.Failure` instance, switch to callback.

More about callbacks

You add multiple callbacks to a Deferred:

```
g = Getter()
d = g.getResult(3)
d.addCallback(processResult)
d.addCallback(printResult)
```

Each callback feeds its return value into the next callback (callbacks will be called in the order you add them). Thus in the previous example, `processResult`'s return value will be passed to `printResult`, instead of the value initially passed into the callback. This gives you a flexible way to chain results together, possibly modifying values along the way, (for example, you may wish to pre-processed database query results).

More about errbacks

Deferred's error handling is modeled after Python's exception handling. In the case that no errors occur, all the callbacks run, one after the other, as described above.

If the errback is called instead of the callback (e.g. because a DB query raised an error), then a `twisted.python.failure.Failure` is passed into the first errback (you can add multiple errbacks, just like with callbacks). You can think of your errbacks as being like `except` blocks of ordinary Python code.

Unless you explicitly `raise` an error in except block, the `Exception` is caught and stops propagating, and normal execution continues. The same thing happens with errbacks: unless you explicitly `return` a `Failure` or (re-)raise an exception, the error stops propagating, and normal callbacks continue executing from that point (using the value returned from the errback). If the errback does returns a `Failure` or raise an exception, then that is passed to the next errback, and so on.

Note: If an errback doesn't return anything, then it effectively returns `None`, meaning that callbacks will continue to be executed after this errback. This may not be what you expect to happen, so be careful. Make sure your errbacks return a `Failure` (probably the one that was passed to it), or a meaningful return value for the next callback.

Also, `twisted.python.failure.Failure` instances have a useful method called trap, allowing you to effectively do the equivalent of:

```
try:
    # code that may throw an exception
    cookSpamAndEggs()
except (SpamException, EggException):
    # Handle SpamExceptions and EggExceptions
    ...
```

You do this by:

```
def errorHandler(failure):
    failure.trap(SpamException, EggException)
    # Handle SpamExceptions and EggExceptions

d.addCallback(cookSpamAndEggs)
d.addErrback(errorHandler)
```

If none of arguments passed to `failure.trap` match the error encapsulated in that `Failure`, then it re-raises the error.

There's another potential "gotcha" here. There's a convenience method `twisted.internet.defer.Deferred.addCallbacks` which is similar to, but not exactly the same as, `addCallback` followed by `addErrback`. In particular, consider these two cases:

```
# Case 1
d = getDeferredFromSomewhere()
d.addCallback(callback1)
d.addErrback(errback1)
d.addCallback(callback2)
d.addErrback(errback2)

# Case 2
d = getDeferredFromSomewhere()
d.addCallbacks(callback1, errback1)
d.addCallbacks(callback2, errback2)
```

If an error occurs in `callback1`, then for Case 1 `errback1` will be called with the failure. For Case 2, `errback2` will be called. Be careful with your callbacks and errbacks.

Unhandled Errors

If a Deferred is garbage-collected with an unhandled error (i.e. it would call the next errback if there was one), then Twisted will write the error's traceback to the log file. This means that you can typically get away with not adding errbacks and still get errors logged. Be careful though; if you keep a reference to the Deferred around, preventing it from being garbage-collected, then you may never see the error (and your callbacks will mysteriously seem to have never been called). If unsure, you should explicitly add an errback after your callbacks, even if all you do is:

```
# Make sure errors get logged
from twisted.python import log
d.addErrback(log.err)
```

4.6.3 Class Overview

This is the overview API reference for Deferred. It is not meant to be a substitute for the docstrings in the Deferred class, but can provide guidelines for its use.

Basic Callback Functions

- `addCallbacks(self, callback[, errback, callbackArgs, errbackArgs, errbackKeywords, asDefaults])`

  This is the method with which you will use to interact with Deferred. It adds a pair of callbacks "parallel" to each other (see diagram above) in the list of callbacks made when the Deferred is called back to. The signature of a method added using addCallbacks should be `myMethod(result, *methodArgs, **methodKeywords)`. If your method is passed in the callback slot, for example, all arguments in the tuple `callbackArgs` will be passed as `*methodArgs` to your method.

There exist various convenience methods that are derivative of addCallbacks. I will not cover them in detail here, but it is important to know about them in order to create concise code.

  - `addCallback(callback, *callbackArgs, **callbackKeywords)`
    Adds your callback at the next point in the processing chain, while adding an errback that will re-raise its first argument, not affecting further processing in the error case.
  - `addErrback(errback, *errbackArgs, **errbackKeywords)`
    Adds your errback at the next point in the processing chain, while adding a callback that will return its first argument, not affecting further processing in the success case.
  - `addBoth(callbackOrErrback, *callbackOrErrbackArgs, **callbackOrErrback Keywords)`
    This method adds the same callback into both sides of the processing chain at both points. Keep in mind that the type of the first argument is indeterminate if you use this method! Use it for `finally:` style blocks.

- `callback(result)`
  Run success callbacks with the given result. *This can only be run once.* Later calls to this or `errback` will raise `twisted.internet.defer.AlreadyCalledError`. If further callbacks or errbacks are added after this point, addCallbacks will run the callbacks immediately.

- `errback(failure)`
  Run error callbacks with the given failure. *This can only be run once.* Later calls to this or `callback` will raise `twisted.internet.defer.AlreadyCalledError`. If further callbacks or errbacks are added after this point, addCallbacks will run the callbacks immediately.

Chaining Deferreds

If you need one Deferred to wait on another, all you need to do is return a Deferred from a method added to addCallbacks. Specifically, if you return Deferred B from a method added to Deferred A using A.addCallbacks, Deferred A's processing chain will stop until Deferred B's .callback() method is called; at that point, the next callback in A will be passed the result of the last callback in Deferred B's processing chain at the time.

If this seems confusing, don't worry about it right now – when you run into a situation where you need this behavior, you will probably recognize it immediately and realize why this happens. If you want to chain deferreds manually, there is also a convenience method to help you.

- `chainDeferred(otherDeferred)`
  Add `otherDeferred` to the end of this Deferred's processing chain. When self.callback is called, the result of my processing chain up to this point will be passed to `otherDeferred.callback`. Further additions to my callback chain do not affect `otherDeferred`
  This is the same as `self.addCallbacks(otherDeferred.callback, otherDeferred.errback)`

Automatic Error Conditions

- `setTimeout(seconds[, timeoutFunc])`

  Set a timeout function to be triggered if this Deferred is not called within that time period. By default, this will raise a TimeoutError after `seconds`.

A Brief Interlude: Technical Details

While deferreds greatly simplify the process of writing asynchronous code by providing a standard for registering callbacks, there are some subtle and sometimes confusing rules that you need to follow if you are going to use them. This mostly applies to people who are writing new systems that use Deferreds internally, and not writers of applications that just add callbacks to Deferreds produced and processed by other systems. Nevertheless, it is good to know.

Deferreds are one-shot. A generalization of the Deferred API to generic event-sources is in progress – watch this space for updates! – but Deferred itself is only for events that occur once. You can only call `Deferred.callback` or `Deferred.errback` once. The processing chain continues each time you add new callbacks to an already-called-back-to Deferred.

The important consequence of this is that *sometimes, addCallbacks will call its argument synchronously, and sometimes it will not*. In situations where callbacks modify state, it is highly desirable for the chain of processing to halt until all callbacks are added. For this, it is possible to `pause` and `unpause` a Deferred's processing chain while you are adding lots of callbacks.

Be careful when you use these methods! If you `pause` a Deferred, it is *your* responsibility to make sure that you unpause it; code that calls `callback` or `errback` should *never* call `unpause`, as this would negate its usefulness!

Advanced Processing Chain Control

- `pause()`

  Cease calling any methods as they are added, and do not respond to `callback`, until `self.unpause()` is called.

- `unpause()`

  If `callback` has been called on this Deferred already, call all the callbacks that have been added to this Deferred since `pause` was called.

  Whether it was called or not, this will put this Deferred in a state where further calls to `addCallbacks` or `callback` will work as normal.

4.6.4 DeferredList

Sometimes you want to be notified after several different events have all happened, rather than individually waiting for each one. For example, you may want to wait for all the connections in a list to close. `twisted.internet.defer.DeferredList` is the way to do this.

To create a DeferredList from multiple Deferreds, you simply pass a list of the Deferreds you want it to wait for:

```
# Creates a DeferredList
dl = defer.DeferredList([deferred1, deferred2, deferred3])
```

You can also add the Deferreds later:

```
dl.addDeferred(deferred4)
```

You can now treat the DeferredList like an ordinary Deferred; you can call `addCallbacks` and so on. The DeferredList will call its callback when all the deferreds have completed. The callback will be called with a list of the results of the Deferreds it contains, like so:

```
def printResult(result):
    print result
deferred1 = defer.Deferred()
deferred2 = defer.Deferred()
deferred3 = defer.Deferred()
dl = defer.DeferredList([deferred1, deferred2, deferred3])
dl.addCallback(printResult)
deferred1.callback('one')
deferred2.errback('bang!')
deferred3.callback('three')
# At this point, dl will fire its callback, printing:
#     [(1, 'one'), (0, 'bang!'), (1, 'three')]
# (note that defer.SUCCESS == 1, and defer.FAILURE == 0)
```

A standard DeferredList will never call errback.

> **Note:**
>
> If you want to apply callbacks to the individual Deferreds that go into the DeferredList, you should be careful about when those callbacks are added. The act of adding a Deferred to a DeferredList inserts a callback into that Deferred (when that callback is run, it checks to see if the DeferredList has been completed yet). The important thing to remember is that it is *this callback* which records the value that goes into the result list handed to the DeferredList's callback.
>
> Therefore, if you add a callback to the Deferred *after* adding the Deferred to the DeferredList, the value returned by that callback will not be given to the DeferredList's callback. To avoid confusion, we recommend not adding callbacks to a Deferred once it has been used in a DeferredList.

```
def printResult(result):
    print result
def addTen(result):
    return result + " ten"

# Deferred gets callback before DeferredList is created
deferred1 = defer.Deferred()
deferred2 = defer.Deferred()
deferred1.addCallback(addTen)
dl = defer.DeferredList([deferred1, deferred2])
dl.addCallback(printResult)
deferred1.callback("one") # fires addTen, checks DeferredList, stores "one ten"
deferred2.callback("two")
# At this point, dl will fire its callback, printing:
#     [(1, 'one ten'), (1, 'two')]
```

```
# Deferred gets callback after DeferredList is created
deferred1 = defer.Deferred()
deferred2 = defer.Deferred()
dl = defer.DeferredList([deferred1, deferred2])
deferred1.addCallback(addTen) # will run *after* DeferredList gets its value
dl.addCallback(printResult)
deferred1.callback("one") # checks DeferredList, stores "one", fires addTen
deferred2.callback("two")
# At this point, dl will fire its callback, printing:
#     [(1, 'one), (1, 'two')]
```

Other behaviours

DeferredList accepts two keywords arguments that modify its behaviour: `fireOnOneCallback` and `fireOnOneErrback`. If `fireOnOneCallback` is set, the DeferredList will immediately call its callback as soon as any of its Deferreds call their callback. Similarly, `fireOnOneErrback` will call errback as soon as any of the Deferreds call their errback. Note that DeferredList is still one-shot, like ordinary Deferreds, so after a callback or errback has been called the DeferredList will do nothing further (it will just silently ignore any other results from its Deferreds).

The `fireOnOneErrback` option is particularly useful when you want to wait for all the results if everything succeeds, but also want to know immediately if something fails.

4.7 Scheduling tasks for the future

Let's say we want to run a task X seconds in the future. The way to do that is defined in the reactor interface `twisted.internet.interfaces.IReactorTime`:

```
from twisted.internet import reactor

def f(s):
    print "this will run in 3.5 seconds: %s" % s

reactor.callLater(3.5, f, "hello, world")
```

If we want a task to run every X seconds repeatedly, we can just re-add it every time it's run:

```
from twisted.internet import reactor

def runEverySecond():
    print "a second has passed"
    reactor.callLater(1, runEverySecond)

reactor.callLater(1, runEverySecond)
```

If we want to cancel a task that we've scheduled:

```
from twisted.internet import reactor
```

```
def f():
    print "I'll never run."

callID = reactor.callLater(5, f)
callID.cancel()
```

4.8 Using Threads in Twisted

4.8.1 Introduction

Before you start using threads, make sure you do at the start of your program:

```
from twisted.python import threadable
threadable.init()
```

This will make certain parts of Twisted thread-safe so you can use them safely. However, note that most parts of Twisted are *not* thread-safe.

4.8.2 Running code in a thread-safe manner

Most code in Twisted is not thread-safe. For example, writing data to a transport from a protocol is not thread-safe. Therefore, we want a way to schedule methods to be run in the main event loop. This can be done using the function `twisted.internet.interfaces.IReactorThreads.callFromThread`:

```
from twisted.internet import reactor
from twisted.python import threadable
threadable.init(1)

def notThreadSafe(x):
     """do something that isn't thread-safe"""
     # ...

def threadSafeScheduler():
    """Run in thread-safe manner."""
    reactor.callFromThread(notThreadSafe, 3) # will run 'notThreadSafe(3)'
                                             # in the event loop
```

4.8.3 Running code in threads

Sometimes we may want to run methods in threads - for example, in order to access blocking APIs. Twisted provides methods for doing so using the IReactorThreads API (`twisted.internet.interfaces.IReactorThreads`). Additional utility functions are provided in `twisted.internet.threads`. Basically, these methods allow us to queue methods to be run by a thread pool.

For example, to run a method in a thread we can do:

```
from twisted.internet import reactor
```

```
def aSillyBlockingMethod(x):
    import time
    time.sleep(2)
    print x

# run method in thread
reactor.callInThread(aSillyBlockingMethod, "2 seconds have passed")
```

4.8.4 Utility Methods

The utility methods are not part of the `twisted.internet.reactor` APIs, but are implemented in `twisted.internet.threads`.

If we have multiple methods to run sequentially within a thread, we can do:

```
from twisted.internet import threads

def aSillyBlockingMethodOne(x):
    import time
    time.sleep(2)
    print x

def aSillyBlockingMethodTwo(x):
    print x

# run both methods sequentially in a thread
commands = [(aSillyBlockingMethodOne, ["Calling First"], {})]
commands.append((aSillyBlockingMethodTwo, ["And the second"], {}))
threads.callMultipleInThread(commands)
```

For functions whose results we wish to get, we can have the result returned as a Deferred:

```
from twisted.internet import threads

def doLongCalculation():
    # .... do long calculation here ...
    return 3

def printResult(x):
    print x

# run method in thread and get result as defer.Deferred
d = threads.deferToThread(doLongCalculation)
d.addCallback(printResult)
```

4.8.5 Managing the Thread Pool

The thread pool is implemented by `twisted.python.threadpool.ThreadPool`.

We may want to modify the size of the threadpool, increasing or decreasing the number of threads in use. We can do this do this quite easily:

```
from twisted.internet import reactor

reactor.suggestThreadPoolSize(20)
```

The size of the thread pool defaults to a maximum of 10 threads. Be careful that you understand threads and their resource usage before drastically altering the thread pool sizes.

4.9 Choosing a Reactor and GUI Toolkit Integration

4.9.1 Overview

Twisted provides a variety of implementations of the `twisted.internet.reactor`. The specialized implementations are suited for different purposes and are designed to integrate better with particular platforms.

The general purpose reactor implementations are:

- *The select()-based reactor* (page 97)
- *The poll()-based reactor* (page 97)

Platform-specific reactor implementations exist for:

- *cReactor for Unix* (page 97)
- *KQueue for FreeBSD* (page 98)
- *Java* (page 98)
- *Win32* (page 98)

The remaining custom reactor implementations provide support for integrating with the native event loops of various graphical toolkits. This lets your Twisted application use all of the usual Twisted APIs while still being a graphical application.

Twisted currently integrates with the following graphical toolkits:

- *GTK+ 1.2 and 2.0* (page 98)
- *Qt* (page 98)
- *Tkinter* (page 99)
- *WxPython* (page 99)
- *Win32* (page 98)
- *PyUI* (page 99)

When using applications that runnable using `twistd`, e.g. TAPs or plugins, there is no need to choose a reactor explicitly, since this can be chosen using `twistd`'s -r option.

In all cases, the event loop is started by calling `reactor.run()`.

IMPORTANT: installing a reactor should be the first thing done in the app, since any code that does `from twisted.internet import reactor` will automatically install the default reactor if the code hasen't already installed one.

4.9.2 Reactor Functionality

	TCP	SSL	UDP	Threading	Processes	Scheduling	Platforms
select()	Y	Y	Y	Y	Y (Unix only)	Y	Unix, Win32
poll()	Y	Y	Y	Y	Y	Y	Unix
Win32	Y	Y	Y	Y	Y	Y	Win32
Java	Y	N	N	Y	N	Y	Java 1.1+
GTK+	Y	Y	Y	Y	Y (Unix only)	Y	Unix, Win32
Qt	Y	Y	Y	Y	Y (Unix only)	Y	Unix, Win32
kqueue	Y	Y	Y	Y	Y	Y	FreeBSD
C	Y	N	N	Y	Y	Y	Unix

Table 4.1: Summary of reactor features

4.9.3 General Purpose Reactors

Select()-based Reactor

The SelectReactor is the default reactor.

```
from twisted.internet import reactor
```

The SelectReactor may be explicitly installed by:

```
from twisted.internet import default
default.install()
```

Poll()-based Reactor

The PollReactor will work on any platform that provides `poll()`. With larger numbers of connected sockets, it may provide for better performance.

```
from twisted.internet import pollreactor
pollreactor.install()
```

4.9.4 Platform-Specific Reactors

cReactor for Unix

The cReactor is a high-performance C implementation of the Reactor interfaces. It is currently experimental and under active development. Be sure to see the *installation notes* (page 20) prior to using the cReactor.

```
from twisted.internet import cReactor
cReactor.install()
```

KQueue

The KQueue Reactor allows Twisted to use FreeBSD's kqueue mechanism for event scheduling. See instructions in the `twisted.internet.kqreactor`'s docstring for installation notes.

```
from twisted.internet import kqreactor
kqreactor.install()
```

Java

The Java Reactor allows Twisted to run under Jython[1]. It does not currently support AWT or Swing integration.

```
from twisted.internet import javareactor
javareactor.install()
```

Win32

The Win32 reactor is not yet complete and has various limitations and issues that need to be addressed. The reactor supports GUI integration with the win32gui module, so it can be used for native Win32 GUI applications.

```
from twisted.internet import win32eventreactor
win32eventreactor.install()
```

4.9.5 GUI Integration Reactors

GTK+

Twisted integrates with PyGTK[2], versions 1.2 and 2.0. Sample applications using GTK+ and Twisted are available in the Twisted CVS.

```
from twisted.internet import gtkreactor
gtkreactor.install()
```

Qt

An example Twisted application that uses Qt can be found in `doc/examples/qtdemo.py`.

When installing the reactor, pass a QApplication instance, and if you don't a new one will be created for you.

```
from qt import QApplication
app = QApplication([])

from twisted.internet import qtreactor
qtreactor.install(app)
```

[1] http://www.jython.org/

[2] http://www.daa.com.au/~james/pygtk/

4.9.6 Non-Reactor GUI Integration

Tkinter

The support for Tkinter[3] doesn't use a specialized reactor. Instead, there is some specialized support code:

```
from Tkinter import *
from twisted.internet import tksupport

root = Tk()
root.withdraw()

# Install the Reactor support
tksupport.install(root)
```

An example Twisted application that uses Tk can be found in `twisted/words/ui/tkim.py`.

wxPython

As with *Tkinter* (this page), the support for integrating Twisted with a wxPython[4] application uses specialized support code rather than a simple reactor.

```
from wxPython.wx import *
from twisted.internet import wxsupport, reactor

myWxAppInstance = wxApp(0)
wxsupport.install(myWxAppInstance)
```

An example Twisted application that uses WxWindows can be found in `doc/examples/wxdemo.py`.

PyUI

As with *Tkinter* (this page), the support for integrating Twisted with a PyUI[5] application uses specialized support code rather than a simple reactor.

```
from twisted.internet import pyuisupport, reactor

pyuisupport.install(args=(640, 480), kw={'renderer': 'gl'})
```

An example Twisted application that uses PyUI can bve found in `doc/examples/pyuidemo.py`.

[3] http://www.python.org/topics/tkinter/
[4] http://www.wxpython.org
[5] http://pyui.sourceforge.net

Chapter 5

Perspective Broker

5.1 Introduction to Perspective Broker

5.1.1 Introduction

Suppose you find yourself in control of both ends of the wire: you have two programs that need to talk to each other, and you get to use any protocol you want. If you can think of your problem in terms of objects that need to make method calls on each other, then chances are good that you can use twisted's Perspective Broker protocol rather than trying to shoehorn your needs into something like HTTP, or implementing yet another RPC mechanism[1].

The Perspective Broker system (abbreviated "PB", spawning numerous sandwich-related puns) is based upon a few central concepts:

- *serialization*: taking fairly arbitrary objects and types, turning them into a chunk of bytes, sending them over a wire, then reconstituting them on the other end. By keeping careful track of object ids, the serialized objects can contain references to other objects and the remote copy will still be useful.
- *remote method calls*: doing something to a local object and causing a method to get run on a distant one. The local object is called a `RemoteReference`, and you "do something" by running its `.callRemote` method.

This document will contain several examples that will (hopefully) appear redundant and verbose once you've figured out what's going on. To begin with, much of the code will just be labelled "magic": don't worry about how these parts work yet. It will be explained more fully later.

5.1.2 Class Roadmap

To start with, here are the major classes involved in PB, with links to the file where they are defined (all of which are under twisted/, of course). Don't worry about understanding what they all do yet: it's easier to figure them out through their interaction than explaining them one at a time.

- *`Application`*: `internet/app.py`
- *`Service`*: `spread/pb.py`, subclassed from `Service` in `cred/service.py`

[1] Most of Twisted is like this. Hell, most of unix is like this: if *you* think it would be useful, someone else has probably thought that way in the past, and acted on it, and you can take advantage of the tool they created to solve the same problem you're facing now.

- *MultiService* : internet/app.py
- *Factory* : internet/protocol.py
- *BrokerFactory* : spread/pb.py
- *Broker* : spread/pb.py
- *AuthRoot* : spread/pb.py

Other classes that are involved at some point:

- *RemoteReference* : spread/pb.py
- *pb.Root* : spread/pb.py, actually defined as Root in spread/flavors.py
- *pb.Referenceable* : spread/pb.py, actually defined as Referenceable in spread/flavors.py

Classes that get involved when you start to care about authorization and security:

- *Authorizer* : cred/authorizer.py
- *Identity* : cred/identity.py
- *Perspective* : spread/pb.py, subclassed from Perspective in cred/perspective.py

Subclassing

Technically you can subclass anything you want, but techically you could also write a whole new framework, which would just waste a lot of time. Knowing which classes are useful to change (by making subclasses) is one of the bits of knowledge you pick up after using Twisted for a few weeks. Here are some hints to get started:

- Protocol: subclass this if you need to implement a new protocol on the wire, like HTTP or SMTP (except that almost all of the standard ones are already implemented). You might also subclass one of the standard implementations if you want to change its back-end behavior: make an SMTP server which actually stores the messages in files instead of mailing them, or a Finger server that returns random messages instead of current login status.
- pb.Root, pb.Referenceable: you'll subclass these to make remotely-referenceable objects using PB. You don't need to change any of the existing behavior, just inherit all of it and add the remotely-accessible methods that you want to export.
- pb.Perspective, pb.Service: you'll probably end up subclassing these when you get into PB programming (with authorization). There are a few methods you'll change, especially with regards to creating new Perspectives.
- Authorizer: subclass this if you want to get users from /etc/passwd, or a database, or LDAP, or other list of usernames and passwords.

XXX: add lists of useful-to-override methods here

5.1.3 Things you can Call Remotely

At this writing, there are three "flavors" of objects that can be accessed remotely through `RemoteReference` objects. Each of these flavors has a rule for how the `callRemote` message is transformed into a local method call on the server. In order to use one of these "flavors", subclass them and name your published methods with the appropriate prefix.

- `twisted.spread.pb.Perspective`

  This is the first class we dealt with. Perspectives are slightly special because they are the root object that a given user can access from a service. A user should only receive a reference to their *own* Perspective. PB works hard to verify, as best it can, that any method that can be called on a perspective directly is being called on behalf of the user who is represented by that perspective. (Services with unusual requirements for "on behalf of", such as simulations with the ability to posess another player's avatar, are accomplished by providing indirected access to another user's Perspective.)

  Perspectives are not usually serialized as remote references, so do not return a perspective directly.

  Remotely accessible methods on Perspectives are named with the `perspective_` prefix.

- `twisted.spread.flavors.Referenceable`

  Referenceable objects are the simplest kind of PB object. You can call methods on them and return them from methods to provide access to other objects' methods.

  However, when a method is called on a Referenceable, it's not possible to tell who called it.

  Remotely accessible methods on Referenceables are named with the `remote_` prefix.

- `twisted.spread.flavors.Viewable`

  Viewable objects are remotely referenceable objects which have the additional requirement that it must be possible to tell who is calling them. The argument list to a Viewable's remote methods is modified in order to include the Perspective representing the calling user.

  Remotely accessible methods on Viewables are named with the `view_` prefix.

5.1.4 Things you can Copy Remotely

In addition to returning objects that you can call remote methods on, you can return structured copies of local objects.

There are 2 basic flavors that allow for copying objects remotely. Again, you can use these by subclassing them. In order to specify what state you want to have copied when these are serialized, you can either use the Python default `__getstate__` or specialized method calls for that flavor.

- `twisted.spread.flavors.Copyable`

  This is the simpler kind of object that can be copied. Every time this object is returned from a method or passed as an argument, it is serialized and unserialized.

  `Copyable` provides a method you can override, `getStateToCopyFor(perspective)`, which allows you to decide what an object will look like for the user who is requesting it. The `perspective` argument will be an instance of the `Perspective` subclass for your service, the one which is either pasing an argument or returning a result an instance of your Copyable class.

For security reasons, in order to allow a particular Copyable class to actually be copied, you must declare a `RemoteCopy` handler for that Copyable subclass. The easiest way to do this is to declare both in the same module, like so:

```
from twisted.spread import flavors
class Foo(flavors.Copyable):
    pass
class RemoteFoo(flavors.RemoteCopy):
    pass
flavors.setCopierForClass(str(Foo), RemoteFoo)
```

In this case, each time a Foo is copied between peers, a RemoteFoo will be instantiated and populated with the Foo's state. If you do not do this, PB will complain that there have been security violations, and it may close the connection.

- `twisted.spread.flavors.Cacheable`

  Let me preface this with a warning: Cacheable may be hard to understand. The motivation for it may be unclear if you don't have some experience with real-world applications that use remote method calling of some kind. Once you understand why you need it, what it does will likely seem simple and obvious, but if you get confused by this, forget about it and come back later. It's possible to use PB without understanding Cacheable at all.

  Cacheable is a flavor which is designed to be copied only when necessary, and updated on the fly as changes are made to it. When passed as an argument or a return value, if a Cacheable exists on the side of the connection it is being copied to, it will be referred to by ID and not copied.

  Cacheable is designed to minimize errors involved in replicating an object between multiple servers, especially those related to having stale information. In order to do this, Cacheable automatically registers observers and queries state atomically, together. You can override the method `getStateToCacheAndObserveFor(self, perspective, observer)` in order to specify how your observers will be stored and updated.

  Similar to `getStateToCopyFor`, `getStateToCacheAndObserveFor` passes a `Perspective` instance from your service. It also passes an `observer`, which is a remote reference to a "secret" fourth referenceable flavor: `RemoteCache`.

  A `RemoteCache` is simply the object that represents your `Cacheable` on the other side of the connection. It is registered using the same method as `RemoteCopy`, above. RemoteCache is different, however, in that it will be referenced by its peer. It acts as a Referenceable, where all methods prefixed with `observe_` will be callable remotely. It is recommended that your object maintain a list (note: library support for this is forthcoming!) of observers, and update them using `callRemote` when the Cacheable changes in a way that should be noticeable to its clients.

  Finally, when all references to a `Cacheable` from a given `Perspective` are lost, `stoppedObserving(perspective, observer)` will be called on the `Cacheable`, with the same perspective/observer pair that `getStateToCacheAndObserveFor` was originally called with. Any cleanup remote calls can be made there, as well as removing the observer object from any lists which it was previously in. Any further calls to this observer object will be invalid.

5.2 Using Perspective Broker

5.2.1 Basic Example

The first example to look at is a complete (although somewhat trivial) application. It uses `BrokerFactory()` on the server side, and `pb.getObjectAt()` on the client side.

```
from twisted.spread import pb
from twisted.internet import app
class Echoer(pb.Root):
    def remote_echo(self, st):
        print 'echoing:', st
        return st
if __name__ == '__main__':
    appl = app.Application("pbsimple")
    appl.listenTCP(8789, pb.BrokerFactory(Echoer()))
    appl.run()
```

Source listing — *pbsimple.py*

```
from twisted.spread import pb
from twisted.internet import reactor
def gotObject(object):
    print "got object:",object
    object.callRemote("echo", "hello network").addCallback(gotEcho)
def gotEcho(echo):
    print 'server echoed:',echo
    reactor.stop()
def gotNoObject(reason):
    print "no object:",reason
    reactor.stop()
pb.getObjectAt("localhost", 8789, 30).addCallbacks(gotObject, gotNoObject)
reactor.run()
```

Source listing — *pbsimpleclient.py*

First we look at the server. This defines an Echoer class (derived from `pb.Root`), with a method called `remote_echo()`. `pb.Root` objects (because of their inheritance of `pb.Referenceable`, described later) can define methods with names of the form `remote_*`; a client which obtains a remote reference to that `pb.Root` object will be able to invoke those methods.

The `pb.Root`-ish object is given to a `pb.BrokerFactory()`. This is a `Factory` object like any other: the `Protocol` objects it creates for new connections know how to speak the PB protocol. The object you give to `pb.BrokerFactory()` becomes the "root object", which simply makes it available for the client to retrieve. The client may only request references to the objects you want to provide it: this helps you implement your security model. Because it is so common to export just a single object (and because a `remote_*` method on that one can return a

reference to any other object you might want to give out), the simplest example is one where the `BrokerFactory` is given the root object, and the client retrieves it.

The client side calls `pb.getObjectAt` to make a connection to a given port. This is a convenience function (not a method) which runs through the PB protocol steps necessary to retrieve the root object from a `BrokerFactory` sitting at the given port.

Because `.getObjectAt()` has to make a network connection and exchange some data, it may take a while, so it returns a Deferred, to which the gotObject() callback is attached. (See the documentation on *Deferring Execution* (page 82) for a complete explanation of `Deferred`s). If and when the connection succeeds and a reference to the remote root object is obtained, this callback is run. The first argument passed to the callback is a remote reference to the distant root object. (you can give other arguments to the callback too, see the other parameters for `.addCallback()` and `.addCallbacks()`).

The callback does:

```
object.callRemote("echo", "hello network")
```

which causes the server's `.remote_echo()` method to be invoked. (running `.callRemote("boom")` would cause `.remote_boom()` to be run, etc). Again because of the delay involved, `callRemote()` returns a `Deferred`. Assuming the remote method was run without causing an exception (including an attempt to invoke an unknown method), the callback attached to that `Deferred` will be invoked with any objects that were returned by the remote method call.

In this example, the server's `Echoer` object has a method invoked, *exactly* as if some code on the server side had done:

```
echoer_object.remote_echo("hello network")
```

and from the definition of `remote_echo()` we see that this just returns the same string it was given: "hello network".

From the client's point of view, the remote call gets another `Deferred` object instead of that string. `callRemote()` *always* returns a `Deferred`. This is why PB is described as a system for "translucent" remote method calls instead of "transparent" ones: you cannot pretend that the remote object is really local. Trying to do so (as some other RPC mechanisms do, coughCORBAcough) breaks down when faced with the asynchronous nature of the network. Using Deferreds turns out to be a very clean way to deal with the whole thing.

The remote reference object (the one given to `getObjectAt()`'s success callback) is an instance the `RemoteReference` class. This means you can use it to invoke methods on the remote object that it refers to. Only instances of `RemoteReference` eligible for `.callRemote()`. The `RemoteReference` object is the one that lives on the remote side (the client, in this case), not the local side (where the actual object is defined).

In our example, the local object is that `Echoer()` instance, which inherits from `pb.Root`, which inherits from `pb.Referenceable`. It is that `Referenceable` class that makes the object eligible to be available for remote method calls[2]. If you have an object that is Referenceable, then any client that manages to get a reference to it can invoke any `remote_*` methods they please.

> **Note:**
> The *only* thing they can do is invoke those methods. In particular, they cannot access attributes. From a security point of view, you control what they can do by limiting what the `remote_*` methods can do.

[2] There are a few other classes that can bestow this ability, but pb.Referenceable is the easiest to understand; see 'flavors' below for details on the others.

Also note: the other classes like `Referenceable` allow access to other methods, in particular `perspective_*` and `view_*` may be accessed. Don't write local-only methods with these names, because then remote callers will be able to do more than you intended.

Also also note: the other classes like `pb.Copyable`*do* allow access to attributes, but you control which ones they can see.

You don't have to be a `pb.Root` to be remotely callable, but you do have to be `pb.Referenceable`. (Objects that inherit from `pb.Referenceable` but not from `pb.Root` can be remotely called, but only `pb.Root`-ish objects can be given to the `BrokerFactory`.)

5.2.2 Complete Example

A service is the "global" state associated with your application, which can contain things such as support for archiving objects, basic abstractions common to all users, and collections of domain-specific objects. A perspective is the representation of a user with respect to a particular service. For PB, a Perspective is where all interaction begins. When a user logs in for the first time, all the methods they can initially call are methods of their Perspective. The Perspective's methods can return objects which themselves have methods that you can call, as well as copies of objects, as described later.

```
from twisted.spread import pb

class QuoteReader(pb.Perspective):
    def perspective_nextQuote(self):
        return self.service.quoter.getQuote()

class QuoteService(pb.Service):
    def __init__(self, quoter, serviceName, serviceParent, authorizer):
        pb.Service.__init__(self, serviceName, serviceParent, authorizer)
        self.quoter = quoter
    perspectiveClass = QuoteReader
```

Quote Service and Perspective — *pbquote.py*

For examples of these, we're returning to the TwistedQuotes project discussed in the "Writing Plugins". The PB `Service` for TwistedQuotes is pretty small. The only thing it needs to keep track of for itself is the quoter object; PB's service, that we will inherit from, already keeps track of perspectives.

The perspective is a `QuoteReader`, which publishes one method. By subclassing `Perspective`, we are declaring that all methods with the `perspective_` prefix are remotely accessible.

In order to get this Service published, so that we can actually connect to it, we need to re-visit the TAP building plugin, so we can actually get an Application that has a PB broker factory listening on a port. (The default port for PB is 8787.)

```
from TwistedQuotes import quoteproto    # Protocol and Factory
from TwistedQuotes import quoters       # "give me a quote" code
from TwistedQuotes import pbquote       # perspective broker binding

from twisted.python import usage        # twisted command-line processing
```

```
from twisted.spread import pb           # Perspective Broker
from twisted.cred import authorizer     # cred authorizer, to allow logins

class Options(usage.Options):
    optParameters = [["port", "p", 8007,
                      "Port number to listen on for QOTD protocol."],
                     ["static", "s", "An apple a day keeps the doctor away.",
                      "A static quote to display."],
                     ["file", "f", None,
                      "A fortune-format text file to read quotes from."],
                     ["pb", "b", None,
                      "Port to listen with PB server"]]

def updateApplication(app, config):
    if config["file"]:                  # If I was given a "file" option...
        # Read quotes from a file, selecting a random one each time,
        quoter = quoters.FortuneQuoter([config['file']])
    else:                               # otherwise,
        # read a single quote from the command line (or use the default).
        quoter = quoters.StaticQuoter(config['static'])
    port = int(config["port"])          # TCP port to listen on
    factory = quoteproto.QOTDFactory(quoter) # here we create a QOTDFactory
    # Finally, set up our factory, with its custom quoter, to create QOTD
    # protocol instances when events arrive on the specified port.
    pbport = config['pb']               # TCP PB port to listen on
    if pbport:
        auth = authorizer.DefaultAuthorizer(app)
        pbserv = pbquote.QuoteService(quoter, "twisted.quotes", app, auth)
        # create a quotereader "guest" give that perspective a password and
        # create an account based on it, with the password "guest".
        pbserv.createPerspective("guest").makeIdentity("guest")
        pbfact = pb.BrokerFactory(pb.AuthRoot(auth))
        app.listenTCP(int(pbport), pbfact)
    app.listenTCP(port, factory)
```

TAP Plugin with PB Quotes Service support — *quotetap2.py*

In the TAP builder, we create a `QuoteService` that wraps the quoter. We then create a `QuoteReader` perspective and attach it to the `QuoteService`, through the `createPerspective` call inherited from `Service`. Finally, we register with the `QuoteService`'s authorizer.

Accessing this through a client is fairly easy, as we can use the `pb.connect` convenience function.

```
from sys import stdout
from twisted.python import log
log.discardLogs()
from twisted.internet import reactor
```

```
from twisted.spread import pb

def connected(perspective):
    perspective.callRemote('nextQuote').addCallbacks(success, failure)

def success(quote):
    stdout.write(quote + "\n")
    reactor.stop()

def failure(error):
    stdout.write("Failed to obtain quote.\n")
    reactor.stop()

pb.connect("localhost", # host name
           pb.portno, # port number
           "guest", # identity name
           "guest", # password
           "twisted.quotes", # service name
           "guest", # perspective name (usually same as identity)
           None, # client reference, used to initiate server->client calls
           30 # timeout of 30 seconds before connection gives up
           ).addCallbacks(connected, # what to do when we get connected
                          failure) # and what to do when we can't

reactor.run() # start the main loop
```

PB Quotes Client Code — *pbquoteclient.py*

`pb.connect` will handle all the details of creating a connection and authenticating. It returns a `Deferred`, which will have its callback called when `pb.connect` connects to a perspective, and have its `errback` called when the object-connection fails for any reason, whether it's host lookup failure, connection refusal, or incorrect authentication credentials.

In this example, the `connected` callback should be made when the script is run. Looking at the code, it should be clear that in the event of a connection success, the client will print out a quote and exit. If you start up a server, you can see:

```
% mktap qotd --pb 8787
Saving qotd application to qotd.tap...
Saved.
% twistd -f qotd.tap
% python -c 'import TwistedQuotes.pbquoteclient'
An apple a day keeps the doctor away.
```

The argument to this callback, `perspective`, is a `RemoteReference`. The `perspective` reference represents a reference to a `QuoteReader` perspective object.

`RemoteReference` objects have one method which is their purpose for being: `callRemote`. This method allows you to call a remote method on the object being referred to by the Reference. `RemoteReference.call`

`Remote`, like `pb.connect`, returns a `Deferred`. When a response to the method-call being sent arrives, the `Deferred`'s `callback` or `errback` will be made, depending on whether an error occurred in processing the method-call.

This introduction to PB does not showcase all of the features that it provides, but hopefully it gives you a good idea of where to get started setting up your own application. Here are some of the other building blocks you can use.

5.2.3 Passing more references

Here is an example of using `pb.Referenceable` in a second class. The second `Referenceable` object can have remote methods invoked too, just like the first. In this example, the initial root object has a method that returns a reference to the second object.

```
#! /usr/bin/python

from twisted.spread import pb
import twisted.internet.app

class Two(pb.Referenceable):
    def remote_three(self, arg):
        print "Two.three was given", arg

class One(pb.Root):
    def remote_getTwo(self):
        two = Two()
        print "returning a Two called", two
        return two

app = twisted.internet.app.Application("pb1server")
app.listenTCP(8800, pb.BrokerFactory(One()))
app.run(save=0)
```

Source listing — *pb1server.py*

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.internet import reactor

def main():
    def1 = pb.getObjectAt("localhost", 8800, 30)
    def1.addCallbacks(got_obj1, err_obj1)
    reactor.run()

def err_obj1(reason):
    print "error getting first object", reason
```

```
    reactor.stop()

def got_obj1(obj1):
    print "got first object:", obj1
    print "asking it to getTwo"
    def2 = obj1.callRemote("getTwo")
    def2.addCallbacks(got_obj2)

def got_obj2(obj2):
    print "got second object:", obj2
    print "telling it to do three(12)"
    obj2.callRemote("three", 12)

main()
```

Source listing — *pb1client.py*

The root object has a method called `remote_getTwo`, which returns the `Two()` instance. On the client end, the callback gets a `RemoteReference` to that instance. The client can then invoke two's `.remote_three()` method.

You can use this technique to provide access to arbitrary sets of objects. Just remember that any object that might get passed "over the wire" must inherit from `Referenceable` (or one of the other flavors). If you try to pass a non-Referenceable object (say, by returning one from a `remote_*` method), you'll get an `InsecureJelly` exception[3].

5.2.4 References can come back to you

If your server gives a reference to a client, and then that client gives the reference back to the server, the server will wind up with the same object it gave out originally. The serialization layer watches for returning reference identifiers and turns them into actual objects. You need to stay aware of where the object lives: if it is on your side, you do actual method calls. If it is on the other side, you do `.callRemote()`[4].

```
#! /usr/bin/python

from twisted.spread import pb
import twisted.internet.app

class Two(pb.Referenceable):
    def remote_print(self, arg):
        print "two.print was given", arg

class One(pb.Root):
```

[3]This can be overridden, by subclassing one of the Serializable flavors and defining custom serialization code for your class. See *pb-copyable.html* (page 119) for details.

[4]The binary nature of this local vs. remote scheme works because you cannot give RemoteReferences to a third party. If you could, then your object A could go to B, B could give it to C, C might give it back to you, and you would be hard pressed to tell if the object lived in C's memory space, in B's, or if it was really your own object, tarnished and sullied after being handed down like a really ugly picture that your great aunt owned and which nobody wants but which nobody can bear to throw out. Ok, not really like that, but you get the idea.

```
    def __init__(self, two):
        #pb.Root.__init__(self)   # pb.Root doesn't implement __init__
        self.two = two
    def remote_getTwo(self):
        print "One.getTwo(), returning my two called", two
        return two
    def remote_checkTwo(self, newtwo):
        print "One.checkTwo(): comparing my two", self.two
        print "One.checkTwo(): against your two", newtwo
        if two == newtwo:
            print "One.checkTwo(): our twos are the same"


app = twisted.internet.app.Application("pb2server")
two = Two()
root_obj = One(two)
app.listenTCP(8800, pb.BrokerFactory(root_obj))
app.run(save=0)
```

Source listing — *pb2server.py*

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.internet import reactor

def main():
    foo = Foo()
    pb.getObjectAt("localhost", 8800, 30).addCallback(foo.step1)
    reactor.run()

# keeping globals around is starting to get ugly, so we use a simple class
# instead. Instead of hooking one function to the next, we hook one method
# to the next.

class Foo:
    def __init__(self):
        self.oneRef = None

    def step1(self, obj):
        print "got one object:", obj
        self.oneRef = obj
        print "asking it to getTwo"
        self.oneRef.callRemote("getTwo").addCallback(self.step2)
```

```
    def step2(self, two):
        print "got two object:", two
        print "giving it back to one"
        print "one is", self.oneRef
        self.oneRef.callRemote("checkTwo", two)

main()
```

Source listing — *pb2client.py*

The server gives a `Two()` instance to the client, who then returns the reference back to the server. The server compares the "two" given with the "two" received and shows that they are the same, and that both are real objects instead of remote references.

A few other techniques are demonstrated in `pb2client.py`. One is that the callbacks are are added with `.addCallback` instead of `.addCallbacks`. As you can tell from the *Deferred* (page 82) documentation, `.addCallback` is a simplified form which only adds a success callback. The other is that to keep track of state from one callback to the next (the remote reference to the main One() object), we create a simple class, store the reference in an instance thereof, and point the callbacks at a sequence of bound methods. This is a convenient way to encapsulate a state machine. Each response kicks off the next method, and any data that needs to be carried from one state to the next can simply be saved as an attribute of the object.

Remember that the client can give you back any remote reference you've given them. Don't base your zillion-dollar stock-trading clearinghouse server on the idea that you trust the client to give you back the right reference. The security model inherent in PB means that they can *only* give you back a reference that you've given them for the current connection (not one you've given to someone else instead, nor one you gave them last time before the TCP session went down, nor one you haven't yet given to the client), but just like with URLs and HTTP cookies, the particular reference they give you is entirely under their control.

5.2.5 References to client-side objects

Anything that's Referenceable can get passed across the wire, *in either direction*. The "client" can give a reference to the "server", and then the server can use .callRemote() to invoke methods on the client end. This fuzzes the distinction between "client" and "server": the only real difference is who initiates the original TCP connection; after that it's all symmetric.

```
#! /usr/bin/python

from twisted.spread import pb
import twisted.internet.app

class One(pb.Root):
    def remote_takeTwo(self, two):
        print "received a Two called", two
        print "telling it to print(12)"
        two.callRemote("print", 12)

app = twisted.internet.app.Application("pb3server")
```

```
app.listenTCP(8800, pb.BrokerFactory(One()))
app.run(save=0)
```

Source listing — *pb3server.py*

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.internet import reactor

class Two(pb.Referenceable):
    def remote_print(self, arg):
        print "Two.print() called with", arg

def main():
    two = Two()
    def1 = pb.getObjectAt("localhost", 8800, 30)
    def1.addCallback(got_obj, two) # hands our 'two' to the callback
    reactor.run()

def got_obj(obj, two):
    print "got One:", obj
    print "giving it our two"
    obj.callRemote("takeTwo", two)

main()
```

Source listing — *pb3client.py*

In this example, the client gives a reference to its own object to the server. The server then invokes a remote method on the client-side object.

5.2.6 Raising Remote Exceptions

Everything so far has covered what happens when things go right. What about when they go wrong? The Python Way is to raise an exception of some sort. The Twisted Way is the same.

The only special thing you do is to define your `Exception` subclass by deriving it from `pb.Error`. (You do define `Exception` subclasses, right? String exceptions are, like, *so* 5 minutes ago. Get with the new century, ok?). When any remotely-invokable method (like `remote_*` or `perspective_*`) raises a `pb.Error`-derived exception, a serialized form of that Exception object will be sent back over the wire[5]. The other side (which did `callRemote`) will have the "`errback`" callback run with a `Failure` object that contains a copy of the exception object. This `Failure` object can be queried to retrieve the error message and a stack traceback.

[5]To be precise, the Failure will be sent if *any* exception is raised, not just pb.Error-derived ones. But the server will print ugly error messages if you raise ones that aren't derived from pb.Error.

`Failure` is a special class, defined in `twisted/python/failure.py`, created to make it easier to handle asynchronous exceptions. Just as exception handlers can be nested, `errback` functions can be chained. If one errback can't handle the particular type of failure, it can be "passed along" to a errback handler further down the chain.

For simple purposes, think of the `Failure` as just a container for remotely-thrown `Exception` objects. To extract the string that was put into the exception, use its `.getErrorMessage()` method. To get the type of the exception (as a string), look at its `.type` attribute. The stack traceback is available too. The intent is to let the errback function get just as much information about the exception as Python's normal `try:` clauses do, even though the exception occurred in somebody else's memory space at some unknown time in the past.

```
#! /usr/bin/python

from twisted.spread import pb
import twisted.internet.app

class MyError(pb.Error):
    """This is an Expected Exception. Something bad happened."""
    pass

class MyError2(Exception):
    """This is an Unexpected Exception. Something really bad happened."""
    pass

class One(pb.Root):
    def remote_broken(self):
        msg = "fall down go boom"
        print "raising a MyError exception with data '%s'" % msg
        raise MyError(msg)
    def remote_broken2(self):
        msg = "hadda owie"
        print "raising a MyError2 exception with data '%s'" % msg
        raise MyError2(msg)

def main():
    app = twisted.internet.app.Application("exc_server")
    app.listenTCP(8800, pb.BrokerFactory(One()))
    app.run(save=0)

if __name__ == '__main__':
    main()
```

Source listing — *exc_server.py*

```
#! /usr/bin/python

from twisted.spread import pb
```

```
from twisted.internet import reactor

def main():
    d = pb.getObjectAt("localhost", 8800, 30)
    d.addCallbacks(got_obj)
    reactor.run()

def got_obj(obj):
    # change "broken" into "broken2" to demonstrate an unhandled exception
    d2 = obj.callRemote("broken")
    d2.addCallback(working)
    d2.addErrback(broken)

def working():
    print "erm, it wasn't *supposed* to work.."

def broken(reason):
    print "got remote Exception"
    # reason should be a Failure (or subclass) holding the MyError exception
    print " .__class__ =", reason.__class__
    print " .getErrorMessage() =", reason.getErrorMessage()
    print " .type =", reason.type
    reactor.stop()

main()
```

Source listing — *exc_client.py*

```
% ./exc_client.py
got remote Exception
 .__class__ = twisted.spread.pb.CopiedFailure
 .getErrorMessage() = fall down go boom
 .type = __main__.MyError
Main loop terminated.
```

Oh, and what happens if you raise some other kind of exception? Something that *isn't* subclassed from `pb.Error`? Well, those are called "unexpected exceptions", which make Twisted think that something has *really* gone wrong. These will raise an exception on the *server* side. This won't break the connection (the exception is trapped, just like most exceptions that occur in response to network traffic), but it will print out an unsightly stack trace on the server's stderr with a message that says "Peer Will Receive PB Traceback", just as if the exception had happened outside a remotely-invokable method. (This message will go the current log target, if `log.startLogging` was used to redirect it). The client will get the same `Failure` object in either case, but subclassing your exception from `pb.Error` is the way to tell Twisted that you expect this sort of exception, and that it is ok to just let the client handle it instead of also asking the server to complain. Look at `exc_client.py` and change it to invoke `broken2()` instead of `broken()` to see the change in the server's behavior.

If you don't add an `errback` function to the `Deferred`, then a remote exception will still send a `Failure` object back over, but it will get lodged in the `Deferred` with nowhere to go. When that `Deferred` finally goes out of scope, the side that did `callRemote` will emit a message about an "Unhandled error in Deferred", along with an ugly stack trace. It can't raise an exception at that point (after all, the `callRemote` that triggered the problem is long gone), but it will emit a traceback. So be a good programmer and *always add `errback` handlers*, even if they are just calls to `log.err`.

5.2.7 Try/Except blocks and Failure.trap

To implement the equivalent of the Python try/except blocks (which can trap particular kinds of exceptions and pass others "up" to higher-level `try/except` blocks), you can use the `.trap()` method in conjunction with multiple `errback` handlers on the `Deferred`. Re-raising an exception in an `errback` handler serves to pass that new exception to the next handler in the chain. The `trap` method is given a list of exceptions to look for, and will re-raise anything that isn't on the list. Instead of passing unhandled exceptions "up" to an enclosing `try` block, this has the effect of passing the exception "off" to later `errback` handlers on the same `Deferred`. The `trap` calls are used in chained errbacks to test for each kind of exception in sequence.

```
#! /usr/bin/python

from twisted.internet.app import Application
from twisted.internet import reactor
from twisted.spread import pb

class MyException(pb.Error):
    pass

class One(pb.Root):
    def remote_fooMethod(self, arg):
        if arg == "panic!":
            raise MyException
        return "response"
    def remote_shutdown(self):
        reactor.stop()

app = Application("trap_server")
app.listenTCP(8800, pb.BrokerFactory(One()))
app.run(save=0)
```

Source listing — *trap_server.py*

```
#! /usr/bin/python

from twisted.spread import pb, jelly
from twisted.python import log
from twisted.internet import reactor
```

```
class MyException(pb.Error): pass
class MyOtherException(pb.Error): pass

class ScaryObject:
    # not safe for serialization
    pass

def worksLike(obj):
    # the callback/errback sequence in class One works just like an
    # asynchronous version of the following:
    try:
        response = obj.callMethod(name, arg)
    except pb.DeadReferenceError:
        print " stale reference: the client disconnected or crashed"
    except jelly.InsecureJelly:
        print " InsecureJelly: you tried to send something unsafe to them"
    except (MyException, MyOtherException):
        print " remote raised a MyException" # or MyOtherException
    except:
        print " something else happened"
    else:
        print " method successful, response:", response

class One:
    def worked(self, response):
        print " method successful, response:", response
    def check_InsecureJelly(self, failure):
        failure.trap(jelly.InsecureJelly)
        print " InsecureJelly: you tried to send something unsafe to them"
        return None
    def check_MyException(self, failure):
        which = failure.trap(MyException, MyOtherException)
        if which == MyException:
            print " remote raised a MyException"
        else:
            print " remote raised a MyOtherException"
        return None
    def catch_everythingElse(self, failure):
        print " something else happened"
        log.err(failure)
        return None

    def doCall(self, explanation, arg):
        print explanation
        try:
```

```
            deferred = self.remote.callRemote("fooMethod", arg)
            deferred.addCallback(self.worked)
            deferred.addErrback(self.check_InsecureJelly)
            deferred.addErrback(self.check_MyException)
            deferred.addErrback(self.catch_everythingElse)
        except pb.DeadReferenceError:
            print " stale reference: the client disconnected or crashed"

    def callOne(self):
        self.doCall("callOne: call with safe object", "safe string")
    def callTwo(self):
        self.doCall("callTwo: call with dangerous object", ScaryObject())
    def callThree(self):
        self.doCall("callThree: call that raises remote exception", "panic!")
    def callShutdown(self):
        print "telling them to shut down"
        self.remote.callRemote("shutdown")
    def callFour(self):
        self.doCall("callFour: call on stale reference", "dummy")

    def got_obj(self, obj):
        self.remote = obj
        reactor.callLater(1, self.callOne)
        reactor.callLater(2, self.callTwo)
        reactor.callLater(3, self.callThree)
        reactor.callLater(4, self.callShutdown)
        reactor.callLater(5, self.callFour)
        reactor.callLater(6, reactor.stop)

deferred = pb.getObjectAt("localhost", 8800, 30)
deferred.addCallback(One().got_obj)
reactor.run()
```

Source listing — *trap_client.py*

```
% ./trap_client.py
callOne: call with safe object
 method successful, response: response
callTwo: call with dangerous object
 InsecureJelly: you tried to send something unsafe to them
callThree: call that raises remote exception
 remote raised a MyException
telling them to shut down
callFour: call on stale reference
 stale reference: the client disconnected or crashed
```

%

In this example, `callTwo` tries to send an instance of a locally-defined class through `callRemote`. The default security model implemented by `pb.Jelly` on the remote end will not allow unknown classes to be unserialized (i.e. taken off the wire as a stream of bytes and turned back into an object: a living, breathing instance of some class): one reason is that it does not know which local class ought to be used to create an instance that corresponds to the remote object[6]. The receiving end of the connection gets to decide what to accept and what to reject. It indicates its disapproval by raising a `pb.InsecureJelly` exception. Because it occurs at the remote end, the exception is returned to the caller asynchronously, so an `errback` handler for the associated `Deferred` is run. That errback receives a `Failure` which wraps the `InsecureJelly`.

Remember that `trap` re-raises exceptions that it wasn't asked to look for. You can only check for one set of exceptions per errback handler: all others must be checked in a subsequent handler. `check_MyException` shows how multiple kinds of exceptions can be checked in a single errback: give a list of exception types to `trap`, and it will return the matching member. In this case, the kinds of exceptions we are checking for (`MyException` and `MyOtherException`) may be raised by the remote end: they inherit from `pb.Error`.

The handler can return `None` to terminate processing of the errback chain (to be precise, it switches to the callback that follows the errback; if there is no callback then processing terminates). It is a good idea to put an errback that will catch everything (no `trap` tests, no possible chance of raising more exceptions, always returns `None`) at the end of the chain. Just as with regular `try: except:` handlers, you need to think carefully about ways in which your errback handlers could themselves raise exceptions. The extra importance in an asynchronous environment is that an exception that falls off the end of the `Deferred` will not be signalled until that `Deferred` goes out of scope, and at that point may only cause a log message (which could even be thrown away if `log.startLogging` is not used to point it at stdout or a log file). In contrast, a synchronous exception that is not handled by any other `except:` block will very visibly terminate the program immediately with a noisy stack trace.

`callFour` shows another kind of exception that can occur while using `callRemote`: `pb.DeadReferenceError`. This one occurs when the remote end has disconnected or crashed, leaving the local side with a stale reference. This kind of exception happens to be reported right away (XXX: is this guaranteed? probably not), so must be caught in a traditional synchronous `try: except pb.DeadReferenceError` block.

Yet another kind that can occur is a `pb.PBConnectionLost` exception. This occurs (asynchronously) if the connection was lost while you were waiting for a `callRemote` call to complete. When the line goes dead, all pending requests are terminated with this exception. Note that you have no way of knowing whether the request made it to the other end or not, nor how far along in processing it they had managed before the connection was lost. XXX: explain transaction semantics, find a decent reference.

5.3 PB Copyable: Passing Complex Types

5.3.1 Overview

This chapter focuses on how to use PB to pass complex types (specifically class instances) to and from a remote process. The first section is on simply copying the contents of an object to a remote process (`pb.Copyable`). The

[6]The naive approach of simply doing `import SomeClass` to match a remote caller who claims to have an object of type "SomeClass" could have nasty consequences for some modules that do significant operations in their `__init__` methods (think `telnetlib.Telnet(host='localhost', port='chargen')`, or even more powerful classes that you have available in your server program). Allowing a remote entity to create arbitrary classes in your namespace is nearly equivalent to allowing them to run arbitrary code.

The `pb.InsecureJelly` exception arises because the class being sent over the wire has not been registered with the serialization layer (known as `jelly`). The easiest way to make it possible to copy entire class instances over the wire is to have them inherit from `pb.Copyable`, and then to use `setUnjellyableForClass(remoteClass, localClass)` on the receiving side. See XXX for an example.

second covers how to copy those contents once, then update them later when they change (`Cacheable`).

5.3.2 Motivation

From the *previous chapter* (page 104), you've seen how to pass basic types to a remote process, by using them in the arguments or return values of a `callRemote` function. However, if you've experimented with it, you may have discovered problems when trying to pass anything more complicated than a primitive int/list/dict/string type, or another `pb.Referenceable` object. At some point you want to pass entire objects between processes, instead of having to reduce them down to dictionaries on one end and then re-instantiating them on the other.

5.3.3 Passing Objects

The most obvious and straightforward way to send an object to a remote process is with something like the following code. It also happens that this code doesn't work, as will be explained below.

```
class LilyPond:
  def __init__(self, frogs):
    self.frogs = frogs

pond = LilyPond(12)
ref.callRemote("sendPond", pond)
```

If you try to run this, you might hope that a suitable remote end which implements the `remote_sendPond` method would see that method get invoked with an instance from the `LilyPond` class. But instead, you'll encounter the dreaded `InsecureJelly` exception. This is Twisted's way of telling you that you've violated a security restriction, and that the receiving end refuses to accept your object.

Security Options

What's the big deal? What's wrong with just copying a class into another process' namespace?

Reversing the question might make it easier to see the issue: what is the problem with accepting a stranger's request to create an arbitrary object in your local namespace? The real question is how much power you are granting them: what actions can they convince you to take on the basis of the bytes they are sending you over that remote connection.

Objects generally represent more power than basic types like strings and dictionaries because they also contain (or reference) code, which can modify other data structures when executed. Once previously-trusted data is subverted, the rest of the program is compromised.

The built-in Python "batteries included" classes are relatively tame, but you still wouldn't want to let a foreign program use them to create arbitrary objects in your namespace or on your computer. Imagine a protocol that involved sending a file-like object with a `read()` method that was supposed to used later to retrieve a document. Then imagine what if that object were created with `os.fdopen("~/.gnupg/secring.gpg")`. Or an instance of `telnetlib.Telnet("localhost", "chargen")`.

Classes you've written for your own program are likely to have far more power. They may run code during `__init__`, or even have special meaning simply because of their existence. A program might have `User` objects to represent user accounts, and have a rule that says all `User` objects in the system are referenced when authorizing a login session. (In this system, `User.__init__` would probably add the object to a global list of known users). The simple act of creating an object would give access to somebody. If you could be tricked into creating a bad object, an unauthorized user would get access.

So object creation needs to be part of a system's security design. The dotted line between "trusted inside" and "untrusted outside" needs to describe what may be done in response to outside events. One of those events is the receipt of an object through a PB remote procedure call, which is a request to create an object in your "inside" namespace. The question is what to do in response to it. For this reason, you must explicitly specific what remote classes will be accepted, and how their local representatives are to be created.

What class to use?

Another basic question to answer before we can do anything useful with an incoming serialized object is: what class should we create? The simplistic answer is to create the "same kind" that was serialized on the sender's end of the wire, but this is not as easy or as straightforward as you might think. Remember that the request is coming from a different program, using a potentially different set of class libraries. In fact, since PB has also been implemented in Java, Emacs-Lisp, and other languages, there's no guarantee that the sender is even running Python! All we know on the receiving end is a list of two things which describe the instance they are trying to send us: the name of the class, and a representation of the contents of the object.

PB lets you specify the mapping from remote class names to local classes with the `setUnjellyableForClass` function[7]. This function takes a remote/sender class reference (either the fully-qualified name as used by the sending end, or a class object from which the name can be extracted), and a local/recipient class (used to create the local representation for incoming serialized objects). Whenever the remote end sends an object, the class name that they transmit is looked up in the table controlled by this function. If a matching class is found, it is used to create the local object. If not, you get the `InsecureJelly` exception.

In general you expect both ends to share the same codebase: either you control the program that is running on both ends of the wire, or both programs share some kind of common language that is implemented in code which exists on both ends. You wouldn't expect them to send you an object of the MyFooziWhatZit class unless you also had a definition for that class. So it is reasonable for the Jelly layer to reject all incoming classes except the ones that you have explicitly marked with `setUnjellyableForClass`. But keep in mind that the sender's idea of a `User` object might differ from the recipient's, either through namespace collisions between unrelated packages, version skew between nodes that haven't been updated at the same rate, or a malicious intruder trying to cause your code to fail in some interesting or potentially vulnerable way.

5.3.4 pb.Copyable

Ok, enough of this theory. How do you send a fully-fledged object from one side to the other?

```
#! /usr/bin/python

from twisted.spread import pb, jelly
from twisted.python import log
from twisted.internet import reactor
```

[7]Note that, in this context, "unjelly" is a verb with the opposite meaning of "jelly". The verb "to jelly" means to serialize an object or data structure into a sequence of bytes (or other primitive transmittable/storable representation), while "to unjelly" means to unserialize the bytestream into a live object in the receiver's memory space. "Unjellyable" is a noun, (*not* an adjective), referring to the the class that serves as a destination or recipient of the unjellying process. "A is unjellyable into B" means that a serialized representation A (of some remote object) can be unserialized into a local object of type B. It is these objects "B" that are the "Unjellyable" second argument of the `setUnjellyableForClass` function.

In particular, "unjellyable" does *not* mean "cannot be jellied". `Unpersistable` means "not persistable", but "unjelly", "unserialize", and "unpickle" mean to reverse the operations of "jellying", "serializing", and "pickling".

```
class LilyPond:
    def setStuff(self, color, numFrogs):
        self.color = color
        self.numFrogs = numFrogs
    def countFrogs(self):
        print "%d frogs" % self.numFrogs

class CopyPond(LilyPond, pb.Copyable):
    pass

class Sender:
    def __init__(self, pond):
        self.pond = pond

    def got_obj(self, remote):
        self.remote = remote
        d = remote.callRemote("takePond", self.pond)
        d.addCallback(self.ok).addErrback(self.notOk)

    def ok(self, response):
        print "pond arrived", response
        reactor.stop()
    def notOk(self, failure):
        print "error during takePond:"
        if failure.type == jelly.InsecureJelly:
            print " InsecureJelly"
        else:
            print failure
        reactor.stop()
        return None

def main():
    from copy_sender import CopyPond  # so it's not __main__.CopyPond
    pond = CopyPond()
    pond.setStuff("green", 7)
    pond.countFrogs()
    # class name:
    print ".".join([pond.__class__.__module__, pond.__class__.__name__])

    sender = Sender(pond)
    deferred = pb.getObjectAt("localhost", 8800, 30)
    deferred.addCallback(sender.got_obj)
    reactor.run()

if __name__ == '__main__':
    main()
```

Source listing — *copy_sender.py*

```
#! /usr/bin/python

from twisted.internet.app import Application
from twisted.internet import reactor
from twisted.spread import pb
from copy_sender import LilyPond, CopyPond

from twisted.python import log
import sys
#log.startLogging(sys.stdout)

class ReceiverPond(pb.RemoteCopy, LilyPond):
    pass
pb.setUnjellyableForClass(CopyPond, ReceiverPond)

class Receiver(pb.Root):
    def remote_takePond(self, pond):
        print " got pond:", pond
        pond.countFrogs()
        return "safe and sound" # positive acknowledgement
    def remote_shutdown(self):
        reactor.stop()

app = Application("copy_receiver")
app.listenTCP(8800, pb.BrokerFactory(Receiver()))
app.run(save=0)
```

Source listing — *copy_receiver.py*

The sending side has a class called `LilyPond`. To make this eligble for transport through `callRemote` (either as an argument, a return value, or something referenced by either of those [like a dictionary value]), it must inherit from one of the four `Serializable` classes. In this section, we focus on `Copyable`. The copyable subclass of `LilyPond` is called `CopyPond`. We create an instance of it and send it through `callRemote` as an argument to the receiver's `remote_takePond` method. The Jelly layer will serialize ("jelly") that object as an instance with a class name of "copy_sender.CopyPond" and some chunk of data that represents the object's state. `pond.__class__.__module__` and `pond.__class__.__name__` are used to derive the class name string. The object's `getStateToCopy` method is used to get the state: this is provided by `pb.Copyable`, and the default just retrieves `self.__dict__`. This works just like the optional `__getstate__` method used by `pickle`. The pair of name and state are sent over the wire to the receiver.

The receiving end defines a local class named `ReceiverPond` to represent incoming `LilyPond` instances. This class derives from the sender's `LilyPond` class (with a fully-qualified name of `copy_sender.LilyPond`), which specifies how we expect it to behave. We trust that this is the same `LilyPond` class as the sender used. (At the very

least, we hope ours will be able to accept a state created by theirs). It also inherits from `pb.RemoteCopy`, which is a requirement for all classes that act in this local-representative role (those which are given to the second argument of `setUnjellyableForClass`). `RemoteCopy` provides the methods that tell the Jelly layer how to create the local object from the incoming serialized state.

Then `setUnjellyableForClass` is used to register the two classes. This has two effects: instances of the remote class (the first argument) will be allowed in through the security layer, and instances of the local class (the second argument) will be used to contain the state that is transmitted when the sender serializes the remote object.

When the receiver unserializes ("unjellies") the object, it will create an instance of the local `ReceiverPond` class, and hand the transmitted state (usually in the form of a dictionary) to that object's `setCopyableState` method. This acts just like the `__setstate__` method that `pickle` uses when unserializing an object. `getStateToCopy`/`setCopyableState` are distinct from `__getstate__`/`__setstate__` to allow objects to be persisted (across time) differently than they are transmitted (across [memory]space).

When this is run, it produces the following output:

```
% ./copy_receiver.py
twisted.spread.pb.BrokerFactory starting on 8800
Starting factory <twisted.spread.pb.BrokerFactory instance at 0x815085c>
   [program pauses here until copy_sender.py is run]
 got pond: <__main__.ReceiverPond instance at 0x832941c>
7 frogs
```

```
% ./copy_sender.py
7 frogs
copy_sender.CopyPond
pond arrived safe and sound
Main loop terminated.
%
```

Controlling the Copied State

By overriding `getStateToCopy` and `setCopyableState`, you can control how the object is transmitted over the wire. For example, you might want perform some data-reduction: pre-compute some results instead of sending all the raw data over the wire. Or you could replace references to a local object on the sender's side with markers before sending, then upon receipt replace those markers with references to a receiver-side proxy that could perform the same operations against a local cache of data.

Another good use for `getStateToCopy` is to implement "local-only" attributes: data that is only accessible by the local process, not to any remote users. For example, a `.password` attribute could be removed from the object state before sending to a remote system. Combined with the fact that `Copyable` objects return unchanged from a round trip, this could be used to build a challenge-response system (in fact PB does this with `pb.Referenceable` objects to implement authorization as described *here* (page 133)).

Whatever `getStateToCopy` returns from the sending object will be serialized and sent over the wire; `setCopyableState` gets whatever comes over the wire and is responsible for setting up the state of the object it lives in.

```
#! /usr/bin/python

from twisted.spread import pb
```

```
class FrogPond:
    def __init__(self, numFrogs, numToads):
        self.numFrogs = numFrogs
        self.numToads = numToads
    def count(self):
        return self.numFrogs + self.numToads

class SenderPond(FrogPond, pb.Copyable):
    def getStateToCopy(self):
        d = self.__dict__.copy()
        d['frogsAndToads'] = d['numFrogs'] + d['numToads']
        del d['numFrogs']
        del d['numToads']
        return d

class ReceiverPond(pb.RemoteCopy):
    def setCopyableState(self, state):
        self.__dict__ = state
    def count(self):
        return self.frogsAndToads

pb.setUnjellyableForClass(SenderPond, ReceiverPond)
```

Source listing — *copy2_classes.py*

```
#! /usr/bin/python

from twisted.spread import pb, jelly
from twisted.python import log
from twisted.internet import reactor
from copy2_classes import SenderPond

class Sender:
    def __init__(self, pond):
        self.pond = pond

    def got_obj(self, obj):
        d = obj.callRemote("takePond", self.pond)
        d.addCallback(self.ok).addErrback(self.notOk)

    def ok(self, response):
        print "pond arrived", response
        reactor.stop()
    def notOk(self, failure):
```

```
        print "error during takePond:"
        if failure.type == jelly.InsecureJelly:
            print " InsecureJelly"
        else:
            print failure
        reactor.stop()
        return None

def main():
    pond = SenderPond(3, 4)
    print "count %d" % pond.count()

    sender = Sender(pond)
    deferred = pb.getObjectAt("localhost", 8800, 30)
    deferred.addCallback(sender.got_obj)
    reactor.run()

if __name__ == '__main__':
    main()
```

Source listing — *copy2_sender.py*

```
#! /usr/bin/python

from twisted.internet.app import Application
from twisted.internet import reactor
from twisted.spread import pb
import copy2_classes # needed to get ReceiverPond registered with Jelly

class Receiver(pb.Root):
    def remote_takePond(self, pond):
        print " got pond:", pond
        print " count %d" % pond.count()
        return "safe and sound" # positive acknowledgement
    def remote_shutdown(self):
        reactor.stop()

app = Application("copy_receiver")
app.listenTCP(8800, pb.BrokerFactory(Receiver()))
app.run(save=0)
```

Source listing — *copy2_receiver.py*

In this example, the classes are defined in a separate source file, which also sets up the binding between them. The `SenderPond` and `ReceiverPond` are unrelated save for this binding: they happen to implement the same

methods, but use different internal instance variables to accomplish them.

The recipient of the object doesn't even have to import the class definition into their namespace. It is sufficient that they import the class definition (and thus execute the `setUnjellyableForClass` statement). The Jelly layer remembers the class definition until a matching object is received. The sender of the object needs the definition, of course, to create the object in the first place.

When run, the `copy2` example emits the following:

```
% ./copy2_receiver.py
twisted.spread.pb.BrokerFactory starting on 8800
Starting factory <twisted.spread.pb.BrokerFactory instance at 0x8337f2c>
 got pond: <copy2_classes.ReceiverPond instance at 0x8150dbc>
 count 7

% ./copy2_sender.py
count 7
pond arrived safe and sound
Main loop terminated.
%
```

Things To Watch Out For

- The first argument to `setUnjellyableForClass` must refer to the class *as known by the sender*. The sender has no way of knowing about how your local `import` statements are set up, and Python's flexible namespace semantics allow you to access the same class through a variety of different names. You must match whatever the sender does. Having both ends import the class from a separate file, using a canonical module name (no "sibiling imports"), is a good way to get this right, especially when both the sending and the receiving classes are defined together, with the `setUnjellyableForClass` immediately following them. (XXX: this works, but does this really get the right names into the table? Or does it only work because both are defined in the same (wrong) place?)

- The class that is sent must inherit from `pb.Copyable`. The class that is registered to receive it must inherit from `pb.RemoteCopy`[8].

- The same class can be used to send and receive. Just have it inherit from both `pb.Copyable` and `pb.RemoteCopy`. This will also make it possible to send the same class symmetrically back and forth over the wire. But don't get confused about when it is coming (and using `setCopyableState`) versus when it is going (using `getStateToCopy`).

- `InsecureJelly` exceptions are raised by the receiving end. They will be delivered asynchronously to an `errback` handler. If you do not add one to the `Deferred` returned by `callRemote`, then you will never receive notification of the problem.

- The class that is derived from `pb.RemoteCopy` will be created using a constructor `__init__` method that takes no arguments. All setup must be performed in the `setCopyableState` method. As the docstring on `RemoteCopy` says, don't implement a constructor that requires arguments in a subclass of `RemoteCopy`. XXX: check this, the code around jelly._Unjellier.unjelly:489 tries to avoid calling `__init__` just in case the constructor requires args.

[8] `pb.RemoteCopy` is actually defined as `flavors.RemoteCopy`, but `pb.RemoteCopy` is the preferred way to access it

More Information

- `pb.Copyable` is mostly implemented in `twisted.spread.flavors`, and the docstrings there are the best source of additional information.
- `Copyable` is also used in `twisted.web.distrib` to deliver HTTP requests to other programs for rendering, allowing subtrees of URL space to be delegated to multiple programs (on multiple machines).
- `twisted.manhole.explorer` also uses `Copyable` to distribute debugging information from the program under test to the debugging tool.

5.3.5 pb.Cacheable

Sometimes the object you want to send to the remote process is big and slow. "big" means it takes a lot of data (storage, network bandwidth, processing) to represent its state. "slow" means that state doesn't change very frequently. It may be more efficient to send the full state only once, the first time it is needed, then afterwards only send the differences or changes in state whenever it is modified. The `pb.Cacheable` class provides a framework to implement this.

`pb.Cacheable` is derived from `pb.Copyable`, so it is based upon the idea of an object's state being captured on the sending side, and then turned into a new object on the receiving side. This is extended to have an object "publishing" on the sending side (derived from `pb.Cacheable`), matched with one "observing" on the receiving side (derived from `pb.RemoteCache`).

To effectively use `pb.Cacheable`, you need to isolate changes to your object into accessor functions (specifically "setter" functions). Your object needs to get control *every* single time some attribute is changed[9].

You derive your sender-side class from `pb.Cacheable`, and you add two methods: `getStateToCacheAndObserveFor` and `stoppedObserving`. The first is called when a remote caching reference is first created, and retrieves the data with which the cache is first filled. It also provides an object called the "observer"[10] that points at that receiver-side cache. Every time the state of the object is changed, you give a message to the observer, informing them of the change. The other method, `stoppedObserving`, is called when the remote cache goes away, so that you can stop sending updates.

On the receiver end, you make your cache class inherit from `pb.RemoteCache`, and implement the `setCopyableState` as you would for a `pb.RemoteCopy` object. In addition, you must implement methods to receive the updates sent to the observer by the `pb.Cacheable`: these methods should have names that start with `observe_`, and match the `callRemote` invocations from the sender side just as the usual `remote_*` and `perspective_*` methods match normal `callRemote` calls.

The first time a reference to the `pb.Cacheable` object is sent to any particular recipient, a sender-side Observer will be created for it, and the `getStateToCacheAndObserveFor` method will be called to get the current state and register the Observer. The state which that returns is sent to the remote end and turned into a local representation using `setCopyableState` just like `pb.RemoteCopy`, described above (in fact it inherits from that class).

After that, your "setter" functions on the sender side should call `callRemote` on the Observer, which causes `observe_*` methods to run on the receiver, which are then supposed to update the receiver-local (cached) state.

When the receiver stops following the cached object and the last reference goes away, the `pb.RemoteCache` object can be freed. Just before it dies, it tells the sender side it no longer cares about the original object. When *that*

[9] of course you could be clever and add a hook to `__setattr__`, along with magical change-announcing subclasses of the usual builtin types, to detect changes that result from normal "=" set operations. The result might be hard to maintain or extend, though.

[10] this is actually a `RemoteCacheObserver`, but it isn't very useful to subclass or modify, so simply treat it as a little demon that sits in your `pb.Cacheable` class and helps you distribute change notifications. The only useful thing to do with it is to run its `callRemote` method, which acts just like a normal `pb.Referenceable`'s method of the same name.

reference count goes to zero, the Observer goes away and the `pb.Cacheable` object can stop announcing every change that takes place. The `stoppedObserving` method is used to tell the `pb.Cacheable` that the Observer has gone away.

With the `pb.Cacheable` and `pb.RemoteCache` classes in place, bound together by a call to `pb.setUnjellyableForClass`, all that remains is to pass a reference to your `pb.Cacheable` over the wire to the remote end. The corresponding `pb.RemoteCache` object will automatically be created, and the matching methods will be used to keep the receiver-side slave object in sync with the sender-side master object.

Example

Here is a complete example, in which the `MasterDuckPond` is controlled by the sending side, and the `SlaveDuckPond` is a cache that tracks changes to the master:

```
#! /usr/bin/python

from twisted.spread import pb

class MasterDuckPond(pb.Cacheable):
    def __init__(self, ducks):
        self.observers = []
        self.ducks = ducks
    def count(self):
        print "I have [%d] ducks" % len(self.ducks)
    def addDuck(self, duck):
        self.ducks.append(duck)
        for o in self.observers: o.callRemote('addDuck', duck)
    def removeDuck(self, duck):
        self.ducks.remove(duck)
        for o in self.observers: o.callRemote('removeDuck', duck)
    def getStateToCacheAndObserveFor(self, perspective, observer):
        self.observers.append(observer)
        # you should ignore pb.Cacheable-specific state, like self.observers
        return self.ducks # in this case, just a list of ducks
    def stoppedObserving(self, perspective, observer):
        self.observers.remove(observer)

class SlaveDuckPond(pb.RemoteCache):
    # This is a cache of a remote MasterDuckPond
    def count(self):
        return len(self.cacheducks)
    def getDucks(self):
        return self.cacheducks
    def setCopyableState(self, state):
        print " cache - sitting, er, setting ducks"
        self.cacheducks = state
    def observe_addDuck(self, newDuck):
```

```
        print " cache - addDuck"
        self.cacheducks.append(newDuck)
    def observe_removeDuck(self, deadDuck):
        print " cache - removeDuck"
        self.cacheducks.remove(deadDuck)

pb.setUnjellyableForClass(MasterDuckPond, SlaveDuckPond)
```

Source listing — *cache_classes.py*

```
#! /usr/bin/python

from twisted.spread import pb, jelly
from twisted.python import log
from twisted.internet import reactor
from cache_classes import MasterDuckPond

class Sender:
    def __init__(self, pond):
        self.pond = pond

    def phase1(self, remote):
        self.remote = remote
        d = remote.callRemote("takePond", self.pond)
        d.addCallback(self.phase2).addErrback(log.err)
    def phase2(self, response):
        self.pond.addDuck("ugly duckling")
        self.pond.count()
        reactor.callLater(1, self.phase3)
    def phase3(self):
        d = self.remote.callRemote("checkDucks")
        d.addCallback(self.phase4).addErrback(log.err)
    def phase4(self, dummy):
        self.pond.removeDuck("one duck")
        self.pond.count()
        self.remote.callRemote("checkDucks")
        d = self.remote.callRemote("ignorePond")
        d.addCallback(self.phase5)
    def phase5(self, dummy):
        d = self.remote.callRemote("shutdown")
        d.addCallback(self.phase6)
    def phase6(self, dummy):
        reactor.stop()

def main():
```

```
    master = MasterDuckPond(["one duck", "two duck"])
    master.count()

    sender = Sender(master)
    deferred = pb.getObjectAt("localhost", 8800, 30)
    deferred.addCallback(sender.phase1)
    reactor.run()

if __name__ == '__main__':
    main()
```

Source listing — *cache_sender.py*

```
#! /usr/bin/python

from twisted.internet.app import Application
from twisted.internet import reactor
from twisted.spread import pb
import cache_classes

class Receiver(pb.Root):
    def remote_takePond(self, pond):
        self.pond = pond
        print "got pond:", pond # a DuckPondCache
        self.remote_checkDucks()
    def remote_checkDucks(self):
        print "[%d] ducks: " % self.pond.count(), self.pond.getDucks()
    def remote_ignorePond(self):
        # stop watching the pond
        print "dropping pond"
        # gc causes __del__ causes 'decache' msg causes stoppedObserving
        self.pond = None
    def remote_shutdown(self):
        reactor.stop()

app = Application("copy_receiver")
app.listenTCP(8800, pb.BrokerFactory(Receiver()))
app.run(save=0)
```

Source listing — *cache_receiver.py*

When run, this example emits the following:

```
% ./cache_receiver.py
 cache - sitting, er, setting ducks
```

```
got pond: <cache_classes.SlaveDuckPond instance at 0x82a15e4>
[2] ducks:  ['one duck', 'two duck']
 cache - addDuck
[3] ducks:  ['one duck', 'two duck', 'ugly duckling']
 cache - removeDuck
[2] ducks:  ['two duck', 'ugly duckling']
dropping pond
%

% ./cache_sender.py
I have [2] ducks
I have [3] ducks
I have [2] ducks
Main loop terminated.
%
```

Points to notice:

- There is one `Observer` for each remote program that holds an active reference. Multiple references inside the same program don't matter: the serialization layer notices the duplicates and does the appropriate reference counting[11].
- Multiple Observers need to be kept in a list, and all of them need to be updated when something changes. By sending the initial state at the same time as you add the observer to the list, in a single atomic action that cannot be interrupted by a state change, you insure that you can send the same status update to all the observers.
- The `observer.callRemote` calls can still fail. If the remote side has disconnected very recently and `stoppedObserving` has not yet been called, you may get a `DeadReferenceError`. It is a good idea to add an errback to those `callRemote`s to throw away such an error. This is a useful idiom:

  ```
  observer.callRemote('foo', arg).addErrback(lambda f: None)
  ```

  (XXX: verify that this is actually a concern)
- `getStateToCacheAndObserverFor` must return some object that represents the current state of the object. This may simply be the object's `__dict__` attribute. It is a good idea to remove the `pb.Cacheable`-specific members of it before sending it to the remote end. The list of Observers, in particular, should be left out, to avoid dizzying recursive Cacheable references. The mind boggles as to the potential consequences of leaving in such an item.
- A `perspective` argument is available to `getStateToCacheAndObserveFor`, as well as `stopped Observing`. I think the purpose of this is to allow viewer-specific changes to the way the cache is updated. If all remote viewers are supposed to see the same data, it can be ignored.

XXX: understand, then explain use of varying cached state depending upon perspective.

[11] this applies to multiple references through the same `Broker`. If you've managed to make multiple TCP connections to the same program, you deserve whatever you get.

More Information

- The best source for information comes from the docstrings in `twisted.spread.flavors`, where `pb.Cacheable` is implemented.
- `twisted.manhole.explorer` uses `Cacheable`, and does some fairly interesting things with it. (XXX: I've heard explorer is currently broken, it might not be a good example to recommend)
- The `spread.publish` module also uses `Cacheable`, and might be a source of further information.

5.4 Authentication with Perspective Broker

5.4.1 Motivation

In the examples shown in *Using Perspective Broker* (page 104) there were some problems. You had to trust the user when they said their name was "bob": no passwords or anything. If you wanted a direct-send one-to-one message feature, you might have implemented it by handing a User reference directly off to another User. (so they could invoke `.remote_sendMessage()` on the receiving User): but that lets them do anything else to that user too, things that should probably be restricted to the "owner" user, like `.remote_joinGroup()` or `.remote_quit()`.

And there were probably places where the easiest implementation was to have the client send a message that included their own name as an argument. Sending a message to the group could just be:

```
class Group(pb.Referenceable):

# ...

  def remote_sendMessage(self, from_user, message):
    for user in self.users:
      user.callRemote("sendMessage", "[%s]: %s" % (from_user, message))
```

But obviously this lets users spoof each other: there's no reason that Alice couldn't do:

```
remotegroup.callRemote("sendMessage", "bob", "i like pork")
```

much to the horror of Bob's vegetarian friends.

(In general, learn to get suspicious if you see `groupName` or `userName` in the argument list of a remotely-invokable method).

You could fix this by adding more classes (with fewer remotely-invokable methods), and making sure that the reference you give to Alice won't let her pretend to be anybody else. You'd probably give Alice her own object, with her name buried inside:

```
class User(pb.Referenceable):
  def __init__(self, name):
    self.name = name
  def remote_sendMessage(self, group, message):
    g = findgroup(group)
    for user in g.users:
      user.callRemote("sendMessage", "[%s]: %s" % (self.name, message))
```

This improves matters because, as long as Alice only has a reference to *this* object and nobody else's, she can't cause a different `self.name` to get used. Of course, you have to make sure that you don't give her a reference to the wrong object.

> **Note:**
> Third party references (there aren't any)
> Note that the reference that the server gives to a client is only useable by that one client: if they try to hand it off to a third party, they'll get an exception (XXX: which? looks like an assert in pb.py:290 RemoteReference.jellyFor). This helps somewhat: only the client you gave the reference to can cause any damage with it. Of course, the client might be a brainless zombie, simply doing anything some third party wants. When it's not proxying `callRemote` invocations, it's probably terrorizing the living and searching out human brains for sustenance. In short, if you don't trust them, don't give them that reference.
>
> Also note that the design of the serialization mechanism (implemented in `twisted.spread.jelly`: pb, jelly, spread.. get it? Also look for "banana" and "marmalade". What other networking framework can claim API names based on sandwich ingredients?) makes it impossible for the client to obtain a reference that they weren't explicitly given. References passed over the wire are given id numbers and recorded in a per-connection dictionary. If you didn't give them the reference, the id number won't be in the dict, and no amount of id guessing by a malicious client will give them anything else. The dict goes away when the connection is dropped, limiting further the scope of those references.
>
> Of course, everything you've ever given them over that connection can come back to you. If expect the client to invoke your method with some object A that you sent to them earlier, and instead they send you object B (that you also sent to them earlier), and you don't check it somehow, then you've just opened up a security hole. It may be better to keep such objects in a dictionary on the server side, and have the client send you an index string instead. Doing it that way makes it obvious that they can send you anything they want, and improves the chances that you'll remember to implement the right checks. (This is exactly what PB is doing underneath, with a per-connection dictionary of `Referenceable` objects, indexed by a number).

But now she could sneak into another group. So you might have to have an object per-group-per-user:

```
class UserGroup(pb.Referenceable):
  def __init__(self, group, user):
    self.group = group
    self.user = user
  def remote_sendMessage(self, message):
    name = self.user.name
    for user in self.group.users:
      user.callRemote("sendMessage", "[%s]: %s" % (name, message))
```

But that means more code, and more code is bad, especially when it's a common problem (everybody designs with security in mind, right? Right??).

So we have a security problem. We need a way to ask for and verify a password, so we know that Bob is really Bob and not Alice wearing her "Hi, my name is Bob" t-shirt. And it would make the code cleaner (i.e.: fewer classes) if some methods could know reliably *who* is calling them.

5.4.2 A sample application

As a framework for this chapter, we'll be referring to a hypothetical game implemented by several programs using the Twisted framework. This game will have multiple players, where users log in using their client programs, and there is a server, and users can do some things but not others[12].

The players make moves in this game by invoking remote methods on objects that live in the server. The clients can't really be relied upon to tell the server who they are with each move they make: they might get it wrong, or (horrors!) lie to mess up the other player.

Let's simplify it to a server-based game of Go (if that can be considered simple). Go has two players, white and black, who take turns placing stones of their own color at the intersections of a 19x19 grid. If we represent the game and board as an object in the server called Game, then the players might interact with it using something like this:

```
class Game(pb.Referenceable):
  def remote_getBoard(self):
    return self.board # a dict, with the state of the board
  def remote_move(self, playerName, x, y):
    self.board[x,y] = playerName
```

"But Wait", you say, yes that method takes a playerName, which means they could cheat and move for the other player. So instead, do this:

```
class Game(pb.Referenceable):
  def remote_getBoard(self):
    return self.board # a dict, with the state of the board
  def move(self, playerName, x, y):
    self.board[x,y] = playerName
```

and move the responsibility (and capability) for calling Game.move() out to a different class. That class is a `pb.Perspective`.

5.4.3 Perspectives

`pb.Perspective` (and some related classes: Identity, Authorizer, and Service) is a layer on top of the basic PB system that handles username/password checking. The basic idea is that there is a separate Perspective object (probably a subclass you've created) for each user[13], and *only* the authorized user gets a remote reference to that Perspective object. You can store whatever permissions or capabilities the user possesses in that object, and then use them when the user invokes a remote method. You give the user access to the Perspective object instead of the objects that do the real work.

Your code can then look like this:

```
class Game:
  def getBoard(self):
    return self.board # a dict, with the state of the board
  def move(self, playerName, x, y):
    self.board[x,y] = playerName
```

[12] There actually exists such a thing. It's called twisted.reality, and was the whole reason Twisted was created. I haven't played it yet: I'm too afraid.

[13] Actually there is a perspective per user*service, but we'll get into that later

```
class PlayerPerspective(pb.Perspective):
  def __init__(self, playerName, game):
    self.playerName = playerName
    self.game = game
  def perspective_move(self, x, y):
    self.game.move(self.playerName, x, y)
  def perspective_getBoard(self):
    return self.game.getBoard()
```

The code on the server side creates the PlayerPerspective object, giving it the right playerName and a reference to the Game object. The remote player doesn't get a reference to the Game object, only their own PlayerPerspective, so they don't have an opportunity to lie about their name: it comes from the `.playerName` attribute, not an argument of their remote method call.

Here is a brief example of using a Perspective. Most of the support code is magic for now: we'll explain it later.

> **Note:**
> This example has more support code than you'd actually need. If you only have one Service, then there's probably a one-to-one relationship between your Identities and your Perspectives. If that's the case, you can use a utility method called Perspective.makeIdentity() instead of creating the perspectives and identities in separate steps. This is shorter, but hides some of the details that are useful here to explain what's going on. Again, this will make more sense later.

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.cred.authorizer import DefaultAuthorizer
import twisted.internet.app

class MyPerspective(pb.Perspective):
    def perspective_foo(self, arg):
        print "I am", self.myname, "perspective_foo(",arg,") called on", self

# much of the following is magic
app = twisted.internet.app.Application("pb5server")
auth = DefaultAuthorizer(app)
# create the service, tell it to generate MyPerspective objects when asked
s = pb.Service("myservice", app, auth)
s.perspectiveClass = MyPerspective

#  create a MyPerspective
p1 = s.createPerspective("perspective1")
p1.myname = "p1"
# create an Identity, give it a name and password, and allow it access to
# the MyPerspective we created before
i1 = auth.createIdentity("user1")
i1.setPassword("pass1")
```

```
i1.addKeyByString("myservice", "perspective1")
auth.addIdentity(i1)


# start the application
app.listenTCP(8800, pb.BrokerFactory(pb.AuthRoot(auth)))
app.run(save=0)
```

Source listing — *pb5server.py*

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.internet import reactor

def main():
    def1 = pb.connect("localhost", 8800,
                      "user1", "pass1",
                      "myservice", "perspective1",
                      timeout=30)
    def1.addCallbacks(connected)
    reactor.run()

def connected(perspective):
    print "got perspective ref:", perspective
    print "asking it to foo(12)"
    perspective.callRemote("foo", 12)

main()
```

Source listing — *pb5client.py*

Note that once this example has done the method call, you'll have to terminate both ends yourself. Also note that the Perspective's `.attached()` and `.detached()` methods are run when the client connects and disconnects. The base class implementations of these methods just prints a message.

Ok, so that wasn't really very exciting. It doesn't accomplish much more than the first PB example, and used a lot more code to do it. Let's try it again with two users this time, each with their own Perspective. We also override `.attached()` and `.detached()`, just to see how they are called.

> **Note:**
>
> The Perspective object is usually expected to outlast the user's connection to it: it is nominally created some time before the user connects, and survives after they disconnect. `.attached()` and `.detached()` are invoked to let the Perspective know when the user has connected and disconnected.
>
> When the client runs `pb.connect` to establish the connection, they can provide it with an optional `client` argument (which must be a `pb.Referenceable` object). If they do, then a reference to

that object will be handed to the server-side Perspective's `.attached` method, in the `clientref` argument.

The server-side Perspective can use it to invoke remote methods on something in the client, so that the client doesn't always have to drive the interaction. In a chat server, the client object would be the one to which "display text" messages were sent. In a game, this would provide a way to tell the clients that someone has made a move, so they can update their game boards. To actually use it, you'd probably want to subclass Perspective and change the .attached method to stash the clientref somewhere, because the default implementation just drops it.

`.attached()` also receives a reference to the `Identity` object that represents the user. (The user has proved, by using a password of some sort, that they are that `Identity`, and then they can access any service/perspective on the Identity's keyring). The method can use that reference to extract more information about the user.

In addition, `.attached()` has the opportunity to return a different Perspective, if it so chooses. You could have all users initially access the same Perspective, but then as they connect (and `.attached()` gets called), give them unique Perspectives based upon their individual Identities. The client will get a reference to whatever `.attached()` returns, so the default case is to 'return self'.

Finally, when the client goes away (i.e., the network connection has been closed), `.detached()` will be called. The Perspective can use this to mark the user as having gone away: this may mean that outgoing messages should be queued in the Perspective until they reconnect, or callers should be given an error message because they messages cannot be delivered, etc. It can also be used to terminate or suspend any sessions the user was participating in. `detached` is called with the same 'clientref' and Identity objects that were given to the original 'attached' call. It will be invoked on the Perspective object that was returned by `.attached()`.

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.cred.authorizer import DefaultAuthorizer
import twisted.internet.app

class MyPerspective(pb.Perspective):
    def attached(self, clientref, identity):
        print "client attached! they are:", identity
        return self
    def detached(self, ref, identity):
        print "client detached! they were:", identity
    def perspective_foo(self, arg):
        print "I am", self.myname, "perspective_foo(",arg,") called on", self

# much of the following is magic
app = twisted.internet.app.Application("pb6server")
auth = DefaultAuthorizer(app)
# create the service, tell it to generate MyPerspective objects when asked
s = pb.Service("myservice", app, auth)
s.perspectiveClass = MyPerspective
```

```
#  create one MyPerspective
p1 = s.createPerspective("perspective1")
p1.myname = "p1"
# create an Identity, give it a name and password, and allow it access to
# the MyPerspective we created before
i1 = auth.createIdentity("user1")
i1.setPassword("pass1")
i1.addKeyByString("myservice", "perspective1")
auth.addIdentity(i1)

#  create another MyPerspective
p2 = s.createPerspective("perspective2")
p2.myname = "p2"
i2 = auth.createIdentity("user2")
i2.setPassword("pass2")
i2.addKeyByString("myservice", "perspective2")
auth.addIdentity(i2)


# start the application
app.listenTCP(8800, pb.BrokerFactory(pb.AuthRoot(auth)))
app.run(save=0)
```

Source listing — *pb6server.py*

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.internet import reactor

def main():
    def1 = pb.connect("localhost", 8800,
                      "user1", "pass1",
                      "myservice", "perspective1",
                      timeout=30)
    def1.addCallbacks(connected)
    reactor.run()

def connected(perspective):
    print "got perspective1 ref:", perspective
    print "asking it to foo(13)"
    perspective.callRemote("foo", 13)

main()
```

Source listing — *pb6client1.py*

```
#! /usr/bin/python

from twisted.spread import pb
from twisted.internet import reactor

def main():
    def1 = pb.connect("localhost", 8800,
                      "user2", "pass2",
                      "myservice", "perspective2",
                      timeout=30)
    def1.addCallbacks(connected)
    reactor.run()

def connected(perspective):
    print "got perspective2 ref:", perspective
    print "asking it to foo(14)"
    perspective.callRemote("foo", 14)

main()
```

Source listing — *pb6client2.py*

While pb6server.py is running, try starting pb6client1, then pb6client2. Compare the argument passed by the `.callRemote()` in each client. You can see how each client logs into a different Perspective.

5.4.4 Class Overview

Now that we've seen some of the motivation behind the Perspective class, let's start to de-mystify some of the parts labeled "magic" in `pb6server.py`. Here are the major classes involved:

- `Application`: `twisted/internet/app.py`
- `Service`: `twisted/cred/service.py`
- `Authorizer`: `twisted/cred/authorizer.py`
- `Identity`: `twisted/cred/identity.py`
- `Perspective`: `twisted/cred/pb.py`

You've already seen `Application`. It holds the program-wide settings, like which uid/gid it should run under, and contains a list of ports that it should listen on (with a Factory for each one to create Protocol objects). When used for PB, we put a pb.BrokerFactory on the port. The `Application` also holds a list of Services.

A `Service` is, well, a service. A web server would be a `Service`, as would a chat server, or any other kind of server you might choose to run. What's the difference between a `Service` and an `Application`? You can

have multiple `Service`s in a single `Application`: perhaps both a web-based chat service and an IM server in the same program, that let you exchange messages between the two. Or your program might provide different kinds of interfaces to different classes of users: administrators could get one `Service`, while mere end-users get a less-powerful `Service`.

> **Note:**
> Note that the `Service` is a server of some sort, but that doesn't mean there's a one-to-one relationship between the `Service` and the TCP port that's being listened to. In theory, several different `Service`s can hang off the same TCP port. Look at the MultiService class for details.

The `Service` is reponsible for providing `Perspective` objects. More on that later.

The `Authorizer` is a class that provides `Identity` objects. The abstract base class is `twisted.cred.authorizer.Authorizer`, and for simple purposes you can just use `DefaultAuthorizer`, which is a subclass that stores pre-generated Identities in a simple dict (indexed by username). The `Authorizer`'s purpose in life is to implement the `.getIdentityRequest()` method, which takes a user name and (eventually) returns the corresponding `Identity` object.

Each `Identity` object represents a single user, with a username and a password of some sort. Its job is to talk to the as-yet-anonymous remote user and verify that they really are who they claim to be. The default `twisted.cred.authorizer.Identity` class implements MD5-hashed challenge-response password authorization, much like the HTTP MD5-Authentication method: the server sends a random challenge string, the client concatenates a hash of their password with the challenge string, and sends back a hash of the result. At this point the client is said to be "authorized" for access to that `Identity`, and they are given a remote reference to the `Identity` (actually a wrapper around it), giving them all the privileges of that `Identity`.

Those privileges are limited to requesting `Perspective`s. The `Identity` object also has a "keyring", which is a list of (serviceName, perspectiveName) pairs that the corresponding authorized user is allowed to access. Once the user has been authenticated, the `Identity`'s job is to implement `.requestPerspectiveForKey()`, which it does by verifying the "key" exists on the keyring, then asking the matching `Service` to do `.getPerspectiveForIdentity()`.

Finally, the `Perspective` is the subclass of pb.Perspective that implements whatever `perspective_*` methods you wish to expose to an authenticated remote user. It also implements `.attached()` and `.detached()`, which are run when the user connects (actually when they finish the authentication sequence) or disconnects. Each `Perspective` has a name, which is scoped to the `Service` which owns the `Perspective`.

5.4.5 Class Responsibilities

Now that we've gone over the classes and objects involved, let's look at the specific responsibilities of each. Most of these classes are on the hook to implement just one or two particular methods, and the rest of the class is just support code (or the main method has been broken up for ease of subclassing). This section indicates what those main methods are and when they get called.

Authorizer

The `Authorizer` has to provide `Identity` objects (requested by name) by implementing `.getIdentityRequest()`. The `DefaultAuthorizer` class just looks up the name in a dict called `self.identities`, so when you use it, you have to make the Identities ahead of time (using `i = auth.createIdentity()`) and store them in that dict (by handing them to `auth.addIdentity(i)`).

However, you can make a subclass of `Authorizer` with a `.getIdentityRequest` method that behaves differently: your version could look in `/etc/passwd`, or do an SQL database lookup[14], or create new Identities for anyone that asks (with a really secret password like '1234' that the user will probably never change, even if you ask them to). The Identities could be created by your server at startup time and stored in a dict, or they could be pickled and stored in a file until needed (in which case `.getIdentityRequest()` would use the username to find a file, unpickle the contents, and return the resulting `Identity` object), or created brand-new based upon whatever data you want. Any function that returns a Deferred (that will eventually get called back with the `Identity` object) can be used here.

> **Note:**
> For static Identities that are available right away, the Deferred's callback() method is called right away. This is why the interface of `.getIdentityRequest()` specifies that its Deferred is returned unarmed, so that the caller has a chance to actually add a callback to it before the callback gets run. (XXX: check, I think armed/unarmed is an outdated concept)

Identity

The `Identity` object thus returned has two responsibilities. The first is to authenticate the user, because so far they are unverified: they have claimed to be somebody (by giving a username to the Authorizer), but have not yet proved that claim. It does this by implementing `.verifyPassword`, which is called by IdentityWrapper (described later) as part of the challenge-response sequence. If the password is valid, `.verifyPassword` should return a Deferred and run its callback. If the password is wrong, the Deferred should have the error-back run instead.

The second responsibility is to provide `Perspective` objects to users who are allowed to access them. The authenticated user gives a service name and a perspective name, and `.requestPerspectiveForKey()` is invoked to retrieve the given `Perspective`. The `Identity` is the one who decides which services/perspectives the user is allowed to access. Unless you override it in a subclass, the default implementation uses a simple dict called `.keyring`, which has keys that are (servicename, perspectivename) pairs. If the requested name pair is in the keyring, access is allowed, and the `Identity` will proceed to ask the `Service` to give back the specified `Perspective` to the user. `.requestPerspectiveForKey()` is required to return a Deferred, which will eventually be called back with a `Perspective` object, or error-backed with a `Failure` object if they were not allowed access.

XXX: explain perspective names being scoped to services better

You could subclass `Identity` to change the behavior of either of these, but chances are you won't bother. The only reason to change `.verifyPassword()` would be to replace it with some kind of public-key verification scheme, but that would require changes to `pb.IdentityWrapper` too, as well as significant changes on the client side. Any changes you might want to make to `.requestPerspectiveForKey()` are probably more appropriate to put in the Service's `.getPerspectiveForIdentity` method instead. The Identity simply passes all requests for Perspectives off to the Service.

The default `Identity` objects are created with a username and password, and a "keyring" of valid service/perspective name pairs. They are children of an `Authorizer` object. The best way to create them is to have the `Authorizer` do it for you, then fill in the details, by doing the following:

```
i = auth.createIdentity("username")
i.setPassword("password")
i.addKeyByString("service", "perspective")
auth.addIdentity(i)
```

[14] See twisted.enterprise.dbcred for a module that does exactly that.

Service

The `Service` object's job is to provide `Perspective` instances, by implementing `.getPerspectiveForIdentity()`. This function takes a Perspective name, and is expected to return a Deferred which will (eventually) be called back with an instance of `Perspective` (or a subclass).

The default implementation (in `twisted.spread.pb.Service`) retrieves static pre-generated `Perspectives` from a dict (indexed by perspective name), much like DefaultAuthorizer does with Identities. And like `Authorizer`, it is very useful to subclass `pb.Service` to change the way `.getPerspectiveForIdentity()` works: to create `Perspectives` out of persistent data or database lookups, to set extra attributes in the `Perspective`, etc.

When using the default implementation, you have to create the `Perspectives` at startup time. Each `Service` object has an attribute named `.perspectiveClass`, which helps it to create the `Perspective` objects for you. You do this by running `p = svc.createPerspective("perspective_name")`.

You should use `.createPerspective()` rather than running the constructor of your Perspective-subclass by hand, because the Perspective object needs a pointer to its parent `Service` object, and the `Service` needs to have a list of all the `Perspectives` that it contains.

5.4.6 How that example worked

Ok, so that's what everything is supposed to do. Now you can walk through the previous example and see what was going on: we created a subclass called `MyPerspective`, made a `DefaultAuthorizer` and added it to the `Application`, created a `Service` and told it to make `MyPerspectives`, used `.createPerspective()` to build a few, for each one we made an `Identity` (with a username and password), and allowed that `Identity` to access a single `MyPerspective` by adding it to the keyring. We added the `Identity` objects to the `Authorizer`, and then glued the authorizer to the `pb.BrokerFactory`.

How did that last bit of magic glue work? I won't tell you here, because it isn't very useful to override it, but you effectively hang an `Authorizer` off of a TCP port. The combination of the object and methods exported by the `pb.AuthRoot` object works together with the code inside the `pb.connect()` function to implement both sides of the challenge-response sequence. When you (as the client) use `pb.connect()` to get to a given host/port, you end up talking to a single `Authorizer`. The username/password you give get matched against the `Identities` provided by that authorizer, and then the servicename/perspectivename you give are matched against the ones authorized by the `Identity` (in its `.keyring` attribute). You eventually get back a remote reference to a `Perspective` provided by the `Service` that you named.

> **Note:**
> Here is how the magic glue code works:
>
> ```
> app.listenTCP(8800, pb.BrokerFactory(pb.AuthRoot(auth)))
> ```
>
> `pb.AuthRoot()` provides objects that are subclassed from `pb.Root`, so as we saw in the first example, they can be served up by `pb.BrokerFactory()`. `AuthRoot` happens to use the `.rootObject` hook described earlier to serve up an `AuthServ` object, which wraps the `Authorizer` and offers a method called `.remote_username`, which is called by the client to declare which `Identity` it claims to be. That method starts the challenge-response sequence.

5.4.7 Code Walkthrough: pb.connect()

So, now that you've seen the complete sequence, it's time for a code walkthrough. This will give you a chance to see the places where you might write subclasses to implement different behaviors. We will look at what happens when `pb6client1.py` meets `pb6server.py`. We tune in just as the client has run the `pb.connect()` call.

The client-side code can be summarized by the following sequence of function calls, all implemented in twisted/spread/pb.py . `pb.connect()` calls `getObjectAt()` directly, after that each step is executed as a callback when the previous step completes.

```
getObjectAt(host,port,timeout)
logIn(): authServRef.callRemote('username', username)
_cbLogInRespond(): challenger.callRemote('respond', f[challenge,password])
_cbLogInResponded(): identity.callRemote('attach', servicename,
                                         perspectivename, client)
usercallback(perspective)
```

The client does `getObjectAt()` to connect to the given host and port, and retrieve the object named `root`. On the server side, the `BrokerFactory` accepts the connection, asks the `pb.AuthRoot` object for its `.rootObject()`, getting an `AuthServ` object (containing both the authorizer and the `Broker` protocol object). It gives a remote reference to that `AuthServ` out to the client.

Now the client invokes the '`.remote_username`' method on that `AuthServ`. The `AuthServ` asks the `Authorizer` to `.getIdentityRequest()`: this retrieves (or creates) the `Identity`. When that finishes, it asks the `Identity` to create a random challenge (usually just a random string). The client is given back both the challenge and a reference to a new `AuthChallenger` object which will only accept a response that matches that exact challenge.

The client does its part of the MD5 challenge-response protocol and sends the response to the `AuthChallenger`'s `.remote_response()` method. The `AuthChallenger` verifies the response: if it is valid then it gives back a reference to an `IdentityWrapper`, which contains an internal reference to the `Identity` that we now know matches the user at the other end of the connection.

The client then invokes the `.remote_attach` method on that `IdentityWrapper`, passing in a serviceName, perspectiveName, and remoteRef. The wrapper asks the `Identity` to get a perspective using `identity.requestPerspectiveForKey`, which does the "is this user allowed to get this service/perspective" check by looking at the tuples on its `.keyring`, and if that is allowed then it gets the `Service` (by giving serviceName to the authorizer), then asks the `Service` to provide the perspective (with `svc.getPerspectiveForIdentity`). The default `Service` will ignore the identity object and just look for `Perspective`s by perspectiveName. The `Service` looks up or creates the `Perspective` and returns it. The `.remote_attach` method runs the Perspective's `.attached` method (although there are some intermediate steps, in `IdentityWrapper._attached`, to make sure `.detached` will eventually be run, and the Perspective's `.brokerAttached` method is executed to give it a chance to return some other Perspective instead). Finally a remote reference to the `Perspective` is returned to the client.

The client gives the `Perspective` reference to the callback that was attached to the `Deferred` that `pb.connect()` returned, which brings us back up to the code visible in `pb6client1.py`.

5.4.8 Viewable

Once you have `Perspective` objects to represent users, the `Viewable` class can come into play. This class behaves a lot like `Referenceable`: it turns into a `RemoteReference` when sent over the wire, and certain methods can

be invoked by the holder of that reference. However, the methods that can be called have names that start with `view_` instead of `remote_`, and those methods are always called with an extra `perspective` argument:

```
class Foo(pb.Viewable):
    def view_doFoo(self, perspective, arg1, arg2):
        pass
```

This is useful if you want to let multiple clients share a reference to the same object. The `view_` methods can use the "perspective" argument to figure out which client is calling them. This gives them a way to do additional permission checks, do per-user accounting, etc.

5.4.9 A Larger Example

Now it's time to look more closely at the Go server described before.

To simplify the example, we will build a server that handles just a single game. There are a variety of players who can participate in the game, named Alice, Bob, etc (the usual suspects). Two of them log in, choose sides, and begin to make moves.

We assume that the rules of the game are encapsulated into a `GoGame` object, so we can focus on the code that handles the remote players.

XXX: finish this section

That's the end of the tour. If you have any questions, the folks at the welcome office will be more than happy to help. Don't forget to stop at the gift store on your way out, and have a really nice day. Buh-bye now! Kevin Turner <http://twistedmatrix.com/users/acapnotic/>

5.5 Managing Clients of Perspectives

5.5.1 Overview

As we've watched several applications build on top of `twisted.cred` and *Perspective Broker* (page 100), we've seen several models of interaction between `Perspective`s and the clients which connect to them. In the future, these patterns may be codified by support classes in the framework, but for now we shall just document them here. They are:

Clientless Perspective **(page 146)** in which the Perspective remains oblivious of the fact that clients attach to it.

Single Client **(page 146)** in which no more than one client is attached to a Perspective. There are two sub-categories, based on how this limit is enforced:

- excess connections from clients are *refused* (page 146) (seen in CVSToys[15]).
- new connections *replace* (page 150) the old (seen in `twisted.words`).

Multiple Client **(page 151)** in which the Perspective keeps a list of clients instead of a single one. The clients all share this Perspective, the actions of any may effect the perspective for all. (Seen in `twisted.manhole`.)

Anonymous Clients **(page 152)** where any number of clients may connect to the service using a particular perspective name, but clients may not effect one another and any changes to the perspective do not persist.

explain or point to how clients get attached to perspectives (pb.connect, guard(?)).

[15] http://purl.net/net/CVSToys/

5.5.2 Clientless Perspective

```
from twisted.cred import perspective

class ClientlessPerspective(perspective.Perspective):
    """I have no notion of 'client' whatsoever.

    I may still have methods which carry out actions and/or return
    objects (perspective_ methods and Referenceable objects, in the
    case of PB), but I take no notice when clients attach or detach
    from me.  Nor do I push data to clients; the only data they
    receive from me is the return values of any methods they choose to
    call.
    """
    pass
```

Source listing — *clientless.py*

Needless to say, the `ClientlessPerspective` is not ideal for all applications. A common model for network applications is to have the client functioning as an observer of messages distributed by the server (i.e. chat services, build failure notification, etc.). For this purpose, the server needs maintain a list of observers on reachable clients. The Perspective class provides facilities for this, offering `attached`() and `detached`() methods which are called with references to clients connecting or disconnecting from the service.

5.5.3 Single Client

```
from twisted.cred import error, perspective

class PerspectiveInUse(error.Unauthorized):
    """Raised when a client requests a perspective already connected to another.
    """
    # XXX: Is there any information this exception should carry, i.e.
    #   the Perspective in question.
    #   the client it's currently attached to.
    #   the Identity which attached it.


class SingleClientPerspective(perspective.Perspective):
    """One client may attach to me at a time.

    If another client tries to attach while a previous one is still connected,
    it will encounter a PerspectiveInUse exception.

    @ivar client: The client attached to me, if any.  (Passed by the
        client as the I{client} argument to L{pb.connect}.
    @type client: L{RemoteReference}
```

```
    """

    client = None

    def attached(self, ref, identity):
        if self.client is not None:
            raise PerspectiveInUse
        self.client = ref

        # Perspective.attached methods must return a Perspective to tell the
        # caller what they actually ended up being attached to.
        return self

    def detached(self, ref, identity):
        assert ref is self.client, "Detaching something that isn't attached."
        del self.client

    def sendMessage(self, message):
        """Send a message to my client.

        (This isn't a defined Perspective method, just an example of something
        you would define in your sub-class to use to talk to your client.)
        """
        # Using 'assert' in this case is probably not a good idea for real
        # code.  Define an exception, or choose to let it pass without comment,
        # as your needs see fit.
        assert self.client is not None, "No client to send a message to!"
        # Nor is the 'message' method defined by twisted.cred -- your client
        # can have any interface you desire, any type of object may be passed
        # to 'attached'.
        self.client.message(message)

    def __getstate__(self):
        state = styles.Versioned.__getstate__(self)
        # References to clients generally aren't persistable.
        try:
            del state['client']
        except KeyError:
            pass
        return state
```

Source listing — *single.py*

Here's a more complex example, using the more specialized `brokerAttached` method of Perspective Broker.

```
from twisted.cred import error
```

```
from twisted.spread import pb

class PerspectiveInUse(error.Unauthorized):
    """Raised when a client requests a perspective already connected to another.
    """
    # XXX: Is there any information this exception should carry, i.e.
    #   the Perspective in question.
    #   the client it's currently attached to.
    #   the Identity which attached it.


class SingleClientPerspective_PB(pb.Perspective):
    """One client may attach to me at a time.

    With verbose logging and some detection for lost connections.
    """

    client = None

    # This example is from cvstoys.actions.pb.Notifiee.

    def brokerAttached(self, ref, identity, broker):
        log.msg("%(identityName)s<auth%(authID)X>@"
                "%(peer)s<broker%(brokerID)X> "
                "requests attaching client %(client)s to "
                "%(perspectiveName)s@%(serviceName)s" %
                {'identityName': identity.name,
                 'authID': id(identity.authorizer),
                 'peer': broker.transport.getPeer(),
                 'brokerID': id(broker),
                 'client': ref,
                 'perspectiveName': self.getPerspectiveName(),
                 'serviceName': self.service.getServiceName(),
                 })

        if self.client:
            oldclient, oldid, oldbroker = self.client
            if oldbroker:
                brokerstr = "<broker%X>" % (id(oldbroker),)
            else:
                brokerstr = "<no broker>"
            log.msg(
                "%(pn)s@%(sn)s already has client %(client)s "
                "from %(id)s@%(broker)s" %
                {'pn': self.getPerspectiveName(),
                 'sn': self.service.getServiceName(),
```

```
                'id': oldid.name,
                'client': oldclient,
                'broker': brokerstr})

            # Here's the part that checks is the currently connected client
            # has a stale connection.  It *shouldn't* happen, but if it did,
            # it would suck to not be able to sign back on because the system
            # wouldn't believe you were logged off.
            if (not oldbroker) or (oldbroker.connected and oldbroker.transport):
                if oldbroker:
                    brokerstr = "%s%s" % (oldbroker.transport.getPeer(),
                                          brokerstr)
                log.msg("%s@%s refusing new client %s from broker %s." %
                        (self.getPerspectiveName(),
                         self.service.getServiceName(),
                         ref, broker))
                raise PerspectiveInUse("This perspective %r already has a "
                                       "client.  (Connected by %r from %s.)"
                                       % (self, oldid.name, brokerstr))
            elif oldbroker:
                log.msg("BUG: Broker %s disconnected but client %s never"
                        "detached.\n(I'm dropping the old client and "
                        "allowing a new one to attach.)" %
                        (oldbroker, self.client,))
                self.brokerDetached(self, self.client, identity, oldbroker)
                # proceed with normal attach
        #endif self.client
        self.client = (ref, identity, broker)
        return self

    def detached(self, ref, identity):
        del self.client

    def sendMessage(self, message):
        """Send a message to my client.

        (This isn't a defined Perspective method, just an example of something
        you would define in your sub-class to use to talk to your client.)
        """
        # Using 'assert' in this case is probably not a good idea for real
        # code.  Define an exception, or choose to let it pass without comment,
        # as your needs see fit.
        assert self.client is not None, "No client to send a message to!"
        # This invokes remote_message(message) on the client object.
        self.client.callRemote("message", message)
```

```
    def __getstate__(self):
        state = styles.Versioned.__getstate__(self)
        try:
            del state['client']
        except KeyError:
            pass
        return state
```

Source listing — *single-pb.py*

Here's an example which attempts to enforce the single-client limit in a different manner:

```
from twisted.spread import pb

class SingleClientWithAKickPerspective(pb.Perspective):
    """One client may attach to me at a time.

    If a new client requests to be attached to me, any currently
    connected perspective will be disconnected.
    """

    # This example is from twisted.words.service.Participant.

    client = None

    def __getstate__(self):
        state = styles.Versioned.__getstate__(self)
        try:
            del state['client']
        except KeyError:
            pass
        return state

    def attached(self, client, identity):
        if self.client is not None:
            self.detached(client, identity)
        self.client = client
        return self

    def detached(self, client, identity):
        self.client = None

        # For the case where 'detached' was called by 'attached' wanting to
        # kick someone off, is this all we need to do?  I'm afraid not --
        # no-one ever told the client that it had been detached!  So the
        # client, which will still have a reference to this perspective until
```

```
        # its broker dies, will continue to execute methods on it, will
        # continue to get results returned by those methods.  It just won't get
        # events sent to self.client.  Meanwhile, the newly attached client
        # will probably be confused, because its Perspective is doing things
        # the new client did not ask it to do and it thinks it is the only
        # thing connected.
```

Source listing — *single-kick.py*

What do we learn?

- `twisted.words`, the only system that ships with Twisted which uses Perspectives in Perspective Broker, is a lousy example. ;)
- `detached` is not sufficient to kick a client off.

In fact, it turns out to be hard to kick a client off a Perspective, because there's no way you can force them to lose the reference they hold. The best you can do is define a "goodbye" method on the client interface and hope they honor and implement it correctly. If the client is talking to you over a transport (as is the case with Perspective Broker), you can kick them off somewhat forcibly by closing the transport, but this is bad practice for several reasons. First, it requires knowing how to access and shut down the transport, which breaks some abstractions. Second, it's a damned inconsiderate thing to do if that transport may have been also carrying traffic for other services.

I can think of several lines along which you could develop from here:

- Add a way to mark references as invalid to Perspective Broker. Then when the client tried to call a method on the perspective, it would get an exception saying it wasn't allowed to talk to that object any more. Obviously, this only works for Perspective Broker, and not for other systems which might access your Service.
- Forget about the whole idea of kicking clients off. Anyone who has gained a reference to the Perspective through the Authorizer has a right to keep it. If another client wants to attach before the first one is done, you'll just have to accommodate them both. Which leads us to...

5.5.4 Multiple Client

```
from twisted.spread import pb

class MultipleClientPerspective(pb.Perspective):
    """Many clients may use this Perspective at once."""

    # This example is from twisted.manhole.service.Perspective.

    def __init__(self, perspectiveName, identityName="Nobody"):
        pb.Perspective.__init__(self, perspectiveName, identityName)
        self.clients = {}

    def attached(self, client, identity):
        # The clients dictionary is really only used as a set and not as a
```

```
        # mapping, but we go ahead and throw the Identity into the value slot
        # because hey, it's there.
        self.clients[client] = identity
        return self

    def detached(self, client, identity):
        try:
            del self.clients[client]
        except KeyError:
            # This is probably something as benign as the client being removed
            # by a DeadReferenceError in sendMessage and again when the broker
            # formally closes down.  No big deal.
            pass

    def sendMessage(self, message):
        """Pass a message to my clients' console.
        """
        for client in self.clients.keys():
            try:
                client.callRemote('message', message)
            except pb.DeadReferenceError:
                # Stale broker.  This is the error you get if in the process
                # of doing the callRemote, the broker finds out the transport
                # just died, or something along those lines.  So remove that
                # client from our list.
                self.detached(client, None)

    def __getstate__(self):
        state = styles.Versioned.__getstate__(self)
        state['client'] = {}
        return state
```

Source listing — *multiple.py*

5.5.5 Anonymous Clients

Last item on the list: Anonymous perspectives. One way to do it would be to use a `ClientlessPerspective` or `MultipleClientPerspective` and promise to not have any methods that stored state on or otherwise modified the perspective instance so no client can interfere with any other. Another way to do it, without that restriction, would be to use disposable Perspectives:

```
from twisted.cred import perspective

class AnonymousPerspective(perspective.Perspective):
    """Define this as a perspective with whatever capabilities you feel safe
```

```
    to give to anonymous users.
    """

class UnattachablePerspective(perspective.Perspective):
    """I am a special class of Perspective that can never be attached to.

    I can be stored in a Service's collection of perspectives and
    placed on an Identity's keyring, but the client will never obtain
    a reference to me.  Instead, they'll get back a single-use
    perspective, of the class named by L{disposablePerspectiveClass}.
    """

    # The code in this example is ALL NEW (and thus not been field-tested or
    # mother-approved), but might be used in CVSToys or BuildBot, where we're
    # publishing public read-only messages and aren't interested in maintaining
    # accounts for the people who sign on to read them.

    disposablePerspectiveClass = AnonymousPerspective
    _counter = 0

    def attached(self, client, identity):
        name = "%s#%d" % (self.name, self._counter)
        self._counter = self._counter + 1
        p = self.disposablePerspectiveClass(name)
        p.setService(self.service)
        # You might add p to the Service's cache of perspectives at this point,
        # so s.getPerspectiveNamed(p.getPerspectiveName()) would work.  Just as
        # long as you remember to remove it from the cache when it's through,
        # so you don't leak memory.
        return p.attached(client, identity)

    def detached(self, client, identity):
        assert 0, "How can this be?  Nothing should have ever attached to me."
```

Source listing — *unattachable.py*

If you wanted to have *all* access to a Service be anonymous, you could make a service like this:

```
class AnonymousService(service.Service):
    class perspectiveClass(UnattachablePerspective):
        disposablePerspectiveClass = MyAnonymousPerspective
        # XXX: does this lazy subclassing work, or do you end up with a class
        # that isn't persistable because it's not module-level or something?
```

But to make only certain log-ins anonymous:

```
theService = Service(serviceName)
```

```
anonymousPerspective = UnattachablePerspective("anonymous")
anonymousPerspective.disposablePerspectiveClass = MyAnonymousPerspective
theService.addPerspective(anonymousPerspective)
# Set anonymous's password to the empty string:
anonymousPerspective.makeIdentity('')
```

5.5.6 Feedback

That's all for today, thanks for playing. We'd like to hear about how you're using this code! Questions, comments, reservations? Please send them to twisted-python@twistedmatrix.com[16].

[16] mailto:twisted-python@twistedmatrix.com

Chapter 6

Web Applications

6.1 Light Weight Templating With Resource Templates

6.1.1 Overview

While Twisted supports solution like *Woven* (page 160) for high-content sophisticated templating needs, sometimes one needs a less file-heavy system which lets one directly write HTML. While ResourceScripts are available, they have a high overhead of coding, needing some boring string arithmetic. ResourceTemplates fill the space between Woven and ResourceScript using Quixote's PTL (Python Templating Language).

ResourceTemplates need Quixote installed. In Debian[1], that means using Python 2.2 and installing the `quixote` package (`apt-get install quixote`). Other operating systems require other ways to install quixote, or it can be done manually.

6.1.2 Configuring Twisted.Web

The easiest way to get Twisted.Web to support ResourceTemplates is to bind them to some extension using the web tap's `--processor` flag. Here is an example:

```
% mktap web --path=/var/www \
        --processor=.rtl=twisted.web.script.ResourceTemplate
```

The above command line binds the `rtl` extension to use the ResourceTemplate processor. Other ways are possible, but would require more Python coding and are outside the scope of this HOWTO.

6.1.3 Using ResourceTemplate

ResourceTemplates are coded in an extension of Python called the "Python Templating Language". Complete documentation of the PTL is available at the quixote web site[2]. The web server will expect the PTL source file to define a variable named `resource`. This should be a `twisted.web.server.Resource`, whose `.render` method be called. Usually, you would want to define `render` using the keyword `template` rather than `def`.

Here is a simple example for a resource template.

[1] http://www.debian.org

[2] http://www.mems-exchange.org/software/quixote/doc/PTL.html

```
from twisted.web.resource import Resource
from TwistedQuotes import quoters

quotefile = os.path.join(os.path.split(__file__)[0], "quotes.txt")

quoter = quoters.FortuneQuoter([quotefile])


class QuoteResource(Resource):

    template render(self, request):
        """\
        <html>
        <head><title>Quotes Galore</title></head>

        <body><h1>Quotes</h1>"""
        quoter.getQuote()
        "</body></html>"


resource = QuoteResource()
```

Resource Template for Quotes — *webquote.rtl*

6.2 Creating XML-RPC Servers and Clients with Twisted

6.2.1 Introduction

XML-RPC[3] is a simple request/reply protocol that runs over HTTP. It is simple, easy to implement and supported by most computer languages. Twisted's XML-RPC support uses the xmlrpclib library for parsing - it's included with Python 2.2, but can be downloaded for Python 2.1 from Pythonware[4].

6.2.2 Creating a XML-RPC server

Making a server is very easy - all you need to do is inherit from `twisted.web.xmlrpc.XMLRPC`. You then create methods beginning with `xmlrpc_`. The methods' arguments determine what arguments it will accept from XML-RPC clients. The result is what will be returned to the clients.

Methods published via XML-RPC can return all the basic XML-RPC types, such as strings, lists and so on (just return a regular python integer, etc). They can also return Failure instances to indicate an error has occured, or `Binary`, `Boolean` or `DateTime` instances (all of these are the same as the respective classes in xmlrpclib. In addition, XML-RPC published methods can return `Deferred` instances whose results are one of the above. This allows you to return

[3] http://www.xmlrpc.com
[4] http://www.pythonware.com/products/xmlrpc/

results that can't be calculated immediately, such as database queries. See the *Deferred documentation* (page 82) for more details.

`XMLRPC` instances are Resource objects, and they can thus be published using a Site. The following example has two methods published via XML-RPC, `add(a, b)` and `echo(x)`. You can run it directly or with `twistd -y script.py`

```
from twisted.web import xmlrpc, server

class Example(xmlrpc.XMLRPC):
    """An example object to be published."""

    def xmlrpc_echo(self, x):
        """Return all passed args."""
        return x

    def xmlrpc_add(self, a, b):
        """Return sum of arguments."""
        return a + b


def main():
    from twisted.internet.app import Application
    app = Application("xmlrpc")
    r = Example()
    app.listenTCP(7080, server.Site(r))
    return app

application = main()

if __name__ == '__main__':
    application.run(save=0)
```

After we run this command, we can connect with a client and send commands to the server:

```
>>> import xmlrpclib
>>> s = xmlrpclib.Server('http://localhost:7080/')
>>> s.echo("lala")
'lala'
>>> s.add(1, 2)
3
```

XML-RPC resources can also be part of a normal Twisted web server, using resource scripts. The following is an example of such a resource script:

```
from twisted.web import xmlrpc
from TwistedQuotes import quoters
import os
```

```
quotefile = os.path.join(os.path.split(__file__)[0], "quotes.txt")
quoter = quoters.FortuneQuoter([quotefile])

class Quoter(xmlrpc.XMLRPC):

    def xmlrpc_quote(self):
        return quoter.getQuote()

resource = Quoter()
```

Source listing — *xmlquote.rpy*

6.2.3 SOAP Support

From the point of view, of a Twisted developer, there is little difference between XML-RPC support and SOAP support. Here is an example of SOAP usage:

```
from twisted.web import soap
from TwistedQuotes import quoters
import os

quotefile = os.path.join(os.path.split(__file__)[0], "quotes.txt")
quoter = quoters.FortuneQuoter([quotefile])

class Quoter(soap.SOAPPublisher):
    """Publish two methods, 'add' and 'echo'."""

    def soap_quote(self):
        return quoter.getQuote()

resource = Quoter()
```

Source listing — *soap.rpy*

6.2.4 Creating an XML-RPC Client

XML-RPC clients in Twisted are meant to look as something which will be familiar either to `xmlrpclib` or to Perspective Broker users, taking features from both, as appropriate. There are two major deviations from the `xmlrpclib` way which should be noted:

1. No implicit `/RPC2`. If the services uses this path for the XML-RPC calls, then it will have to be given explicitly.
2. No magic `__getattr__`: calls must be made by an explicit `callMethod`.

The interface Twisted presents to XML-RPC client is that of a proxy object: `twisted.web.xmlrpc.Proxy`. The constructor for the object receives a URL: it must be an HTTP or HTTPS URL. When an XML-RPC service is described, the URL to that service will be given there.

Having a proxy object, one can just call the `callMethod` method, which accepts a method name and a variable argument list (but no named arguments, as these are not supported by XML-RPC). It returns a deferred, which will be called back with the result. If there is any error, at any level, the errback will be cauled. The exception will be the relevant Twisted error in the case of a problem with the underlying connection (for example, a timeout), `IOError` containing the status and message in the case of a non-200 status or a `xmlrpclib.Fault` in the case of an XML-RPC level problem.

```
from twisted.web.xmlrpc import Proxy
from twisted.internet import reactor

def printValue(value):
    print repr(value)
    reactor.stop()

def printError(error):
    print 'error', error
    reactor.stop()

proxy = Proxy('http://advogato.org/XMLRPC')
proxy.callRemote('test.sumprod', 3, 5).addCallbacks(printValue, printError)
reactor.run()
```

prints:

```
[8, 15]
```

Chapter 7

Woven

7.1 Woven

Woven is a Web Application Framework for building highly interactive web applications, written in Python. It separates HTML Templates from page-generation logic written in Python, and uses the Model View Controller (MVC) pattern to create dynamic HTML on the fly. Woven is higher level framework that depends on the Twisted Web package of the Twisted Framework.

7.1.1 Twisted Overview

Twisted is a framework written in Python for building network applications. A core design feature of Twisted is its asynchronous networking nature. Because of the high overhead and locking requirements of threads, Twisted chooses to instead use the highly efficient network event notification mechanisms provided by the OS in the form of the C `poll()` or `select()` calls. Twisted uses the Reactor pattern, which is an event-loop style of programming which facilitates asynchronous programming.

Asynchronous programming requires breaking your program into smaller function chunks that trigger an operation which may potentially take a long time (for example, a network request) and return. In order to continue the flow of your code when the operation has completed, you must register a "callback function" which will be called with the resulting data when it is ready. Twisted includes a generalized callback handling mechanism, Deferred, discussed in the Deferred execution paper[1].

However, since writing Woven applications already involves breaking your functions into small, reusable Model-View-Controller components, Woven is able to handle the asynchronous nature of Twisted for you. By writing Models which provide data, potentially asynchronously, and Views which render data when it is ready, you are doing all that is required to act as a good citizen within the Twisted framework.

7.1.2 Twisted Web Object Publishing and Woven

Twisted includes a Web Server that handles HTTP requests and returns dynamic pages. It is useful when used in conjunction with Apache for serving static files such as Images. Apache can be set up to forward a specific URL via

[1] http://www.twistedmatrix.com/documents/historic/2003/pycon/deferex/deferex.html

`ProxyPass` to the Twisted Web server. Twisted Web uses the concept of Object Publishing, similar to Zope, where there is a root Python Object below which alll other Objects representing URLs are located.

When a request comes in to Twisted Web, Twisted Web splits the URL into segments and begins looking for Objects below the root by calling getChild tail-recursively. For example, if the URL `http://example.com/foo/bar/baz` is requested, Twisted splits this into the list of path segments `['foo', 'bar', 'baz']`. It then calls `root.getChild('foo')`, calls `getChild('bar')` on the result, calls `getChild('baz')` on the second result, and finally calls `render(request)` on the result of the final `getChild` call.

For more details about Twisted Web, see *Overview of Twisted Web* (page 13).

7.1.3 Smalltalk Model-View-Controller Overview

Originally developed for Smalltalk, the MVC design pattern is a flexible mechanism for creating both GUI and web application user interfaces. The primary advantage of the MVC pattern is separation of business logic from presentation details and provides a *loose coupling* between an application's Model (state) and View (presentation). All of this makes code reuse easier and enables a division of labor between application design and user interface design, albeit at the expense of a little extra work.

A "Model" is an object that represents or encapsulates an application's business logic or state. The model contains both data and business logic code, but does not contain presentation or rendering code.

A "View" is an object that contains presentation or rendering code, but does not contain business logic code.

Finally, a "Controller" is a dispatcher object that mediates flow between the Model and the View. In traditional Smalltalk MVC, the Controller is responsible for polling the Mouse and Keyboard and converting the user's actions (Click a button, for example) into high-level events (Change the Model data from 0 to 1, and redraw a View which represents this Model to the user).

7.1.4 Woven Model-View-Controller Overview

In Woven, a Model is a python object that holds the data that will eventually be rendered by a view object into a portion of an HTML page. Woven Models may be any Python object; Woven accomplishes this using "`IModel` Adapters":Components. Since different Python objects may act as "Containers" using different semantics, `IModel` adapters are required to allow Woven to address all Container objects uniformly. For example, Dictionaries are indexed using string keys. Lists are indexed using integer keys. Objects provide references to other objects using dot syntax (`foo.bar`), not square bracket syntax (`foo['bar']`). `IModel` Adapters are provided for all the basic Python types, Dictionaries, Lists, Integers, Floats, Strings, and Instances, and work behind the scenes to provide Model data to your Pages.

In Woven, a View is comprised of a Page object and many Widget objects. A Page object loads a template file (an XHTML file) that contains references to Widget objects (python objects that replace specific portions of the DOM created from the XHTML file). A single XHTML template references one Page object, but many Widget objects.

Widgets come in two flavors: local and global. Local Widgets are specific to only one template file, because the logic they perform is very specific, while global Widgets are general enough to replace placeholder content in many template files. Local Widgets are defined on the Page class, by defining a method with the prefix `wvupdate_` Global Widgets are defined as subclasses of the Widget class.

In Woven, Page objects act as the default Controller object, similar to Servlets in Struts. ((please explain further?)) Since the Web is Request-Response and not event-driven like a Smalltalk application, the most basic event to be handled from the user is "URL Requested". The root Page object contains logic for locating the correct Page object to handle the request. Once this object is located, it handles the "url requested" event by rendering itself into HTML. Thus, the Page object acts as both the main View and Controller for this event.

However, unlike Struts, Woven also supports more Smalltalk-like Controller programming. With a Controller, it is possible to register a Python event handling function which will be called when a specific JavaScript event occurs in the Browser. These events are relayed to the server out-of-band (without causing the main page to refresh) and can be handled asynchronously. Thus, it is possible to program Web Applications which act more like traditional Smalltalk Desktop Applications.

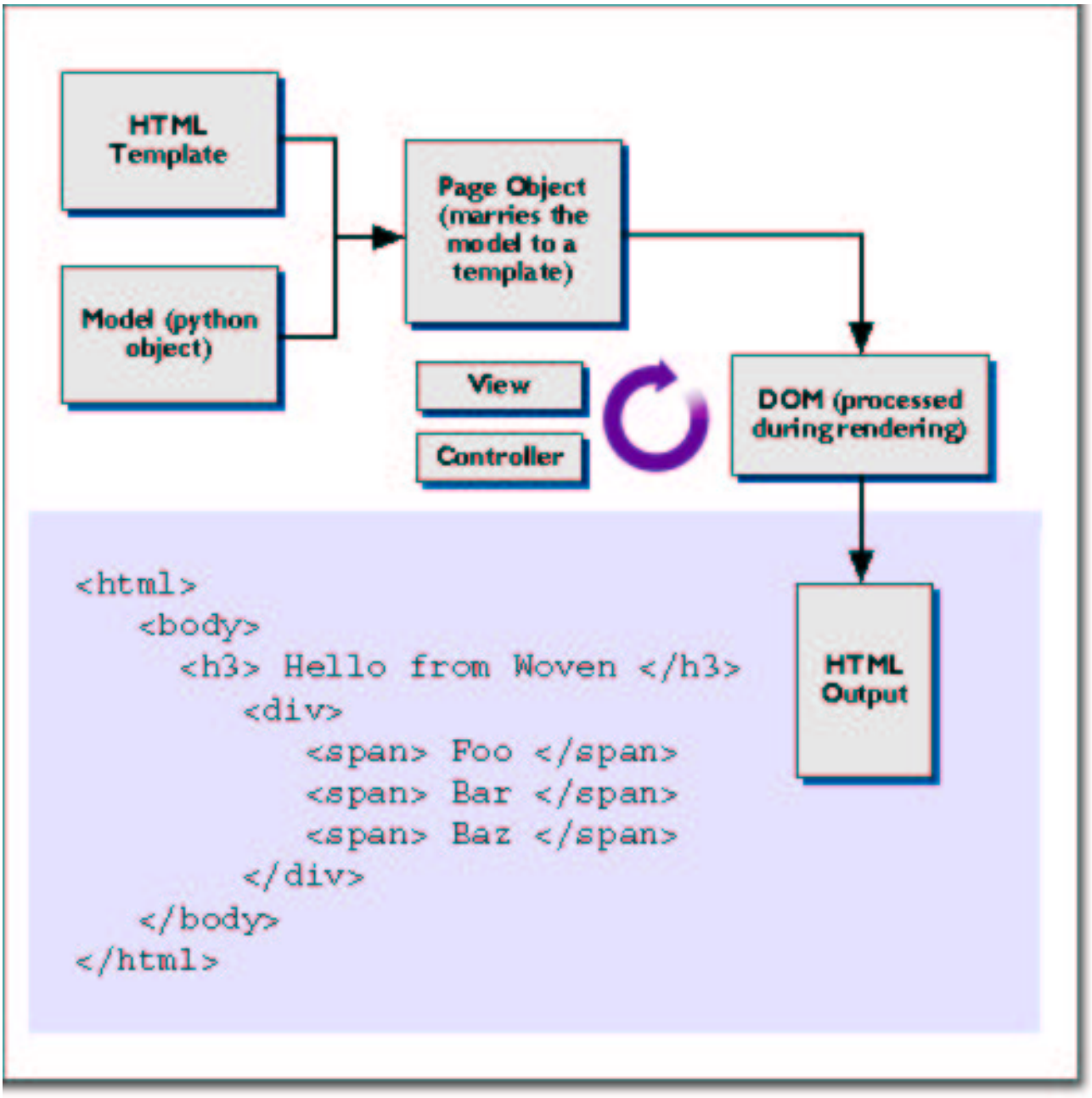
Often in Woven, it is convenient for a single object to have both the View and Controller responsibilities, though this is not strictly necessary. It is only useful to split out the Controller logic from the View if the request argument handling is general enough to be reusable across multiple pages.

7.1.5 Overview of Woven Main Concepts

- *XHTML Templates* (page 163) must be valid XHTML documents. They provide a skeleton html page with placeholder content. Any element on the page which is destined for dynamic content must include special attributes to specify the name of model and view, like this: `<tag model="aModel" view="aView">placeholder text</tag>`
- *Model* (page 164) objects provide data for display in a web page.
- *View* (page 165) objects are given a DOM node created from the HTML template and model data, and are responsible for inserting the data into the node using the DOM api.
- *Controller* (page 165) objects accept input from the request and update the Model objects with the new input.
- *Page* (page 165) objects tie a model tree to a template, and provide view and controller factories to the template. This is the entry point of a web page built using Woven.
- *Rendering* (page 166) occurs when a web browser visits a Page. Woven recurses the template looking for nodes to handle, connects the correct Model object to a View and a Controller, and invokes them to render the node.
- *Further Concepts* (page 168) contains links to pages with more in depth information about Woven components.

7.1.6 In Depth Pages about Woven components

- *Twisted Web* (page 13)
- *Model* (page 176)
- *View* (page 183)
- *Controller* (page 190)
- *Page* (page 196)
- *LivePage* (page 194)
- *Form* (page 200)
- *Guard* (page 200)



7.1.7 Templates

Templates in Woven are XHTML documents, marked up with four special woven attributes:

- `model=` indicates which model object will be associated with this node.
- `view=` indicates which view object will be associated with this node.
- `controller=` indicates which controller object will be associated with this node.
- `pattern=` marks a node so it may be located by the View code, without the view knowing where the pattern= node is located or what style the pattern node contains.

HTML Template example

```
<html>
  <body>
    <h3 model="name" view="Text" />
    <div model="stuff" view="List">
      <span pattern="listItem" view="Text" />
    </div>
  </body>
</html>
```

7.1.8 Models

Model objects are arranged in a tree. Each Woven page has a model tree with exactly one root. All data required for display by a Woven page is made available through named sub-models below this root.

Any Python object may be used as a Woven model.

An example of a model tree built using simple python data structures, Dictionaries, Lists, and Strings:

```
model = {
  'name': 'Welcome to Woven',
  'stuff': [
    'Foo',
    'Bar',
    'Baz'
  ]
}
```

Each model in this tree has a submodel path which we can use to refer to it.

- The main dictionary is named `/`
- The name string is named `/name`
- The stuff list is named `/stuff`
- The first element of the stuff list is named `/stuff/0`
- The second element of the stuff list is named `/stuff/1`
- The third element of the stuff list is named `/stuff/2`

7.1.9 Views

View objects are constructed each time a `view=` directive is encountered.

If `view="Text"` is specified on a `Node`, an instance of the `Text` class will be constructed to handle the node.

An example View widget which simply inserts the model data into the DOM as a text node:

```
class Text(view.View):
    def generate(self, request, node, model):
        data = str(model.getData())
        newTextNode = request.d.createTextNode(data)
        node.appendChild(newTextNode)
        return node
```

The node that is returned from the generate method replaces the template node in the final HTML output.

> **Note:**In the above case, the same node that was passed in was returned, after being changed ("mutated").

The `View` object should return a DOM node that has been populated with the given model data.

7.1.10 Controllers

Controllers are responsible for accepting input from the user and making appropriate changes to the model.

They are also responsible for ensuring that the data submitted by the user is valid before changing the model.

Very few applications need the flexibility of separate Controller objects. Often, is is more convenient and clear to place the Controller logic in the View, where the View can make sure it has the latest data before rendering itself.

An example of a Controller which verifies the user's input before committing it to the Model:

```
class NewName:
    def handle(self, request):
        newName = request.args.get("newname", None)
        if newName is None:
          ## The user did not submit the form; do not do anything.
          return
        if newName == "":
          self.view.setError("Sorry, you didn't enter a name.")
        else:
          self.model.setData(newName)
          ## Tell the model that we are done making changes to it,
          ## and Views that rely upon this model should rerender.
          self.model.notify({'request': request})
```

7.1.11 Pages

Pages are the entry point into a Woven application. The Page object accepts a request to render a web page from `twisted.web` and drives the page rendering process by parsing the template, locating Model objects in the tree, and invoking Controller and View objects.

Page is a subclass of Resource, the `twisted.web` class representing an individual URL. Resource instances can be hooked up to the twisted.web HTTP server in several ways. The simplest way to hook up a Resource to a web URL is to start a static twisted.web server, which will serve files out of the given directory:

```
% mktap web --path /Users/dsp/Sites
% twistd -nf web.tap
```

If you visit the URL `http://localhost:8080/`, you will see the contents of the directory you specified. To create a URL which will be served by an instance of `Page`, create a Python script. In this script, instantiate a `Page` instance, passing it a `Model` and a `Template`, and assign it to a variable named `resource`:

```
from twisted.web.woven import page

model = {'name': 'Welcome to Woven',
         'stuff': ['Foo', 'Bar', 'Baz']}

template = """<html>
  <body>
      <h3 model="name" view="Text" />
      <div model="stuff" view="List">
        <p pattern="listItem" view="Text" />
      </div>
    </body>
  </html>
"""

resource = page.Page(model, template=template)
```

Name this script `test.rpy` and place it in the directory served by `twisted.web`. Then visit the URL `http://localhost:8080/test.rpy` with your web browser, and you should see a page with the HTML-formatted model data.

Page rendering process

When Woven renders a page, it first constructs a DOM (Document Object Model) which represents the template in memory using Python objects.

Woven then traverses the DOM, depth first, looking for nodes with woven directives (nodes with `model=`, `view=`, or `controller=` attributes).

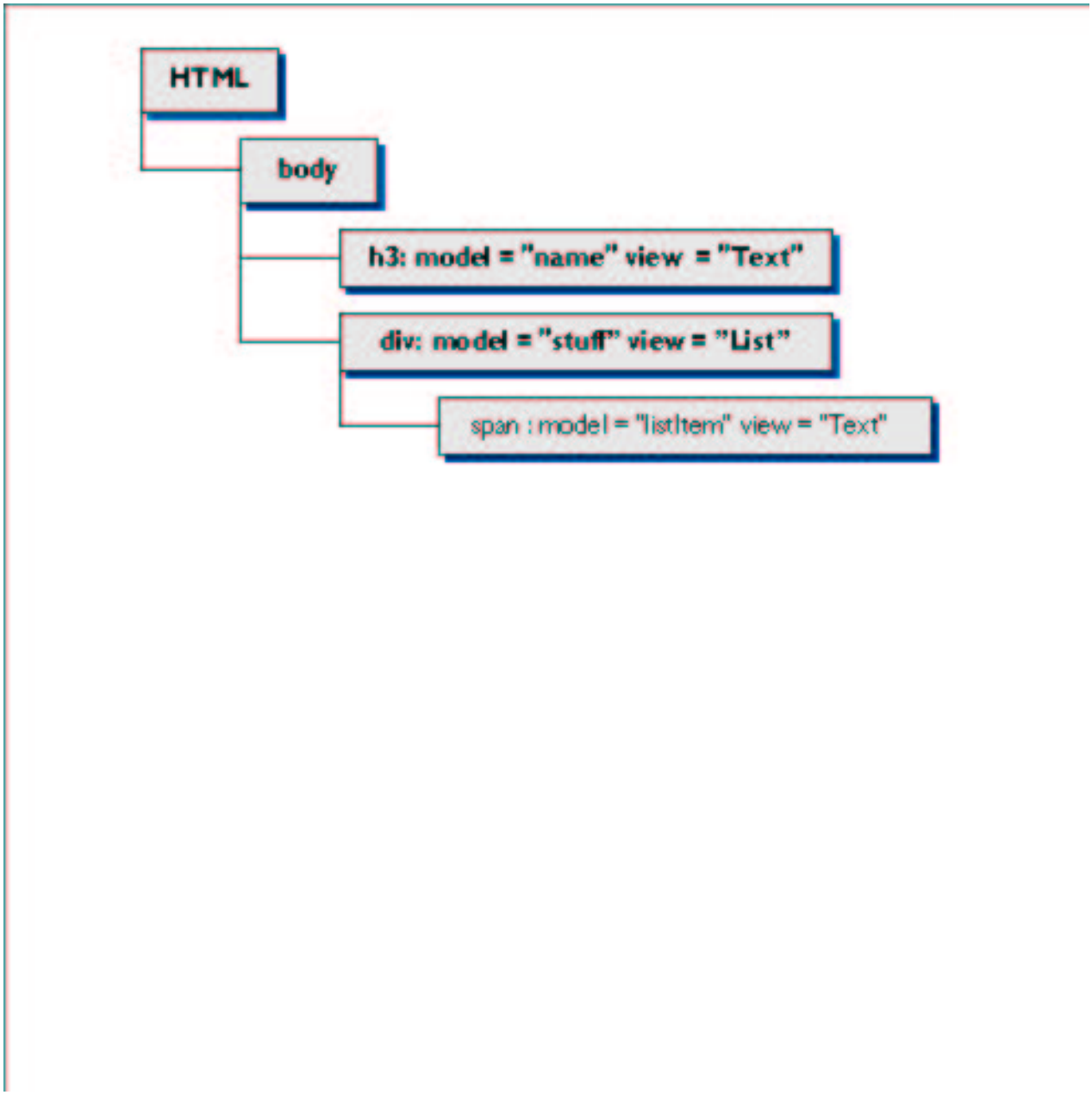
When a directive node is encountered, Woven locates/constructs Model, View, and Controller objects to handle this node.

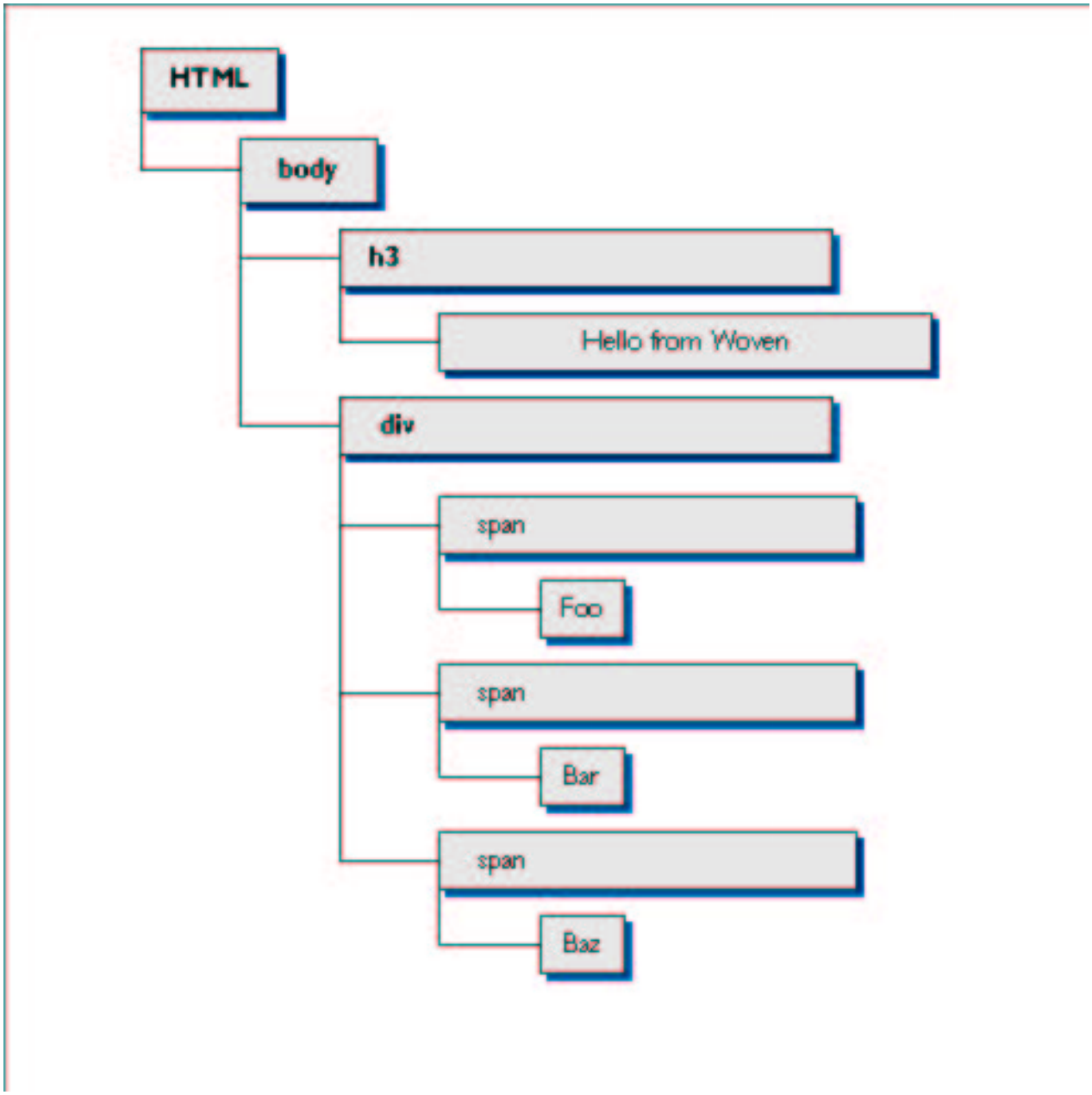
The Controller is then triggered by calling handle. The controller may take any action required of it to update the Model data, or may do nothing.

The View is then rendered by calling generate. The View object is passed a DOM node and a reference to the Model. The view then manipulates the DOM node, placing the Model data in it.

The DOM returned from the View is then traversed, looking for directives to handle.

When the entire DOM has been traversed and mutated, the DOM is converted to HTML and sent to the browser.


HTML
body
h3: model = "name" view = "Text"
div: model = "stuff" view = "List"
span : model = "listItem" view = "Text"



7.1.12 Further Reading

Twisted Web (page 13) is the Object-publishing web server woven uses to glue HTTP requests to Page rendering.

Page (page 196) objects are the IResource implementors in the Woven framework. They represent URL segments and drive the Woven template rendering process. They also contain convenient methods for specifying Page trees.

Model (page 176) objects provide data to Woven pages. Woven includes IModel adapters for the basic Python types and makes it easy for you to write your own Model classes and IModel adapters for your already-existing classes.

View (page 183) objects insert Model data into the DOM provided by the Template. They use DOM syntax for HTML generation, and have convenient syntax for locating and copying `pattern=` nodes abstractly.

Controller (page 190) objects accept input from the request and update the Model data. Controller objects are optional; often your Page or View instances can contain the controller logic and still make sense. Controllers are for cases which are general enough to warrant validation and commit logic.

LivePage (page 194) objects allow you to build DHTML behaviors into your Woven pages using pure server-side Python. It includes code for asynchronously forwarding client-side JavaScript events to the server without refreshing the page, and sending JavaScript to a page from the server after it has already been loaded.

Form (page 200) is a woven module that makes it easy to create HTML forms from existing Python methods which take keyword arguments. It also supports basic input validation.

Guard (page 200) is a woven module that allows you to wrap your Page instances with login pages, to prevent unauthorized users from accessing them.

7.2 PicturePile: a tutorial Woven application

To illustrate the basic design of a Woven app, we're going to walk through building a simple image gallery. Given a directory of images, it will display a listing of that directory; when a subdirectory or image is clicked on, it will be displayed.

To begin, we write an HTML template for the directory index:

```
<html>
  <head>
    <title model="title" view="Text">Directory listing</title>
  </head>
  <body>
    <h1 model="title" view="Text"></h1>
    <ul model="directory" view="List">
      <li pattern="listItem"><a view="Anchor" /></li>
      <li pattern="emptyList">This directory is empty.</li>
    </ul>
  </body>
</html>
```

The main things that distinguish a Woven template from standard XHTML are the 'model', 'view', and 'pattern' attributes on tags. Predictably, 'model' and 'view' specify which model and view will be chosen to fill the corresponding node. The 'pattern' attribute is used with views that have multiple parts, such as List. This example uses two patterns List provides; 'listItem' marks the node that will be used as the template for each item in the list, and 'emptyList' marks the node displayed when the list has no items.

Next, we create a `Page` that will display the directory listing, filling the template above (after a few imports):

```
import os
from twisted.internet import app
from twisted.web.woven import page
from twisted.web import server
```

```
class DirectoryListing(woven.page.Page):

    templateFile = "directory-listing.xhtml"

    def initialize(self, *args, **kwargs):
        self.directory = kwargs['directory']

    def wmfactory_title(self, request):
        return self.directory

    def wmfactory_directory(self, request):
        files = os.listdir(self.directory)
        for i in xrange(len(files)):
            if os.path.isdir(os.path.join(self.directory,files[i])):
                files[i] = files[i] + '/'
        return files

    def getDynamicChild(self, name, request):
        path = os.path.join(self.directory,name)
        if os.path.exists(path):
            if os.path.isdir(path):
                return DirectoryListing(directory=path)
            else:
                return ImageDisplay(image=path)
```

Due to the somewhat complex inheritance hierarchy in Woven's internals, a lot of processing is done in the '__init__' method for Page. Therefore, a separate 'initialize' method is provided so that one can easily access keyword args without having to disturb the internal setup; it is called with the same args that Page.__init__ receives.

The 'templateFile' attribute tells the Page what file to load the template from; in this case, we will store the templates in the same directory as the Python module. The 'wmfactory' (short for Woven Model Factory) methods return objects to be used as models; In this case, 'wmfactory_title' will return a string, the directory's name, and 'wmfactory_directory' will return a list of strings, the directory's content.

Upon rendering, Woven will scan the template's DOM tree for nodes to fill; when it encounters one, it gets the model (in this case by calling methods on the Page prefixed with 'wmfactory_'), then creates a view for that model; this page uses standard widgets for its models and so contains no custom view code. The view fills the DOM node with the appropriate data. Here, the view for 'title' is `Text`, and so will merely insert the string. The view for 'directory' is `List`, and so each element of the list will be formatted within the '<ul>'. Since the view for list items is Anchor, each item in the list will be formatted as an '<a>' tag.

So, for a directory "Images" containing "foo.jpeg", "baz.png", and a directory "MoreImages", the rendered page will look like this:

```
<html>
  <head>
    <title>/Users/ashort/Pictures</title>
  </head>
  <body>
```

```
    <h1>/Users/ashort/Pictures</h1>
    <ul>
      <li>
        <a href="foo.jpeg">foo.jpeg</a>
      </li>
      <li>
        <a href="baz.png">baz.png</a>
      </li>
      <li>
        <a href="MoreImages/">MoreImages/</a>
      </li>
    </ul>
  </body>
</html>
```

As you can see, the nodes marked with 'model' and 'view' are replaced with the data from their models, as formatted by their views. In particular, the List view repeated the node marked with the 'listItem' pattern for each item in the list.

For displaying the actual images, we use this template:

```
<html>
  <head>
    <title model="image" view="Text">Filename</title>
  </head>
  <body>
    <img src="preview" />
  </body>
</html>
```

And here is the definition of 'ImageDisplay':

```
class ImageDisplay(page.Page):

    templateFile="image-display.xhtml"

    def initialize(self, *args, **kwargs):
        self.image = kwargs['image']

    def wmfactory_image(self, request):
        return self.image

    def wchild_preview(self, request):
        return static.File(self.image)
```

Instead of using 'getDynamicChild', this class uses a 'wchild_' method to return the image data when the 'preview' child is requested. 'getDynamicChild' is only called if there are no 'wchild_' methods available to handle the requested URL.

Finally, we create a webserver set to start with a directory listing, and connect it to a port:

```
rootDirectory = os.path.expanduser("~/Pictures")
site = server.Site(DirectoryListing(directory=rootDirectory))
application = app.Application("PicturePile")
application.listenTCP(8088, site)
```

And then start the server:

```
if __name__ == '__main__':
    import sys
    from twisted.python import log
    log.startLogging(sys.stdout, 0)
    application.run()
```

7.2.1 Custom Views

Now, let's add thumbnails to our directory listing. We begin by changing the view for the links to "thumbnail":

```
<html>
  <head>
    <title model="title" view="Text">Directory listing</title>
  </head>
  <body>
    <h1 model="title" view="Text"></h1>
    <ul model="directory" view="List">
      <li pattern="listItem"><a view="thumbnail" /></li>
      <li pattern="emptyList">This directory is empty.</li>
    </ul>
  </body>
</html>
```

Woven doesn't include a standard "thumbnail" widget, so we'll have to write the code for this view ourselves. (Standard widgets are named with initial capital letters; by convention, custom views are named like methods, with initial lowercase letters.)

The simplest way to do it is with a 'wvupdate_' (short for Woven View Update) method on our DirectoryListing class:

```
    def wvupdate_thumbnail(self, request, node, data):
        a = microdom.lmx(node)
        a['href'] = data
        if os.path.isdir(os.path.join(self.directory,data)):
            a.text(data)
        else:
            a.add('img', src=(data+'/preview'),width='200',height='200')
```

When the 'thumbnail' view is requested, this method is called with the HTTP request, the DOM node marked with this view, and the data from the associated model (in this case, the name of the image or directory). With this approach, we can now modify the DOM as necessary. First, we wrap the node in `lmx`, a class provided by Twisted's DOM implementation that provides convenient syntax for modifying DOM nodes; attributes can be treated as dictionary keys, and the 'text' and 'add' methods provide for adding text to the node and adding children, respectively. If this item is a directory, a textual link is displayed; else, it produces an 'IMG' tag of fixed size.

7.2.2 Simple Input Handling

Limiting thumbnails to a single size is rather inflexible; our app would be nicer if one could adjust it. Let's add a list of thumbnail sizes to the directory listing. Again, we start with the template:

```
<html>
<head>
  <title model="title" view="Text">Directory listing</title>
</head>
<body>
  <h1 model="title" view="Text"></h1>
  <form action="">
    Thumbnail size:
    <select name="thumbnailSize" onChange="submit()" view="adjuster">
      <option value="400">400x400</option>
      <option value="200">200x200</option>
      <option value="100">100x100</option>
      <option value="50">50x50</option>
    </select>
  </form>
  <ul model="directory" view="List">
    <li pattern="listItem"><a view="thumbnail" /></li>
    <li pattern="emptyList">This directory is empty.</li>
  </ul>
</body>
</html>
```

Source listing — *directory-listing3.html*

This time, we add a form with a list of thumbnail sizes named 'thumbnailSize': we want the form to reflect the selected option, so we place an 'adjuster' view on the 'select' tag that looks for the right 'option' tag and puts 'selected=1' on it (the default size being 200):

```
def wvupdate_adjuster(self, request, widget, data):
    size = request.args.get('thumbnailSize',('200',))[0]
    domhelpers.locateNodes(widget.node.childNodes,
                           'value', size)[0].setAttribute('selected', '1')
```

'request.args' is a dictionary, mapping argument names to lists of values (since multiple HTTP arguments are possible). In this case, we only care about the first argument named 'thumbnailSize'. 'domhelpers.locateNodes' is a helper function which, given a list of DOM nodes, a key, and a value, will search each tree and return all nodes that have the requested key-value pair.

Next, we modify the 'thumbnail' view to look at the arguments from the HTTP request and use that as the size for the images:

```
def wvupdate_thumbnail(self, request, node, data):
    size = request.args.get('thumbnailSize',('200',))[0]
    a = microdom.lmx(node)
```

```
        a['href'] = data
        if os.path.isdir(os.path.join(self.directory,data)):
            a.text(data)
        else:
            a.add('img', src=(data+'/preview'),width=size,height=size)
```

7.2.3 Sessions

A disadvantage to the approach taken in the previous section is that subdirectories do receive the same thumbnail sizing as their parents; also, reloading the page sets it back to the default size of 200x200. To remedy this, we need a way to store data that lasts longer than a single page render. Fortunately, twisted.web provides this in the form of a Session object. Since only one Session exists per user for all applications on the server, the Session object is Componentized, and each application adds adapters to contain their own state and behaviour, as explained in the *Components* (page 61) documentation. So, we start with an interface, and a class that implements it, and registration of our class upon Session:

```
class IPreferences(components.Interface):
    pass

class Preferences(components.Adapter):
    __implements__ = IPreferences

components.registerAdapter(Preferences, server.Session, IPreferences)
```

We're just going to store data on this class, so no methods are defined.

Next, we change our view methods, 'wvupdate_thumbnail' and 'wvupdate_adjuster', to retrieve their size data from the Preferences object stored on the Session, instead of the HTTP request:

```
    def wvupdate_thumbnail(self, request, node, data):
        prefs = request.getSession(IPreferences)
        size = getattr(prefs, 'size','200')
        a = microdom.lmx(node)
        a['href'] = data
        if os.path.isdir(os.path.join(self.directory,data)):
            a.text(data)
        else:
            a.add('img', src=(data+'/preview'),width=size,height=size)

    def wvupdate_adjuster(self, request, widget, data):
        prefs = request.getSession(IPreferences)
        size = getattr(prefs, 'size','200')
        domhelpers.locateNodes(widget.node.childNodes,
                               'value', size)[0].setAttribute('selected', '1')
```

Controllers

Now we turn to the question of how the data gets into the session in the first place. While it is possible to to place it there from within the 'wvupdate_' methods, since they both have access to the HTTP request, it is desirable at times to

separate out input handling, which is what controllers are for. So, we add a 'wcfactory_' (short for Woven Controller Factory) method to DirectoryListing:

```
    def wcfactory_adjuster(self, request, node, model):
        return ImageSizer(model, name='thumbnailSize')
```

ImageSizer is a controller. It checks the input for validity (in this case, since it subclasses Anything, it merely ensures the input is non-empty) and calls 'handleValid' if the check succeeds; in this case, we retrieve the Preferences component from the session, and store the size received from the form upon it:

```
class ImageSizer(input.Anything):
    def handleValid(self, request, data):
        prefs = request.getSession(IPreferences)
        prefs.size = data
```

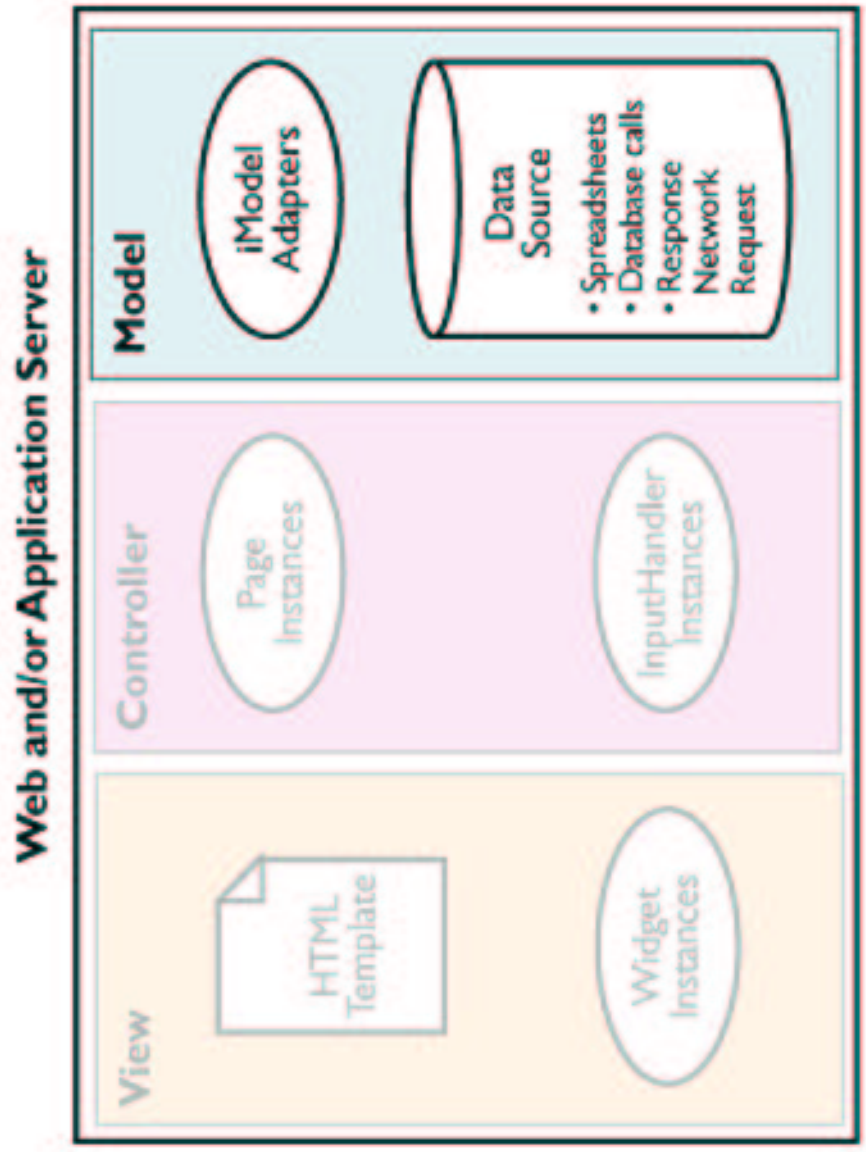
Finally, we must modify the template to use our new controller. Since we are concerned with the input from the '<select>' element of the form, we place the controller upon it:

```
    <html>
    <head>
      <title model="title" view="Text">Directory listing</title>
    </head>
    <body>
      <h1 model="title" view="Text"></h1>
      <form action="">
        Thumbnail size:
        <select name="thumbnailSize" onChange="submit()" view="adjuster"
          controller="adjuster">
          <option value="400">400x400</option>
          <option value="200">200x200</option>
          <option value="100">100x100</option>
          <option value="50">50x50</option>
        </select>
      </form>
      <ul model="directory" view="List">
        <li pattern="listItem"><a view="thumbnail" /></li>
        <li pattern="emptyList">This directory is empty.</li>
      </ul>
    </body>
  </html>
```

Source listing — *directory-listing4.html*

Now, the selected size will be remembered across subdirectories and page reloads.

7.3 Model In Depth



Model objects provide data to View objects as a Page is being rendered.

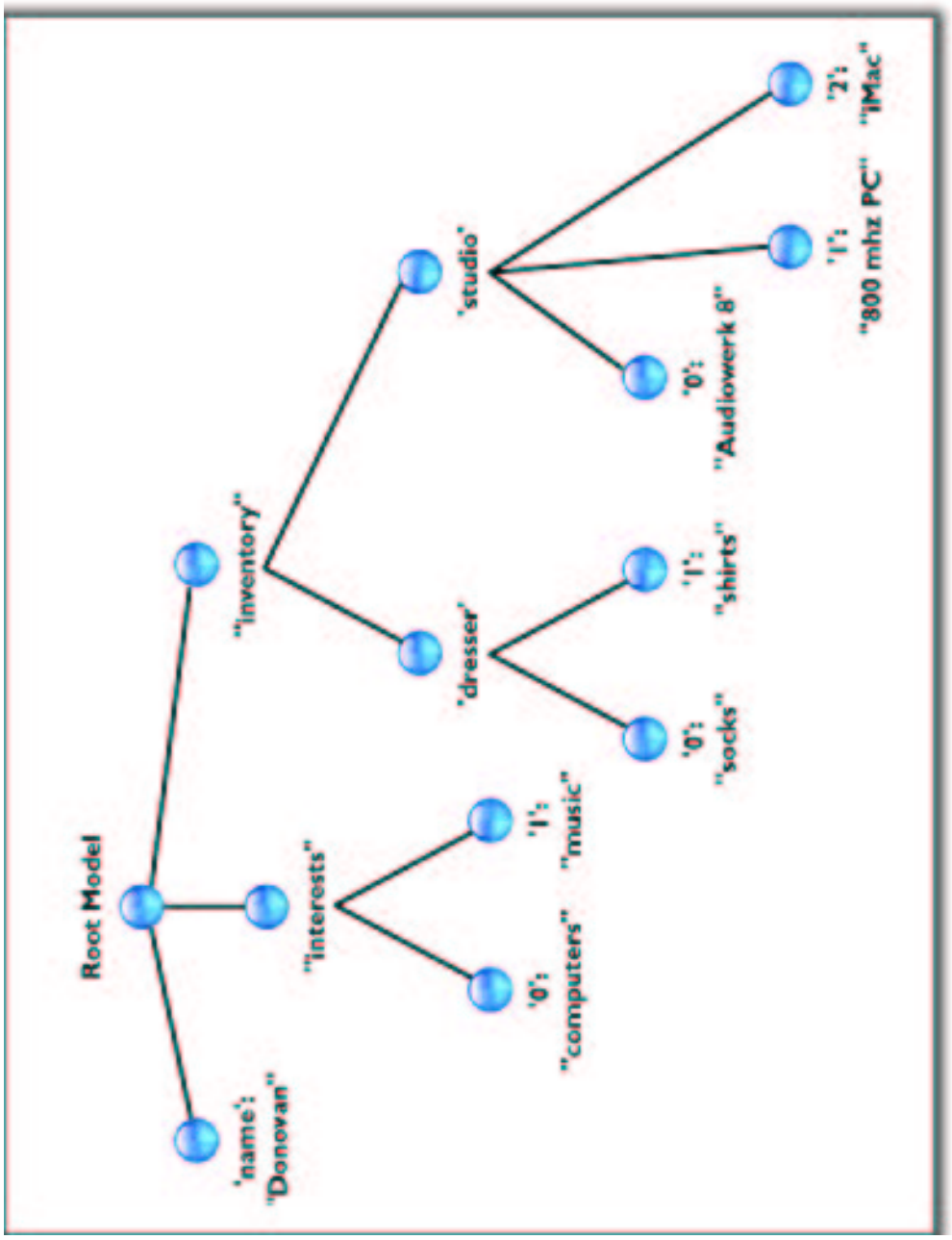
7.3.1 Main Concepts

- Root Models are the data entry point for every woven Page. All Model data for display on a Page should be made available through this Root Model. Described further in the *Page section* (page 196).
- *Submodel Paths* (this page) allow Woven to locate the correct Model data for a node.
- *The Model Stack* (page 179) is how Woven keeps track of which Model object is currently "in scope". Instead of specifying `model=` attributes in the Template with "absolute submodel paths", you can specify a model relative to the top of the "Model stack" with a "relative submodel path".
- *IModel Adapters* (page 180) allow you to write wrappers for existing objects. Subclassing a base Model in the `models` module will make writing an IModel Adapter easier.
- *Model Factories* (page 181) allow you to produce Model objects on demand with a Python method.

7.3.2 Submodel Paths

Each Model Woven has access to in the tree has a "submodel path". Submodel paths start at the Root Model and specify each segment Woven must follow to locate the Model. Submodel paths are slash-separated strings similar to filesystem paths. For the basic Python container types, Dictionaries and Lists, a submodel path segment is simply the key into the container. Given the model:

```
model = {'name': "Donovan",
         'interests': ["Computers", "Music"],
         'inventory': {'dresser': ['socks','shirts'],
                       'studio': ['Audiowerk8', '800mhz PC', 'iMac'],
                      }
         }
```



The following submodel paths are valid:

- `/` specifies the Root Model, a Dictionary
- `/name` specifies the `name` entry in the Dictionary, a String

- `/interests` specifies the `interests` entry in the Dictionary, a List
- `/interests/0` specifies the first element of the `interests` list, a String
- `/interests/1` specifies the second element of the `interests` list, a String
- `/inventory/dresser/0` specifies the first element of the `dresser` list in the `inventory` dictionary, a String

etc...

When woven encouters a `model=` directive on a node, it will look up the model and pass it to the View object that will render the node:

```
<html>
    <body>
        <h3 model="/interests/3" view="Text" />
    </body>
</html>
```

7.3.3 The Model Stack and Relative Submodel Paths

While "absolute model paths" are useful for specifying exactly which Model data you want associated with a node, the more frequent use case is to specify a "relative model path" which is a path relative to the Model currently on top of the "Model stack". Relative model paths are easy to distinguish because they do not begin with a slash.

When Woven encounters a node with a `model=` attribute, it looks up the Model object and places it on top of the "Model stack". During the processing of this node and all of the node's child nodes, this Model object remains on the top of the stack. Once all child nodes have completed processing, it is popped off of the Model stack.

This means that child nodes can refer to elements of the Model on top of the Model stack with relative submodel paths. For example, we may wish to render the "interests" list from the above example as two separate HTML elements. To do so, we first place the "interests" list on top of the Model stack, and then refer to elements of this list:

```
<html>
  I am interested in:
  <div model="interests" view="None">
    <p>First thing: <span model="0" view="Text" /></p>
    <p>Second thing: <span model="1" view="Text" /></p>
  </div>
</html>
```

In this case, the "interests" list was in scope for the duration of the tag, and the individual interest strings were in scope for the duration of the individual tags.

The List widget uses this Stack concept to operate on DOM nodes abstractly, without knowing or caring what directives will occur when the child nodes it returns are handled. We can also use the familiar `.` and `..` concepts from unix shell syntax to refer to Models:

```
<html>
  <div model="interests" view="List">
    <h3 pattern="listHeader" model="../name" view="Text" />>
    <p pattern="listItem" view="Text" />
```

```
    <h6 pattern="listFooter" model="." view="Text" />
  </div>
<html>
```

The List widget makes copies of the `pattern` nodes without knowing or caring which directives have been placed on them, or how many children are contained within the node. It then simply sets the `model=` attribute of each of the nodes to the correct index into the list. More about pattern directives is available in the *Views* (page 183) section.

In the above example, even though the `interests` list had been placed on the Model stack, we were able to access the `name` string without knowing its absolute path by using the relative path `../name`, and we were able to render the `interests` list with a different View Widget using the relative path `..`

The output from generating the above HTML will look like this:

```
<html>
  <div>
    <h3>Donovan</h3>
    <p>Computers</p>
    <p>Music</p>
    <h6>['Computers', 'Music']</h6>
    </div>
</html>
```

7.3.4 IModel Adapters

The IModel interface is documented in `twisted.web.woven.interfaces.IModel`. It describes the interfaces Models must implement in order to participate in the Woven Model stack. If you are inheriting from `twisted.web.woven.model.Model`, most of these interfaces will be implemented for you.

The interfaces that we will be most interested in implementing are those that are designed to be overridden for customization, getData and setData.

For example, we may wish to create a wrapper for some data which we will retrieve out of a SQL database. To do so, we create a subclass of Model:

```
class DatabaseJunk(model.Model):
    def getData(self, request):
        someCursor.execute("select * from foo")
        return someCursor.fetchall()

    def getSubmodel(self, request, name):
        row = self.getData(request)[int(name)]
        return RowUpdater(row)

class RowUpdater(model.Model):
    def __init__(self, id):
        self.row = row

    def getData(self, request):
        return self.row
```

```
    def setData(self, request, data):
        someCursor.execute(
        "update foo set bar=%s, baz=%s where id = %s",
        (data[0], data[1], self.row[0]))
```

The result of getData must be an IModel implementor, or may be a Deferred. Thus you may use the IModel interface to produce data from an adbapi call, a pb call, etc. When the data returned is a Deferred, Woven will pause rendering of the current node until the data is available.

7.3.5 Registering an IModel adapter for a class

Woven makes use of the twisted component system. Components, which are discussed in the *Components* (page 61) section, allow classes to declare that they implement a specific Interface for another class. This is useful if you already have classes in which you store data, and wish to create thin IModel adapter wrappers around them:

```
class MyData:
    def __init__(self, something=""):
        self.something = something

class MyDataModel(models.MethodModel):
    ## When the MyDataModel adapter is wrapped around an instance
    ## of MyData, the original MyData instance will be stored in 'orig'
    def wmfactory_something(self, request):
        return self.orig.something

from twisted.python import components
from twisted.web.woven import interfaces

components.registerAdapter(MyDataModel, MyData, interfaces.IModel)
```

7.3.6 Model Factories

Using a separate Model class for each individual piece of data in the system makes sense when you are able to generalize your Model classes enough so they are reusable. However, it is often easier, especially if you need to perform highly varied SQL calls to produce your data, to use a Model which supports Model factories.

There are two ways to use Model factories. The first is to have a separate Model class which subclasses `model.MethodModel`. The second is to simply not pass any Model at all to the Page instance, in which case the Page itself will act as a MethodModel.

MethodModel classes should provide methods prefixed with `wmfactory_`, which will be called when the directive `model=` is present in a template. For example, given the node `<div model="foo" />`, a method named `wmfactory_foo` will be called:

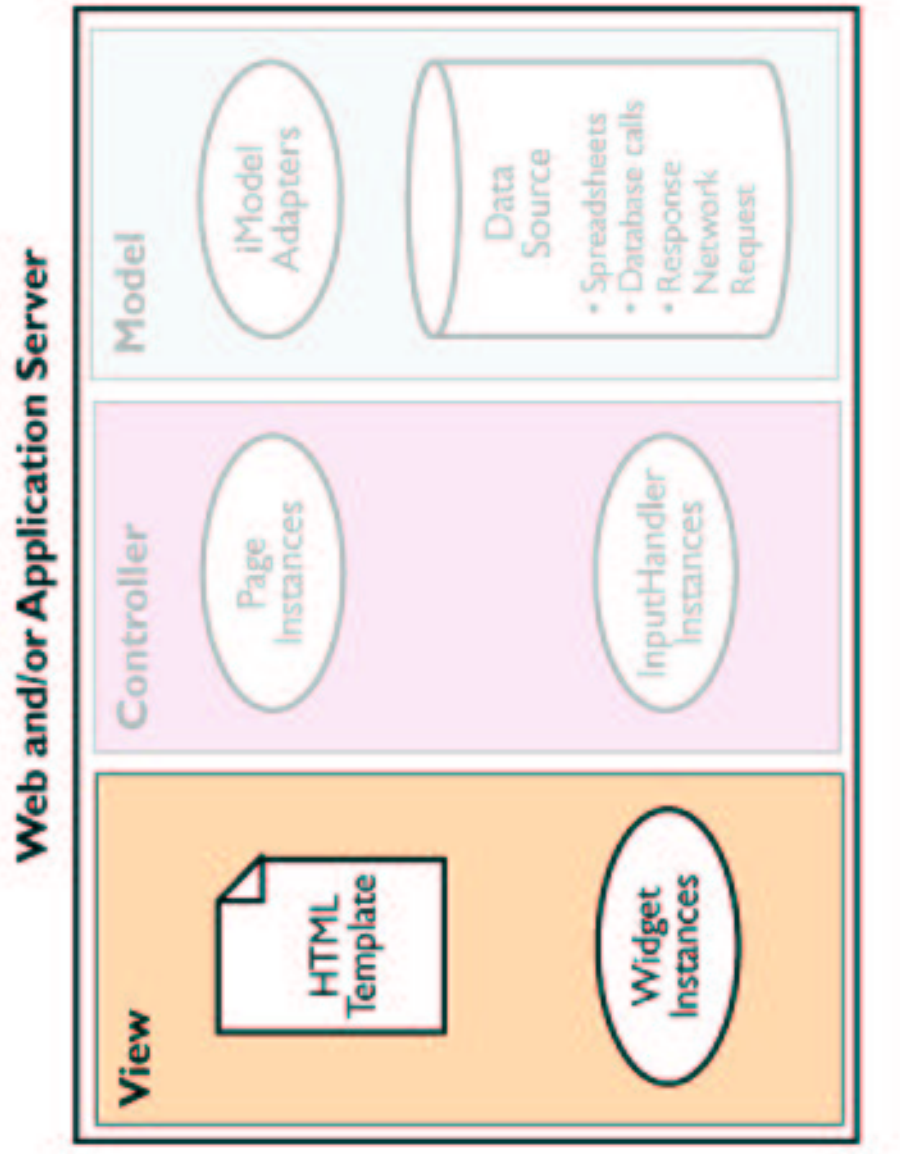
```
class MyModel(model.MethodModel):
    def wmfactory_foo(self, request):
        return ['foo', 'bar', 'baz']
```

If you did not pass any Model object when you created your Page instance, the Page class will act as a MethodModel. Thus, you can place your `wmfactory_` methods directly on your Page subclass:

```
class MyPage(page.Page):
    def wmfactory_foo(self, request):
        return ['foo', 'bar', 'baz']
```

Model factories are a useful way to write some Python code which generates your page model data, for pages which need to look up or calculate data in some way.

7.4 View In Depth



View objects are given a Model and a template DOM node, and use the DOM api to insert the given Model data into the DOM. Views are where you manipulate the HTML, in the form of DOM, which will be sent to the web

browser.

7.4.1 Main Concepts

- *View factories* (this page) provide the glue from a DOM node with a `'view='` directive to an instance of a View class.
- *generate* (page 185) is the method which is called on the View instance to render a node.
- *Widgets* (page 185) are views that have convenient syntax for rendering a View.
- *lmx* (page 186) is a much more convenient API for constructing DOM nodes programatically than the actual DOM API.
- *wvupdate_* (page 188) methods provide a convenient way to customize a generic Widget's rendering process without writing an inconvenient amount of boilerplate.
- *The View stack* (page 188) allows your View classes to expose private subviews which are only visible while your View is in scope on the stack.

7.4.2 View factories

View factories provide the glue between a `view=` directive on a DOM node and a View instance. When a DOM node with a `view=` directive is encountered, Woven looks for a corresponding `wvfactory_` method on your Page instance. A View factory is required to return an object which implements the interface `IView`:

```
class MyView(view.View):
  def generate(self, request, node, model):
      return request.d.createTextNode("Hello, world!")

class MyPage(page.Page):
    def wvfactory_foo(self, request, node, model):
        return MyView(model)
```

A View factory should almost always construct the View with the Model object it is passed. The exception to this rule is when the View is designed to render data which is not available in the Model tree, such as data which is obtained from the request or from a session object:

```
class MyPage(page.Page):
    def wvfactory_currentPageName(self, request, node, model):
        return widgets.Text(request.prepath[-1])
```

Note that if the Model the View is constructed with is not the Model which was passed in to the factory, Woven will notice this and place the new Model data on the Model stack.

You may set View factories programatically on a generic Page instance after it has been constructed. The first View factory example could be written:

```
class MyView(view.View):
    def generate(self, request, node, model):
        return request.d.createTextNode("Hello, world!")

resource = page.Page()
resource.setSubviewFactory("foo", MyView)
```

7.4.3 generate

The generate method is the most important method in the IView interface. It is the entry point from the Woven framework into your custom Python View code. When your View instance was constructed, it was passed a Model as the first argument. This is the Model data which generate should insert into the DOM. generate is passed the request and a template DOM node, and must return a DOM node, which will replace the template in the DOM tree:

```
class MyView(view.View):
    def generate(self, request, node):
        return request.d.createTextNode("Hello, world!")
```

Note that the current DOM Document object is available as `request.d`. You should use this document object as a text node and element factory, so the details about the underlying DOM implementation remain hidden.

Often, it is incredibly useful to use the incoming template node as a "skin" for your Views. In the simplest form, this involves simply adding nodes to the incoming template node and returning it from generate:

```
class MySkinnedView(view.View):
      def generate(self, request, node):
          modelData = self.getData()
          newNode = request.d.createTextNode(str(modelData))
          node.appendChild(newNode)
          return node
```

However, Woven also supports the concept of "pattern=" nodes, nodes which are marked in the template with a given "pattern=" directive so they may be located by the View abstractly. To support this, Woven contains a View subclass called Widget, which provides a far more convenient API for rendering your Views.

7.4.4 Widgets

Rendering Views is such an important part of developing a Woven application that it needs to be as convenient as possible. To support reducing the amount of boilerplate required to write a new View, the View subclass Widget was created. When subclassing Widget, simply override setUp instead of generate. setUp differs from generate in that it is passed a reference to the Model data, not the Model wrapper, and may simply mutate the template DOM node in place without having to worry about returning anything:

```
class MyWidget(widgets.Widget):
    def setUp(self, request, node, data):
        newNode = request.d.createTextNode(str(data))
        node.appendChild(newNode)
```

Widget also supports a very useful and convenient method called getPattern which allows you to locate nodes in the template node which have a `pattern=` attribute on them, regardless of where they are in the template, what style the node is, or how many children the node has:

```
class MyPatternWidget(widgets.Widget):
    def setUp(self, request, node, data):
        if data > 10:
            newNode = self.getPattern("large")
        else:
            newNode = self.getPattern("small")
        node.appendChild(newNode)
```

This widget could be used with the following template to abstractly allow the designer to style elements which are larger than 10:

```
<div model="listOfIntegers" view="List">
  <div pattern="listItem" view="MyPatternWidget">
      <span pattern="large" style="background-color: red" view="Text" />
      <span pattern="small" style="background-color: blue" view="Text" />
  </div>
</div>
```

Notice how the Widgets chain themselves to create the final page; the List widget makes copies of the pattern node which have `view="MyPatternWidget"` on them; the `MyPatternWidget` widget makes copies of the `pattern="large"` or `pattern="small"` nodes which have `view="Text"` directives on them; and the Text widget inserts the actual model data from the list into the innermost `<span>` element.

Widgets, along with the DOM api and the getPattern helper method, provide a powerful way for you to write view logic in Python without knowing or caring what type of HTML nodes are in your Template.

7.4.5 lmx

Generating View structure using the DOM is very useful for separating the Template from the actual logic which structures the View. However, if you need to do a large amount of HTML generation in Python, it becomes very cumbersome quickly. lmx is a lightweight wrapper around DOM nodes that allows you to quickly and easily build large HTML structures from Python:

```
from twisted.web.microdom import lmx

class LMXWidget(widgets.Widget):
    def setUp(self, request, node, data):
        l = lmx(node)
        for color in data:
            l.div(style=
                "width: 2in; height: 1in; background-color: %s" % color)
```

When an lmx instance is wrapped around a DOM node, calling a method on the lmx instance creates a new DOM node inside a new lmx instance. The new DOM node will have the same tag name as the name of the method that was

called, and an attribute for each keyword argument that was passed to the method. The returned value is the new DOM node wrapped in a new lmx instance. Text nodes can be added to an lmx instance by calling the special method `text`.

lmx can enable you to quickly generate a large amount of HTML programatically. For example, to build a calendar for the current month, create a Widget which uses lmx to add DOM nodes to the incoming template node. Here is a complete example which when placed in an rpy and visited through the web will render the current month's calendar:

```
import time
import calendar
calendar.setfirstweekday(calendar.SUNDAY)

from twisted.web.microdom import lmx
from twisted.web.woven import widgets

class Calendar(widgets.Widget):
    def setUp(self, request, node, data):
        node.tagName = "table"
        curTime = time.localtime()
        curMonth = calendar.monthcalendar(curTime[0], curTime[1])
        today = curTime[2]
        month = lmx(node)
        headers = month.tr()
        for dayName in ["Su", "M", "T", "W", "Th", "F" , "S"]:
            headers.td(
                _class="dayName", align="middle"
            ).text(dayName)
        for curWeek in curMonth:
            week = month.tr(_class="week")
            for curDay in curWeek:
                if curDay == 0:
                    week.td(_class="blankDay")
                else:
                    if curDay == today:
                        className = "today"
                    else:
                        className = "day"
                    week.td(
                        _class=className, align="right"
                    ).text(str(curDay))


from twisted.web.woven import page


resource = page.Page(template="""<html>
    <head>
        <style type="text/css">
```

```
.week {  }
.day { border: 1px solid black; height: 2em; width: 2em; color: blue }
.today { border: 1px solid red; height: 2em; width: 2em; color: red }
.blankDay { height: 2em; width: 2em;}
        </style>
    </head>
    <body>
        <div view="calendar" />
    </body>
</html>""")

resource.setSubviewFactory("calendar", Calendar)
```

7.4.6 wvupdate_

Sometimes, you need to create some view-rendering code for a very specific purpose. Since this code will most likely not be reusable across pages, it is irritating to have to create a Widget just to house this code. Thus, Woven allows you to place specially named `wvupdate_` methods on your Page subclass. Think of a `wvupdate_` method as a setUp method that lives on the Page class. When Woven encounters a view= directive that matches with a `wvupdate_` method name, it will create a generic Widget instance and call the `wvupdate_` method instead of `setUp`.

Note that the generic Widget instance is passed in as the third argument to a `wvupdate_` method instead of a DOM node instance. Often this fact is not important, however, if you wish to access a Widget API such as getPattern, you must do so using the widget argument rather than self:

```
class MyPage(page.Page):
    def wvupdate_foo(self, request, widget, data):
        if data > 10:
            newNode = widget.getPattern("large")
        else:
            newNode = widget.getPattern("small")
        newNode.appendChild(request.d.createTextNode(str(data)))
        widget.appendChild(newNode)
```

It is often possible to use `wvupdate_` methods to quickly prototype some View code, and generalize this code later. By moving the `wvupdate_` code into a Widget subclass, you make this code available to many different Pages.

7.4.7 The View stack

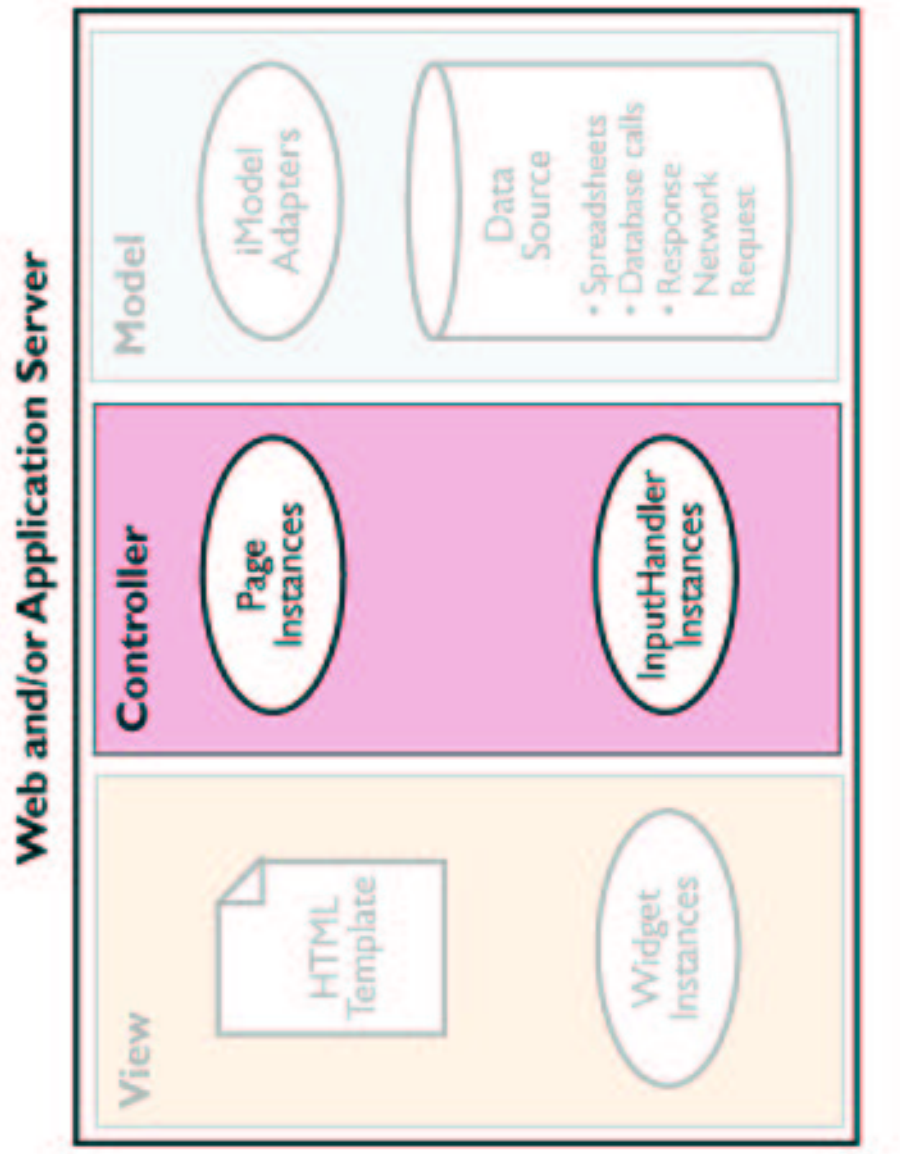
Woven uses a View stack to keep track of which View objects are currently in scope. You can use this fact to provide View objects which contain a lot of view-manipulation logic, but are still cleanly implemented. When Woven encounters a node with a `view=` directive, it locates the View (by looking for a `wvfactory_` method) and places it on the View stack.

While this node is being rendered, the new View is in scope, and is searched for `wvfactory_` methods before other Views and the Page object. Thus you can create a View which is made up of other smaller parts:

```
from twisted.web.woven import view, page
```

```
class ShowHide(view.View):
    template = """<span>
    <div view="hider">
        <div pattern="contents" view="contents">
            Here are the contents!
        </div>
    </div>
</span>"""

    def wvupdate_hider(self, request, widget, data):
        ## We want the widget to be cleared before rendering
        widget.clearNode = 1

        hidden = int(request.args.get("hide", [0])[0])

        if hidden:
            opener = request.d.createElement("a")
            opener.setAttribute("href", "?hide=0")
            opener.appendChild(request.d.createTextNode("Open"))
            widget.appendChild(opener)
        else:
            closer = request.d.createElement("a")
            closer.setAttribute("href", "?hide=1")
            closer.appendChild(request.d.createTextNode("Close"))
            widget.appendChild(closer)
            widget.appendChild(widget.getPattern("contents"))

    def wvupdate_contents(self, request, widget, data):
        widget.clearNode = 1
        widget.appendChild(request.d.createTextNode("Some contents here"))

resource = page.Page(template="""<html>
    <body>
        <span view="showHide" />
    </body>
</html>""")

resource.setSubviewFactory("showHide", ShowHide)
```

7.5 Controllers in Depth



Controller objects are a way to generalize and reuse input handling logic. In Twisted Web, form input is passed to a Resource instance in request.args. You can create controller classes to encapsulate generic request.args handling,

and perform validation and Model updating tasks.

7.5.1 Main Concepts

- *Controller factories* (this page) provide the glue from a DOM node with a 'controller=' directive to an instance of a Controller class.
- *handle* (this page) is the method which is called on the Controller instance to handle a node.
- *InputHandlers* (this page) are Controllers which have (somewhat) convenient syntax for handling a node.
- *Event handlers* (page 192), when used with *LivePage* (page 194), are a brain-exploding way of handling JavaScript events in your pages with server-side Python code.

7.5.2 Controller factories

Controller factories provide the glue between a `controller=` directive on a DOM node and a Controller instance. When a DOM node with a `controller=` directive is encountered, Woven looks for a corresponding `wcfactory_` method on your Page instance. A Controller factory is required to return an object which implements the interface `IController`.

```
class MyController(controller.Controller):
    pass

class MyPage(page.Page):
  def wcfactory_foo(self, request, node, model):
    return MyController(model)
```

7.5.3 Handle

Handle is the API your controller must implement to handle a node. It's return value may be a Deferred if you wish to pause the rendering of the View until some data is ready, or it may be None

```
class MyController(controller.Controller):
  def handle(self, request, node):
    name = request.args.get("name", [None])[0]
    print "HOORJ! YOUR NAME IS %s" % name
```

7.5.4 InputHandlers

InputHandlers are defined in `woven.input`. They were an early attempt to create a class which made it easy to create new input validators and input committers. It is usable in its current state, although the API is a bit baroque. Subclasses of `input.InputHandler` can override the following methods to decide what to do with data

`initialize()` initialize this Controller. This is most useful for registering event handlers on the View with *addEventHandler* (page 192), discussed below.

`getInput(self, request)` get input from the request and return it. Return None to indicate no data was available for this InputHandler to handle.

check(self, request, data) Check the input returned from getInput and return:

- None if no data was submitted (data was None), or
- True if the data that was submitted was valid, or
- False if the data that was submitted was not valid.

handleValid(self, request, data) handle the valid submission of some data. By default this calls `self.parent.aggregateValid`.

aggregateValid(self, request, inputhandler, data) Some input was validated by a child Controller. This is generally implemented on a controller which is placed on a `<form>` to gather input from controllers placed on `<input>` nodes.

handleInvalid(self, request, data) handle the invalid submission of some data. By default this calls `self.parent.aggregateInvalid`.

aggregateInvalid(self, request, inputhandler, data) Some input was declared invalid by a child Controller. This is generally implemented on a controller which is placed on a `<form>` to gather input from controllers placed on `<input>` nodes.

commit(self, request, node, data) Enough valid input was gathered to allow us to change the Model.

InputHandlers have been parameterized enough so you may simply use a generic InputHandler rather than subclassing and overriding:

```
class MyPage(page.Page):
  def checkName(self, request, name):
    if name is None: return None
    # No fred allowed
    if name == 'fred':
      return False
    return True

  def commitName(self, request, name=""):
    ctx = getContext()
    ctx.execute("insert into people (name) values %s", name)

  def wcfactory_addPerson(self, request, node, model):
      return input.InputHandler(
          model,
          name="name", # The name of the argument in the request to check
          check=self.checkName,
          commit=self.commitName)
```

7.5.5 Event handlers

Note:
In order for Event Handlers to work, you must be using *LivePage* (page 194), and include the webConduitGlue View in your HTML template.

Event handlers give you the powerful ability to respond to in-browser JavaScript event handlers with server-side Python code. Event handlers are registered on the View instance; in some cases, it may make most sense for your View instances to implement their own event handlers. However, in order to support good separation of concerns and code reuse, you may want to consider implementing your event handlers on a Controller instance.

The easiest way to achieve this is to subclass `input.Anything` (XXX: this should just be controller.Controller) and override `initialize` (XXX: this should be setUp):

```
class MyEventHandler(input.Anything):
  def initialize(self):
      self.view.addEventHandler("onclick", self.onClick)
      self.view.addEventHandler("onmouseover", self.onMouseOver, "'HELLO'")

  def onClick(self, request, widget):
      print self, "CLICKED!!!"

  def onMouseOver(self, request, widget, argument):
      print self, "MOUSE OVER!!!", argument
```

Note that the first argument to addEventHandler is the JavaScript event name, and the second argument is the python function or method which will handle this event. You may also pass any additional arguments you desire. These arguments must be valid JavaScript, and will be evaluated in the browser context. The results of these JavaScript expressions will be passed to your Python event handler.

Note that when we passed an extra argument when adding an `onmouseover` event handler, we passed a string enclosed in two sets of quotes. This is because the result of evaluating `"'HELLO'"` as JavaScript in the browser is the string `'HELLO'`, which is then passed to the Python event handler. If we had simply passed `"HELLO"` to addEventHandler, Woven would have evaluated `"HELLO"` in the browser context, resulting in an error because the variable `HELLO` is not defined.

Any normal client-side JavaScript object may be accessed, such as `document` and `window`. Also, the JavaScript variable `node` is defined as the DOM node on which the event handler is operating. This is useful for examining the current value of an `<input>` node.

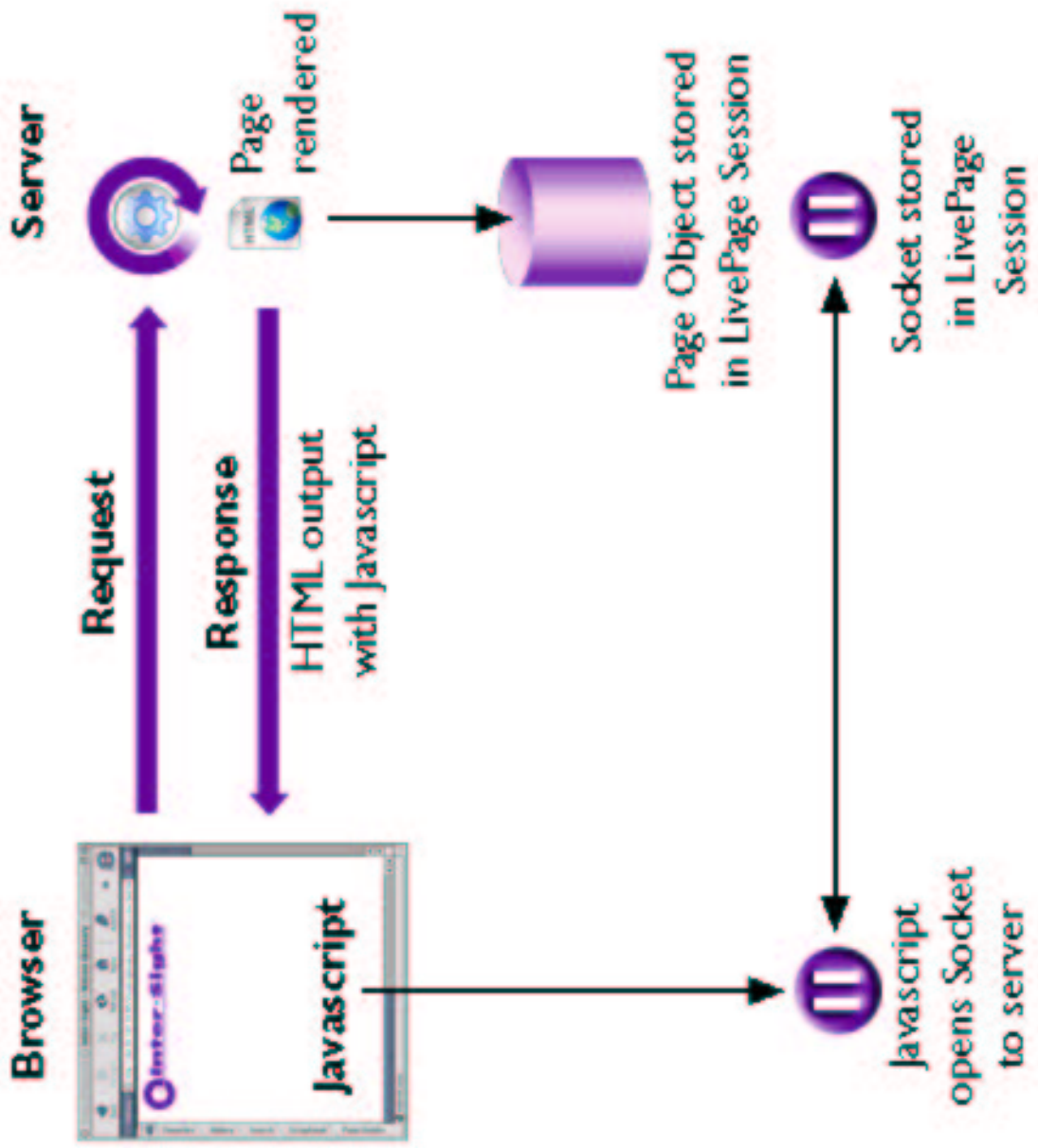
Here are some examples of useful Event handlers:

```
class Redirect(input.Anything):
  def initialize(self):
      self.view.addEventHandler(
          "onclick",
          self.onClick,
          "window.location = 'http://www.google.com'")

  def onClick(self, request, widget, arg):
      print "The window was redirected."

class OnChanger(input.Anything):
  def initialize(self):
      self.view.addEventHandler(
          "onchange",
          self.changed,
```

```
            "node.value")

    def changed(self, request, widget, newValue):
        print "The input box changed to", newValue
```

7.6 LivePage

Note:
This is just a quick bootstrap page for now.



To use LivePage, subclass or instantiate `LivePage` instead of `Page`. Then, in your HTML template, include the following HTML fragment somewhere towards the bottom of the page:

```
<span view="webConduitGlue" />
```

Then, *Event handlers* (page 192) can forward client-side JavaScript events to the Server, and you can send JavaScript to the browser after a page has already loaded. Example:

```
class Foo(page.LivePage):
    template = ('<html><body>'
                'Nothing here!<span view="webConduitGlue" />'
'</body></html>')
    def setUp(self, request):
        global currentPage

        # don't save this in a global but somewhere your code can get
        # to it later
        currentPage = request.getSession(interfaces.IWovenLivePage)

# then later, in response to some server-side event
def fooHappened():
    global currentPage

    currentPage.sendScript("alert('hello, world!')")
```

7.7 Page In Depth

Page objects are the glue between a web request, a Model object, and a Template.

7.7.1 Main Concepts

- *Root Models* (this page) are passed to Page objects when they are constructed. If no Model is passed, a Page will act as its own Root Model.
- *Templates* (page 197) for Page objects can be specified in various ways.
- *Child Pages* (page 198) for handling the next URL segment can be constructed using a convenient syntax supported by Page.
- *Factories* (page 199) for View and Controller objects are contained in the Page. The View factories and Controller factories will be matched up with `view=` and `controller=` directives located in the template during the rendering process.

7.7.2 Root Models

A Root Model is the base of a Woven Model tree. All Model data that the Page will use for rendering should be made available through this Model. Any Python object can be used as a Model within Woven, even Dictionaries, Lists, Strings, Integers, and Floats. This is accomplished through the use of IModel adapters, which normalize Model access methods.

A Root Model is passed to the Page constructor as the first argument:

```
model = {'name': 'Donovan',
               'interests': ['Computers', 'Music', 'Bling Bling']
               }
```

```
resource = page.Page(model)
```

If no Model object is passed as the first argument to the Page constructor, the Page object itself will be treated like a MethodModel. See *Models* (page 176) for more information about Model objects.

Using a Page object as a Model factory (by not passing a Root Model) is discussed below in *Factories* (page 199).

7.7.3 Templates

The Template a page will render can be specified in various ways.

- Passing `template="<html>Hello</html>"`
- Passing `templateFile="Template.html"`
- Passing both templateFile and `templateDirectory="/Users/dsp/Templates"`

Every Page object must be able to find a Template in order to render itself. There are three main ways a template can be specified. The first is simply by passing the template as a keyword argument to the Page constructor:

```
resource = page.Page(template="<html>Hello world!</html>")
```

However, it is desireable to store templates as separate HTML files on disk, where they can be edited easily by an external HTML editor. This can be accomplished by placing the template next to the .rpy script in the twisted.web directory and passing templateFile to the Page constructor:

```
resource = page.Page(templateFile="MyTemplate.html")
```

Finally, you may wish to place templates in a specific location, away from the python code entirely. To do so, pass both templateFile and templateDirectory to the Page constructor, indicating where you would like the template to be found:

```
resource = page.Page(
  templateFile="MyTemplate.html",
  templateDirectory="/Users/dsp/Templates")
```

If you are subclassing Page to provide child, model, view, or controller factories (discussed below), you may wish instead to specify a Page's template using a class attribute:

```
class MyPage(page.Page):
    templateFile = "MyTemplate.html"
```

A useful technique for storing your templates in a place where they are conveniently located next to your Python modules is to define templateDirectory as a class attribute, using Python's introspection abilities to discover where your Python module is located:

```
class MyPage(page.Page):
    templateFile = "MyTemplate.html"
    templateDirectory = os.path.join(os.path.split(__file__)[0], "templates")
```

How you manage your templates is up to you.

7.7.4 Child Pages

As discussed in the *Twisted Web* (page 23) section of the documentation, Resource objects provide access to their children by providing a getChild method which returns the next Resource object in the URL tree. Woven Page instances implement IResource and thus follow the same rules as any other Resource instance.

Woven Page instances can be built into Resource Trees in the same manner as regular Resources, using putChild. However, it is often convenient to construct a Page instance on the fly with a method.

Page instances with methods prefixed with `wchild_` will be invoked in getChild if there is a method matching the requested name. For example, if an instance of this class is used as the root Resource object, several URLs will be valid:

```
class MyPage(page.Page):
    template = """<html>
        Root Page
        <p><a href="fred">Fred</a></p>
        <p><a href="bob">Bob</a></p>
    </html>"""

    def wchild_fred(self, request):
        return page.Page(template="<html>Fred!</html>")

    def wchild_bob(self, request):
        return page.Page(template="<html>Bob!</html>")
```

The following URLs would then be valid:

- `http://example.com/`
- `http://example.com/fred`
- `http://example.com/bob`
- `http://example.com/fred/`
- `http://example.com/bob/`

There is one special wchild method for when the URL ends in a slash. When `twisted.web` calls `getChild` with an empty string (when the URL ends in a slash), the wchild method that is called is `wchild_index`.

By default, all Page instances will attempt to add a slash to the end of the URL if they are visited through the web. Thus, visiting `http://example.com/fred` in the above example will redirect your browser to `http://example.com/fred/`. This generally makes writing relative links to other pages easier.

If this is not the behavior you would like, define the class attribute `addSlash` to be false:

```
class MyPage(page.Page):
    addSlash = False
    template = "<html>No slash for you!</html>"
```

7.7.5 Factories

So far, we have observed the use of the special `model=`, `view=`, and `controller=` attributes ("directives") in Woven templates, but have not discussed how these attributes are translated to Python code.

There are three types of Woven factories:

1. *View factories* (this page)
2. *Controller factories* (page 200)
3. *Model factories* (page 200)

View factories

When a view directive is encountered in a Woven template, it is translated into a `wvfactory_` call. For example, the node `<div view="cool" />` will cause the method `wvfactory_cool` to be called on your Page instance. View factories are methods which have the following signature, and must return an IView implementor:

```
    def wvfactory_cool(self, request, node, model):
        return widgets.Text(model)
```

Widget subclasses are the most common return value from `wvfactory_` methods. Widgets are discussed in the *Views* (page 183) section. However, Page is also an implementor of IView, and you may take advantage of this to insert HTML fragments from other locations into a page which is being rendered:

```
class MyPage(page.Page):
    template = """<html>
    <body>
        Some stuff goes here.
        <div view="header" />
        Some more stuff goes here.
        <div view="body" />
        Even more stuff goes here.
    </body>
</html>"""

    def wvfactory_header(self, request, node, model):
        return page.Page(template="<div>This is the header.</div>")

    def wvfactory_body(self, request, node, model):
        return page.Page(template="<div>This is the body.</div>")
```

There is also a convenient special method, `wvupdate_`, which reduces the amount of boilerplate code required to quickly modify the template. `wvupdate_` methods have a slightly different signature; instead of being passed the DOM node which contained the `view=` directive, they are passed an instance of the generic Widget class, and they are passed the unwrapped Model data rather than the IModel wrapper:

```
    def wvupdate_red(self, request, widget, data):
        widget.setAttribute('style', 'color: red')
```

See the *Views* (page 183) section for more information on writing your application's View code.

Note that if an appropriately named View factory is not found on your page class, Woven will look for the name in the `widgets` module before giving up and raising an exception. This is why we have been able to create templates that have nodes like `<div view="Text" />` and `<div view="List" />` without getting exceptions.

Controller factories

When a controller directive is encountered in a Woven template, it is translated into a `wcfactory_` call. For example, the node `<input type="text" name="foo" controller="number" /<` will cause the method `wcfactory_number` to be called on your Page instance. Controller factories are methods which have the following signature, and must return an IController implementor:

```
def wcfactory_number(self, request, node, model):
    return input.Integer(model)
```

The IController implementation classes which validate input currently live in the `input` module. This will probably be changed in the future.

See the *Controllers* (page 190) section for more information on writing your application's Controller code.

Note that if an appropriately named Controller factory is not found on your page class, Woven will look for the name in the `input` module before giving up and raising an exception.

Model factories

If your Page instance is passed a Root Model composed of basic python types, Woven is able to use IModel adapters to allow your Template to access the entire Model tree automatically. However, often it can be useful to produce your model data in some sort of method call which retrieves the data.

If your Page instance was initialized without a Root Model object, Woven will use the Page instance itself as a MethodModel. When a model directive is encountered in a Woven template, it will be translated into a `wmfactory_` call on your Page instance. For example, the node `<div model="name" />` will cause the method `wmfactory_name` to be called. Model factories are methods which have the following signature, and may return any Python object:

```
def wmfactory_name(self, request):
    return "Fred Bob"
```

See the *Models* (page 176) section for more information on writing your application's `IModel` adapters.

7.8 Form In Depth

XXX: To be written

7.9 Guard In Depth

XXX: To be written

Chapter 8

Dot Products

8.1 Creating and working with a names (DNS) server

A Names server can be perform three basic operations:

- act as a recursive server, forwarding queries to other servers
- perform local caching of recursively discovered records
- act as the authoritative server for a domain

Creating a non-authoritative server

The first two of these are easy, and you can create a server that performs them with the command `mktap dns --recursive --cache`, or launch `tkmktap` and configure a dns server with it. The result should be a file named `dns.tap`. Now switch to a superuser account (if required by your platform to bind to port 53) and run `twistd -f dns.tap`. The Application will run and bind to port 53. Try performing a lookup with it, `dig twistedmatrix.com @127.0.0.1`.

Creating an authoritative server

To act as the authority for a domain, two things are necessary: the address of the machine on which the domain name server will run must be registered as a nameserver for the domain; and the domain name server must be configured to act as the authority. The first requirement is beyond the scope of this howto and will not be covered.

To configure Names to act as the authority for `example-domain.com`, we first create a zone file for this domain.

```
zone = [
    SOA(
        # For whom we are the authority
        'example-domain.com',

        # This nameserver's name
        mname = "ns1.example-domain.com",
```

```
        # Mailbox of individual who handles this
        rname = "root.example-domain.com",

        # Unique serial identifying this SOA data
        serial = 2003010601,

        # Time interval before zone should be refreshed
        refresh = "1H",

        # Interval before failed refresh should be retried
        retry = "1H",

        # Upper limit on time interval before expiry
        expire = "1H",

        # Minimum TTL
        minimum = "1H"
    ),

    A('example-domain.com', '127.0.0.1'),
    NS('ns1.example-domain.com', 'example-domain.com'),

    CNAME('www.example-domain.com', 'example-domain.com'),
    CNAME('ftp.example-domain.com', 'example-domain.com'),

    MX('example-domain.com', 0, 'mail.example-domain.com'),
    A('mail.example-domain.com', '123.0.16.43')
]
```

Zone file — *example-domain.com*

Next, run the command `mktap dns --pyzone example-domain.com`, and then (as above) `twistd -f dns.tap`. Now try querying the domain locally (again, with dig): `dig -t any example-domain.com @127.0.0.1`.

Names can also read a traditional, BIND-syntax zone file. Specify these with the `--bindzone` parameter. The $GENERATE and $INCLUDE directives are not yet supported.

8.2 Using the Lore Documentation System

8.2.1 Writing Lore Documents

Overview

Lore documents are a special subset of XHTML documents. They use specific subset of XHTML, together with custom classes, to allow a wide variety of document elements, including some Python-specific ones. Lore documents,

in particular, are well-formed XML documents. XML can be written using a wide variety of tools: from run of the mill editors such as vi, through editors with XML help like EMACS and ending with XML specific tools like (need name of XML editor here). Here, we will not cover the specifics of writing XML documents, except for a very broad overview.

XML documents contain elements, which are delimited by an opening tag which looks like `<tag-name attribute="value">` and ends with a closing tag, which looks like `</tag-name>`. If an elements happen to contain nothing, it can be shortened to `<tag-name />`. Elements can contain other elements, or text. Text can contain any characters except <, > and &. These characters are rendered by <, > and &, respectively.

A Lore document is a single `html` element. Inside this element, there are exactly two top-level elements: `head` and `body`. The `head` element must contain exactly one element: `title`, containing the title of the document. Most of the document will be contained in the `body` element. The `body` element must start with an `h1` (top-level header) element, which contains the exact same content as the `title` element.

Thus, a fairly minimal Lore document might look like:

```
<html>
<head><title>Title</title></head>
<body><h1>Title</h1></body>
</html>
```

Elements and Their Uses

`p`: The paragraph element. Most of the document should be inside paragraphs.

`span`: The span element is an element which has no meaning – unless it has a special `class` attributes. The following classes have the stated meanings:

`footnote` a small comment which should not be inside the main text-flow.

`manhole-output` This signifies, within a manhole transcript, that the enclosed text is the output and not something the user has to input.

`div`: The div element is equivalent to a span, except it always appears outside paragraphs. The following classes have the given meanings:

`note` A short note which is not necessary for the understanding of the text.

`doit` An indication that the discussed feature is not complete or implemented yet.

`boxed` An indication that the text should be clearly separated from its surroundings.

`a`: This element can have several meanings, depending on the attributes:

`name` attribute Add a label to the current position, which might be used in this document or other documents to refer to.

`href=URL` Refer to some WWW resource.

`href=relative-path`, `href=relative-path#label` or `href=#label` Refer to a position in a Lore resource. By default, relative links to `.html` files are changed to point to a `.xhtml` file. If you need a link to a local non-Lore .html file, use `class=absolute` to make Lore treat it as an absolute link.

`href=relative-path` with `class=py-listing` or `class=html-listing` Indicate the given resource is a part of the text flow, and should be inlined (and if possible, syntax highlighted).

`ol`, `ul`: A list. It can be enumerated or bulleted. Inside a list, the element `li` (for a list element) is valid.
`h2`, `h3`: Second- and third-level section headings.
`code`: a string which has meaning to the computer. There are many possible classes:

`API` A class, function or a module. It does not have to be a fully qualified name – but if it isn't, a `base` attribute is necessary. Example: `<code class="API" base="urllib">urlencode<code>`.

`shell` Shell (usually Bourne) code.

`python` Python code

`py-prototype` Function prototype

`py-filename` Python file

`py-src-string` Python string

`py-signature` Function signature

`py-src-parameter` Parameter

`py-src-identifier` Identifier

`py-src-keyword` Keyword

`pre`: Preformatted text, usually for file listings. It can be used with the `python` class to indicate Python syntax coloring. Other possible classes are `shell` (to indicate a shell-transcript) or `python-interpreter` (to indicate an interactive interpreter transcript).
`img`: Insert the image indicated by the `src` attribute.
`q`: The quote signs (`"`) are not recommended except in preformatted or code environment. Instead, quote by using the `q` element which allows nested quotes and properly distinguishes opening quote from closing quote.
`em`, `strong`: Emphasise (or strongly emphasise) text.
`table`: Tabular data. Inside a table, use the `tr` element for each rows, and inside it use either `td` for a regular table cell or `th` for a table header (column or row).
`blockquote`: A long quote which should be properly seperated from the main text.
`cite`: Cite a resource.
`sub`, `sup`: subscripts and superscripts.
`link`: currently, the only `link` elements supported are for for indicating authorship. `<link rel="author" href="author-address@examples.com" title="Author Name" />` should be used to indicate authorship. Multiple instances are allowed, and indicate shared authorship.

8.2.2 Writing Lore XHTML Templates

One of Lore's output formats is XHTML. Lore itself is very markup-light, but the output XHTML is much more markup intensive. Part of the auto-generated markup is directed by a special template.

The output of Lore is inserted into template in the following way:

- The title is appended into each element with class `title`.

- The body is inserted into the first element that has class `body`.
- The table of contents is inserted into the first element that has class `toc`.

In particular, most of the header is not tampered with – so it is easy to indicate a CSS stylesheet in the template.

8.2.3 Using Lore to Generate HTML

After having written a template, the easiest way to build HTML from the Lore document is by:

```
% lore --config template=myteplate.tpl mydocument.html
```

This will create a file called `mydocument.xhtml`.

8.2.4 Using Lore to Generate LaTex

Articles

```
% lore --output latex mydocument.html
```

Books

Have a Lore file for each section. Then, have a LaTeX file which inputs all the given LaTeX files. Generate all the LaTeX files by using

```
% lore --output latex --config section *.html
```

in the relevant directory.

8.2.5 Linting

```
% lore --output lint mydocument.html
```

This will generate compiler-style (file:line:column:message) warnings. It is possible to integrate these warnings into a smart editor such as EMACS, but it has not been done yet.

8.3 Extending the Lore Documentation System

8.3.1 Overview

The *Lore Documentation System* (page 202), out of the box, is specialized for documenting Twisted. Its markup includes CSS classes for Python, HTML, filenames, and other Twisted-focused categories. But don't think this means Lore can't be used for other documentation tasks! Lore is designed to allow extensions, giving any Python programmer the ability to customize Lore for documenting almost anything.

There are several reasons why you would want to extend Lore. You may want to attach file formats Lore does not understand to your documentation. You may want to create callouts that have special meanings to the reader, to give a memorable appearance to text such as, "WARNING: This software was written by a frothing madman!" You may want to create color-coding for a different programming language, or you may find that Lore does not provide you with enough structure to mark your document up completely. All of these situations can be solved by creating an extension.

8.3.2 Inputs and Outputs

Lore works by reading the HTML source of your document, and producing whatever output the user specifies on the command line. If the HTML document is well-formed XML that meets a certain minimum standard, Lore will be able to to produce some output. All Lore extensions will be written to redefine the *input*, and most will redefine the output in some way. The name of the default input is "lore". When you write your extension, you will come up with a new name for your input, telling Lore what rules to use to process the file.

Lore can produce XHTML, LaTeX, and DocBook document formats, which can be displayed directly if you have a user agent capable of viewing them, or processed into a third form such as PostScript or PDF. Another output is called "lint", after the static-checking utility for C, and is used for the same reason: to statically check input files for problems. The "lint" output is just a stream of error messages, not a formatted document, but is important because it gives users the ability to validate their input before trying to process it. For the first example, the only output we will be concerned with is LaTeX.

Creating New Inputs

Create a new input to tell Lore that your document is marked up differently from a vanilla Lore document. This gives you the power to define a new tag class, for example:

```
<p>The Frabjulon <span class="productname">Limpet 2000</span>
is the <span class="marketinglie">industry-leading</span> aquatic
mollusc counter, bar none.</p>
```

The above HTML is an instance of a new input to Lore, which we will call MyHTML, to differentiate it from the "lore" input. We want it to have the following markup:

- A `productname` class for the tag, which produces underlined text
- A `marketinglie` class for tag, which produces larger type, bold text

Note that I chose class names that are valid Python identifiers. You will see why shortly. To get these two effects in Lore's HTML output, all we have to do is create a cascading stylesheet (CSS), and use it in the Lore XHTML Template. However, we also want these effects to work in LaTeX, and we want the output of lint to produce no warnings when it sees lines with these 2 classes. To make LaTeX and lint work, we start by creating a plugin.

```
register('MyHTML', "myhtml.factory", description="My Lore Plugin",
         type="lore", tapname="myhtml")
```

Listing 1: The Plugin File — *plugins.tml*

Name this file `plugins.tml`, and put it in a new package directory named `myhtml`. Also create an `__init__.py` file in your new package. Note that *the __init__ file can contain nothing but a doc string, but it must exist.* If `__init__.py` is empty, you will have problems with certain unzip programs that don't extract empty files.

The combination of plugin file and __init__ file causes the new package to be treated like a Twisted plugin, one that Lore knows how to make use of. The first three arguments to `register()` are the human-readable name, module name, and description of your plugin. The `type` parameter makes this plugin visible to the Lore system (rather than some other part of Twisted). The `tapname` parameter is an arbitrary filename with no extension; by convention you should use the lowercase version of your first argument (the human-readable name). Users of your extension will pass

this argument to lore with the `--input` parameter on the command line. (For more details on plugins, read *Writing a New Plug-In for Twisted* (page 43).)

Let's look at that module name more closely: `myhtml.factory`. We will be creating this file next, in the package named `myhtml`. The purpose of the factory module is to tell Lore how to process your input.

```
from twisted.lore import default
import spitters

class MyProcessingFunctionFactory(default.ProcessingFunctionFactory):
    latexSpitters={None: spitters.MyLatexSpitter,
                   }

# initialize the global variable factory with an instance of your new factory
factory=MyProcessingFunctionFactory()
```

Listing 2: The Input Factory — *factory.py-1*

In Listing 2, we create a subclass of ProcessingFunctionFactory. This class provides a hook for you, a class variable named `latexSpitters`. This variable tells Lore what new class will be generating LaTeX from your input format. We redefine `latexSpitters` to `MyLatexSpitter` in the subclass because this class knows what to do with the new input we have already defined. Last, you must define the module-level variable `factory`. It should be an instance with the same interface as `ProcessingFunctionFactory` (e.g. an instance of a subclass, in this case, `MyProcessingFunctionFactory`).

Now let's actually write some code to generate the LaTeX. Doing this requires at least a familiarity with the LaTeX language. Search Google for "latex tutorial" and you will find any number of useful LaTeX resources.

```
from twisted.lore import latex
from twisted.lore.latex import processFile
import os.path

class MyLatexSpitter(latex.LatexSpitter):
    def visitNode_span_productname(self, node):
        # start an underline section in LaTeX
        self.writer('\\underline{')
        # process the node and its children
        self.visitNodeDefault(node)
        # end the underline block
        self.writer('}')

    def visitNode_span_marketinglie(self, node):
        # this example turns on more than one LaTeX effect at once
        self.writer('\\begin{bf}\\begin{Large}')
        self.visitNodeDefault(node)
        self.writer('\\end{Large}\\end{bf}')
```

Listing 3: spitters.py — *spitters.py-1*

The method `visitNode_span_productname` is our handler for tags with the `class="productname"` identifier. Lore knows to try methods `visitNode_span_*` and `visitNode_div_*` whenever it encounters a new class in one of these tags. This is why the class names have to be valid Python identifiers.

Now let's see what Lore does with these new classes with the following input file:

```
<html>
  <head>
    <title>My First Example</title>
  </head>
  <body>
    <h1>My First Example</h1>
    <p>The Frabjulon <span class="productname">Limpet 2000</span>
    is the <span class="marketinglie">industry-leading</span> aquatic
    mollusc counter, bar none.</p>
  </body>
</html>
```

Listing 4: 1st_example.html — *1st_example.html*

First, verify that your package is laid out correctly. Your directory structure should look like this:

```
1st_example.html
myhtml/
       __init__.py
       factory.py
       plugins.tml
       spitters.py
```

In the parent directory of myhtml (that is, `myhtml/..`), run lore and pdflatex on the input:

```
$ lore --input myhtml --output latex 1st_example.html
[########################################] (*Done*)

$ pdflatex 1st_example.tex
[ . . . latex output omitted for brevity . . . ]
Output written on 1st_example.pdf (1 page, 22260 bytes).
Transcript written on 1st_example.log.
```

And here's what the rendered PDF looks like:

What happens when we run lore on this file using the lint output?

```
$ lore --input myhtml --output lint 1st_example.html
1st_example.html:7:47: unknown class productname
1st_example.html:8:38: unknown class marketinglie
[########################################] (*Done*)
```

Lint reports these classes as errors, even though our spitter knows how to process them. To fix this problem, we must add to `factory.py`.

```
from twisted.lore import default
import spitters

class MyProcessingFunctionFactory(default.ProcessingFunctionFactory):
    latexSpitters={None: spitters.MyLatexSpitter,
                   }

    # redefine getLintChecker to validate our classes
    def getLintChecker(self):
        # use the default checker from parent
        checker = lint.getDefaultChecker()
        checker.allowedClasses = checker.allowedClasses.copy()
        oldSpan = checker.allowedClasses['span']
        checkfunc=lambda cl: oldSpan(cl) or cl in ['marketinglie',
                                                   'productname']
        checker.allowedClasses['span'] = checkfunc
        return checker

# initialize the global variable factory with an instance of your new factory
factory=MyProcessingFunctionFactory()
```

Listing 5: Input Factory with Lint Support — *factory.py-2*

The method `getLintChecker` is called by Lore to produce the lint output. This modification adds our classes to the list of classes lint ignores:

```
$ lore --input myhtml --output lint 1st_example.html
[########################################] (*Done*)
$ # Hooray!
```

Finally, there are two other sub-outputs of LaTeX, for a total of three different ways that Lore can produce LaTeX: the default way, which produces as output an entire, self-contained LaTeX document; with `--config section` on the command line, which produces a LaTeX \section; and with `--config chapter`, which produces a LaTeX \chapter. To support these options as well, the solution is to make the new spitter class a mixin, and use it with the `SectionLatexSpitter` and `ChapterLatexSpitter`, respectively. Comments in the following listings tell you everything you need to know about making these simple changes:

- ```
  from twisted.lore import default
  import spitters

  class MyProcessingFunctionFactory(default.ProcessingFunctionFactory):
      # 1. add the keys "chapter" and "section" to latexSpitters to handle the
      # --config chapter and --config section options
      latexSpitters={None: spitters.MyLatexSpitter,
  ```
  ```

```
                    "section": spitters.MySectionLatexSpitter,
                    "chapter": spitters.MyChapterLatexSpitter,
                    }

    def getLintChecker(self):
        checker = lint.getDefaultChecker()
        checker.allowedClasses = checker.allowedClasses.copy()
        oldSpan = checker.allowedClasses['span']
        checkfunc=lambda cl: oldSpan(cl) or cl in ['marketinglie',
                                                   'productname']
        checker.allowedClasses['span'] = checkfunc
        return checker

factory=MyProcessingFunctionFactory()
```

factory.py — *factory.py-3*

- ```
  from twisted.lore import latex
  from twisted.lore.latex import processFile
  import os.path

  # 2. Create a new mixin that does what the old MyLatexSpitter used to do:
  # process the new classes we defined
  class MySpitterMixin:
      def visitNode_span_productname(self, node):
          self.writer('\\underline{')
          self.visitNodeDefault(node)
          self.writer('}')

      def visitNode_span_marketinglie(self, node):
          self.writer('\\begin{bf}\\begin{Large}')
          self.visitNodeDefault(node)
          self.writer('\\end{Large}\\end{bf}')

  # 3. inherit from the mixin class for each of the three sub-spitters
  class MyLatexSpitter(MySpitterMixin, latex.LatexSpitter):
      pass

  class MySectionLatexSpitter(MySpitterMixin, latex.SectionLatexSpitter):
      pass

  class MyChapterLatexSpitter(MySpitterMixin, latex.ChapterLatexSpitter):
      pass
  ```
  ```

spitters.py — *spitters.py-2*

Creating New Outputs

write some stuff

8.3.3 Other Uses for Lore Extensions

write some stuff

Color-Code Programming Languages

write some stuff

Add New Structural Elements

write some stuff

Support New File Formats

write some stuff

Chapter 9

Working on the Twisted Code Base

9.1 Twisted Coding Standard

9.1.1 Naming

Try to choose names which are both easy to remember and meaningful. Some silliness is OK at the module naming level (see `twisted.spread`...) but when choosing class names, be as precise as possible. Write code with a dictionary and thesaurus open on the table next to you.

Try to avoid overloaded terms. This rule is often broken, since it is incredibly difficult, as most normal words have already been taken by some other software. More importantly, try to avoid meaningless words. In particular, words like “handler”, “processor”, “engine”, “manager” and “component” don’t really indicate what something does, only that it does *something*.

9.1.2 Testing

Unit tests are written using the `twisted.trial` framework. Many examples are in the `twisted.test` package. Test modules should start with ’test_’ in their name.

Acceptance tests are all automated by the admin/accepttests script currently. (TODO: real acceptance tests strategy!)

Run the unit tests tests before you check anything in.

Let me repeat that, for emphasis: *run the unit tests before you check* anything *in*. Code which breaks functionality is unfortunate and unavoidable. The acceptance tests are highly nonportable and sometimes a pain to run, so this is pardonable. Code which breaks the unit tests in a way that you could have prevented by running them yourself, however, may be grounds for anything from merciless taunting through revertion of the breakage to revocation of cvs commit privileges.

It is strongly suggested that developers learn to use Emacs, and use the `twisted-dev.el` file included in the TwistedEmacs package to bind the F9 key to “run unit tests” and bang on it frequently. Support for other editors is unavailable at this time but we would love to provide it.

If you modify, or write a new, HOWTO, please read the *Lore documentation* (page 202) to learn the format the docs.

9.1.3 Whitespace

Indentation is 4 spaces per indent. Tabs are not allowed. It is preferred that every block appear on a new line, so that control structure indentation is always visible.

9.1.4 Modules

Modules must be named in all lower-case, preferably short, single words. If a module name contains multiple words, they may be separated by underscores or not separated at all.

In most cases, modules should contain more than one class, function, or method; if a module contains only one object, consider refactoring to include more related functionality in that module.

Depending on the situation, it is acceptable to have imports look like this:

```
from twisted.internet.defer import Deferred
```

or like this:

```
from twisted.internet import defer
```

That is, modules should import *modules* or *classes and functions*, but not *packages*.

9.1.5 Packages

Package names should follow the same conventions as module names. All modules must be encapsulated in some package. Nested packages may be used to further organize related modules.

`__init__.py` must never contain anything other than a docstring and (optionally) an `__all__` attribute. Packages are not modules and should be treated differently. This rule may be broken to preserve backwards compatibility if a module is made into a nested package as part of a refactoring.

If you wish to promote code from a module to a package, for example, to break a large module out into several smaller files, the accepted way to do this is to promote from within the module. For example,

```
# parent/
# --- __init__.py ---
import child

# --- child.py ---
import parent
class Foo:
    pass
parent.Foo = Foo
```

Every package should be added to the list in `setup.py`.

9.1.6 Docstrings

Wherever possible, docstrings should be used to describe the purpose of methods, functions, classes, and modules. In cases where it's desirable to avoid documenting thoroughly – for example, and evolving interface – insert a placeholder docstring (`"UNDOCUMENTED"` is preferred), so that the auto-generated API documentation will not pick up an extraneous comment as the documentation for that module/class/function.

Docstrings are *never* to be used to provide semantic information about an object; this rule may be violated if the code in question is to be used in a system where this is a requirement (such as Zope).

Docstrings should be indented to the level of the code they are documenting.

Docstrings should be triple-quoted.

Docstrings should be written in epytext format; more documentation is available in the Epytext Markup Language documentation[1].

Additionally, to accommodate emacs users:

- Single quotes of the type of the docstring's triple-quote should be escaped. This will prevent font-lock from accidentally fontifying large portions of the file as a string.
- Code examples in docstrings should be prefixed by the — character. This will prevent IM-Python from regarding sample code as real functions, methods, and classes.

For example,

```
def foo2bar(f):
    """I am a function to convert foos to bars.

    I should be used when you have a foo but you want a bar; note that this is
    a non-destructive operation.  If I can\'t convert the foo to a bar I will
    raise a FooException().

    For example::

      |  import wombat
      |  def sample(something):
      |      f = something.getFoo()
      |      f.doFooThing()
      |      b = wombat.foo2bar(f)
      |      b.doBarThing()
      |      return b

    """
    # Optionally, actual code can go here.
```

9.1.7 Scripts

For each "script", that is, a program you expect a Twisted user to run from the command-line, the following things must be done:

1. Write a module in `twisted.scripts` which contains a callable global named `run`. This will be called by the command line part with no arguments (it will usually read `sys.argv`). Feel free to write more functions or classes in this module, if you feel they are useful to others.
2. Write a file in `bin/` which contains the Twisted running-from-CVS header, and ending with

[1] http://epydoc.sourceforge.net/epytext.html

```
from twisted.scripts.yourmodule import run
run()
```

3. Write a manpage in `doc/man`. On debian systems you can find a skeleton example of a manpage in `/usr/share/doc/man-db/examples/manpage.example`.

4. Add your script to the script list in `setup.py`.

This will insure your program will work correctly for users of CVS, Windows releases and Debian packages.

9.1.8 Standard Library Extension Modules

When using the extension version of a module for which there is also a Python version, place the import statement inside a try/except block, and import the Python version if the import fails. This allows code to work on platforms where the extension version is not available. For example:

```
try:
    import cPickle as pickle
except ImportError:
    import pickle
```

Use the ”as” syntax of the import statement as well, to set the name of the extension module to the name of the Python module.

9.1.9 ChangeLog

All changes that will affect the way end-users see Twisted should come with an appropriate entry in the ChangeLog that summarizes that impact.

The correct format for the ChangeLog is GNU changelog format. There is an emacs mode for editing this, use `M-x add-change-log-entry`. If you are, for whatever absurd reason, using an editor other than emacs to edit Twisted, you can use Moshe Zadka’s helpfully provided `admin/change` script to add a properly-formatted entry.

9.1.10 Classes

Classes are to be named in mixed case, with the first letter capitalized; each word separated by having its first letter capitalized. Acronyms should be capitalized in their entirety. Class names should not be prefixed with the name of the module they are in. Examples of classes meeting this criteria:

- twisted.spread.pb.ViewPoint
- twisted.parser.patterns.Pattern

Examples of classes *not* meeting this criteria:

- event.EventHandler
- main.MainGadget

An effort should be made to prevent class names from clashing with each other between modules, to reduce the need for qualification when importing. For example, a Service subclass for Forums might be named twisted.forum.service.ForumService, and a Service subclass for Words might be twisted.words.service.WordsService. Since neither of these modules are volatile *(see above)* the classes may be imported directly into the user's namespace and not cause confusion.

9.1.11 Methods

Methods should be in mixed case, with the first letter lower case, each word separated by having its first letter capitalized. For example, `someMethodName`, `method`.

Sometimes, a class will dispatch to a specialized sort of method using its name; for example, twisted.reflect.Accessor. In those cases, the type of method should be a prefix in all lower-case with a trailing underscore, so method names will have an underscore in them. For example, `get_someAttribute`. Underscores in method names in twisted code are therefore expected to have some semantic associated with them.

9.1.12 Functions

Functions should be named similiarly to methods.

Functions or methods which are responding to events to complete a callback or errback should be named `_cb MethodName` or `_ebMethodName`, in order to distinguish them from normal methods.

9.1.13 Attributes

Attributes should be named similarly to functions and methods. Attributes should be named descriptively; attribute names like `mode`, `type`, and `buf` are generally discouraged. Instead, use `displayMode`, `playerType`, or `inputBuffer`.

Do not use Python's "private" attribute syntax; prefix non-public attributes with a single leading underscore. Since several classes have the same name in Twisted, and they are distinguished by which package they come from, Python's double-underscore name mangling will not work reliably in some cases. Also, name-mangled private variables are more difficult to address when unit testing or persisting a class.

An attribute (or function, method or class) should be considered private when one or more of the following conditions are true:

- The attribute represents intermediate state which is not always kept up-to-date.
- Referring to the contents of the attribute or otherwise maintaining a reference to it may cause resources to leak.
- Assigning to the attribute will break internal assumptions.
- The attribute is part of a known-to-be-sub-optimal interface and will certainly be removed in a future release.

9.1.14 Database

Database tables will be named with plural nouns.

Database columns will be named with underscores between words, all lower case, since most databases do not distinguish between case.

Any attribute, method argument, or method name that corresponds *directly* to a column in the database will be named exactly the same as that column, regardless of other coding conventions surrounding that circumstance.

All SQL keywords should be in upper case.

9.1.15 C Code

Wherever possible, C code should be optional, and the default python implementation should be maintained in tandem with it. C code should be strict ANSI C, and *must* build using GCC as well as Visual Studio for Windows, and really shouldn't have any problems with other compilers either. Don't do anything tricky.

C code should only be used for efficiency, not for binding to external libraries. If your particular code is not frequently run, write it in Python. If you require the use of an external library, develop a separate, external bindings package and make your twisted code depend on it.

9.1.16 Checkin Messages

Thanks to CVSToys, the checkin messages are being used in a myriad of ways. Because of that, you need to observe a few simple rules when writing a checkin message.

The first line of the message is being used as both the subject of the commit e-mail and the announcement on #twisted. Therefore, it should be short (aim for < 80 characters) and descriptive – and must be able to stand alone (it is best if it is a complete sentence). The rest of the e-mail should be separated with *hard line breaks* into short lines ($<$ 70 characters). This is free-format, so you can do whatever you like here.

Checkin messages should be about *what*, not *how*: we can get how from CVS diff. Explain reasons for checkins, and what they affect.

Each commit should be a single logical change, which is internally consistent. If you can't summarize your changes in one short line, this is probably a sign that they should be broken into multiple checkins.

9.1.17 Recommendations

These things aren't necessarily standardizeable (in that code can't be easily checked for compliance) but are a good idea to keep in mind while working on Twisted.

If you're going to work on a fragment of the Twisted codebase, please consider finding a way that you would *use* such a fragment in daily life. I use the Twisted Web server on the main TML website, and aside from being good PR, this encourages you to actively maintain and improve your code, as the little everyday issues with using it become apparent.

Twisted is a *big* codebase! If you're refactoring something, please make sure to recursively grep for the names of functions you're changing. You may be surprised to learn where something is called. Especially if you are moving or renaming a function, class, method, or module, make sure that it won't instantly break other code.

9.2 HTML Documentation Standard for Twisted

9.2.1 Allowable Tags

Please try to restrict your HTML usage to the following tags (all only for the original logical purpose, and not whatever visual effect you see): `<html>`, `<title>`, `<head>`, `<body>`, `<h1>`, `<h2`, `<h3>`, `<ol>`, `<ul>`, `<dl>`, `<li>`,

<dt>, <dd>, <p>, <code>, <img>, <blockquote>, <a>, <cite>, , , , , <pre>, <q>, <table>,<tr>, <td> and <th>.

Please avoid using the quote sign (") for quoting, and use the relevant html tags (<q></q>) – it is impossible to distinguish right and left quotes with the quote sign, and some more sophisticated output methods work better with that distinction.

9.2.2 Multi-line Code Snippets

Multi-line code snippets should be delimited with a <pre> tag, with a mandatory "class" attribute. The conventionalized classes are "python", "python-interpreter", and "shell". For example:

"python"

```
    <p>
    For example, this is how one defines a Resource:
    </p>

    <pre class="python">
from twisted.web import resource

class MyResource(resource.Resource):
    def render(self, request):
        return "Hello, world!"
    </pre>
```

For example, this is how one defines a Resource:

```
from twisted.web import resource

class MyResource(resource.Resource):
    def render(self, request):
        return "Hello, world!"
```

Note that you should never have leading indentation inside a <pre> block – this makes it hard for readers to copy/paste the code.

"python-interpreter"

```
    <pre class="python-interpreter">
    \&gt;\&gt;\&gt; from twisted.web import resource
    \&gt;\&gt;\&gt; class MyResource(resource.Resource):
    ...     def render(self, request):
    ...         return "Hello, world!"
    ...
    \&gt;\&gt;\&gt; MyResource().render(None)
    "Hello, world!"
    </pre>
```

```
>>> from twisted.web import resource
>>> class MyResource(resource.Resource):
...     def render(self, request):
...         return "Hello, world!"
...
>>> MyResource().render(None)
"Hello, world!"
```

“shell”

```
    <pre class="shell">
    $ mktap web --path /var/www
    </pre>
```

```
$ mktap web --path /var/www
```

9.2.3 Code inside paragraph text

For single-line code-snippets and attribute, method, class, and module names, use the <code> tag, with a class of “API” or “python”. During processing, module or class-names with class “API” will automatically be looked up in the API reference and have a link placed around it referencing the actual API documents for that module/classname. If you wish to reference an API document, then make sure you at least have a single module-name so that the processing code will be able to figure out which module or class you’re referring to.

You may also use the `base` attribute in conjuction with a class of “API” to indicate the module that should be prepended to the module or classname. This is to help keep the documentation clearer and less cluttered by allowing links to API docs that don’t need the module name.

```
        <p>
    To add a <code class="API">twisted.web.widgets.Widget</code>
    instance to a <code class="API"
    base="twisted.web.widgets">Gadget</code> instance, do
    <code class="python">myGadget.putWidget("widgetPath",
    MyWidget())</code>.
        </p>

        <p>
    (implementation note: the widgets are stored in the <code
    class="python">gadgetInstance.widgets</code> attribute,
    which is a
    list.)
        </p>
```

To add a `twisted.web.widgets.Widget` instance to a `Gadget` instance, do `myGadget.putWidget("widgetPath", MyWidget())`.

(implementation note: the widgets are stored in the `gadgetInstance.widgets` attribute, which is a list.)

9.2.4 Headers

It goes without mentioning that you should use <hN> in a sane way – <h1> should only appear once in the document, to specify the title. Sections of the document should use <h2>, sub-headers <h3>, and so on.

9.2.5 XHTML

XHTML is mandatory. That means tags that don't have a closing tag need a "/"; for example, `<hr />` . Also, tags which have "optional" closing tags in HTML *need* to be closed in XHTML; for example, `<li>foo</li>`

9.2.6 Tag Case

All tags will be done in lower-case. XHTML demands this, and so do I. :-)

9.2.7 Footnotes

Footnotes are enclosed inside `<span class="footnote"></span>`. They must not contain any markup.

9.2.8 Suggestions

Use `hlint` to check your documentation is not broken. `hlint` will never change your HTML, but it will complain if it doesn't like it.

Don't use tables for formatting. 'nuff said.

9.2.9 __all__

`__all__` is a module level list of strings, naming objects in the module that are public. Make sure publically exported classes, functions and constants are listed here.

9.3 Unit Tests in Twisted

Each *unit test* tests one bit of functionality in the software. Unit tests are entirely automated and complete quickly. Unit tests for the entire system are gathered into one test suite, and may all be run in a single batch. The result of a unit test is simple: either it passes, or it doesn't. All this means you can test the entire system at any time without inconvenience, and quickly see what passes and what fails.

9.3.1 Unit Tests in the Twisted Philosophy

The Twisted development team adheres to the practice of Extreme Programming[2] (XP), and the usage of unit tests is a cornerstone XP practice. Unit tests are a tool to give you increased confidence. You changed an algorithm – did you break something? Run the unit tests. If a test fails, you know where to look, because each test covers only a small amount of code, and you know it has something to do with the changes you just made. If all the tests pass, you're good to go, and you don't need to second-guess yourself or worry that you just accidently broke someone else's program.

[2] http://c2.com/cgi/wiki?ExtremeProgramming

9.3.2 What to Test, What Not to Test

You don't have to write a test for every single method you write, only production methods that could possibly break.
– Kent Beck, Extreme Programming Explained, p. 58.

9.3.3 Running the Tests

How

```
$ Twisted/admin/runtests
```

You'll find that having something like this in your emacs init files is quite handy:

```
(defun runtests () (interactive)
  (compile "python /somepath/Twisted/admin/runtests"))

(global-set-key [(alt t)] 'runtests)
```

When

Always always *always* be sure all the tests pass[3] before committing any code. If someone else checks out code at the start of a development session and finds failing tests, they will not be happy and may decide to *hunt you down*.

Since this is a geographically dispersed team, the person who can help you get your code working probably isn't in the room with you. You may want to share your work in progress over the network, but you want to leave the main CVS tree in good working order. So use a branch[4], and merge your changes back in only after your problem is solved and all the unit tests pass again.

9.3.4 Adding a Test

Please don't add new modules to Twisted without adding tests for them too. Otherwise we could change something which breaks your module and not find out until later, making it hard to know exactly what the change that broke it was, or until after a release, and nobody wants broken code in a release.

Tests go in Twisted/twisted/test/, and are named `test_foo.py`, where `foo` is the name of the module or package being tested. Extensive documentation on using the PyUnit framework for writing unit tests can be found in the *links section* (page 223) below.

One deviation from the standard PyUnit documentation: To ensure that any variations in test results are due to variations in the code or environment and not the test process itself, Twisted ships with its own, compatible, testing framework. That just means that when you import the unittest module, you will `from twisted.trial import unittest` instead of the standard `import unittest`.

As long as you have followed the module naming and placement conventions, `runtests` will be smart enough to pick up any new tests you write.

[3] http://www.xprogramming.com/xpmag/expUnitTestsAt100.htm
[4] http://www.cvshome.org/docs/manual/cvs_5.html

9.3.5 Links

- A chapter on Unit Testing[5] in Mark Pilgrim's Dive Into Python[6].
- `unittest`[7] module documentation, in the Python Library Reference[8].
- UnitTests[9] on the PortlandPatternRepository Wiki[10], where all the cool ExtremeProgramming[11] kids hang out.
- Unit Tests[12] in Extreme Programming: A Gentle Introduction[13].
- Ron Jeffries espouses on the importance of Unit Tests at 100%[14].
- Ron Jeffries writes about the Unit Test[15] in the Extreme Programming practices of C3[16].
- PyUnit's homepage[17].
- twisted.test[18]'s inline documentation.
- The twisted/test directory[19] in CVS.

[5] http://diveintopython.org/roman_divein.html
[6] http://diveintopython.org
[7] http://www.python.org/doc/current/lib/module-unittest.html
[8] http://www.python.org/doc/current/lib/
[9] http://c2.com/cgi/wiki?UnitTests
[10] http://c2.com/cgi/wiki
[11] http://c2.com/cgi/wiki?ExtremeProgramming
[12] http://www.extremeprogramming.org/rules/unittests.html
[13] http://www.extremeprogramming.org
[14] http://www.xprogramming.com/xpmag/expUnitTestsAt100.htm
[15] http://www.xprogramming.com/Practices/PracUnitTest.html
[16] http://www.xprogramming.com/Practices/xpractices.htm
[17] http://pyunit.sourceforge.net
[18] http://twistedmatrix.com/documents/TwistedDocs/current/api/public/toc-twisted.test-module.html
[19] http://twistedmatrix.com/users/jh.twistd/viewcvs/cgi/viewcvs.cgi/twisted/test/?cvsroot=Twisted

Chapter 10

Manual Pages

10.1 COIL.1

10.1.1 NAME

coil - configure twisted TAP files

10.1.2 SYNOPSIS

coil [–new=*name*] <*file.tap*>
coil –help

10.1.3 DESCRIPTION

Once you've launched coil, point your browser at http://localhost:9080 to configure the TAP file, and when done hit Ctrl-C to shutdown and save the changes.

–help Print out a usage message to standard output.

***-n, –new*<*name*>** Create a new twisted Application.

***-p, –port*<*port*>** Run the coil web server on <port> (defaults to 9080)

-l, –localhost Bind only to localhost, instead of to all interfaces, thus only letting local users access coil.

10.1.4 AUTHOR

Written by Itamar Shtull-Trauring, based on coil's help messages

10.1.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.1.6 COPYRIGHT

10.1.7 SEE ALSO

twistd(1), mktap(1)

10.2 CONCH.1

10.2.1 NAME

conch - connect to SSH servers

10.2.2 SYNOPSIS

conch [-l *user*] [-i *identity* [-i *identity* ...]] [-c *cipher*] [-m *MAC*] [-p *port*] [-n] [-t] [-T] [-V] [-C] [-N] [-s] [arg [...]]
conch –help

10.2.3 DESCRIPTION

The *–help* prints out a usage message to standard output.

-t, –user<**user**> User name to use

-i, –identity<**identity**> Add an identity file.

-c, –cipher<**cipher**> Cipher algorithm to use.

-m, –macs<**mac**> Specify MAC algorithms for protocol version 2.

-p, –port<**port**> Port to connect to.

-n, –null Redirect input from /dev/null

-t, –tty Allocate a tty even if command is given.

-n, –notty Do not allocate a tty.

-V, –version Display version number only.

-C, –compress nable compression.

-N, –noshell Do not execute a shell or command.

-s, –subsystem Invoke command (mandatory) as SSH2 subsystem

–log Log to stderr

10.2.4 DESCRIPTION

Open an SSH connection to specified server, and either run the command given there or open a remote interactive shell.

10.2.5 AUTHOR

Written by Moshe Zadka, based on conch’s help messages

10.2.6 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.2.7 COPYRIGHT

10.2.8 SEE ALSO

ssh(1)

10.3 GENERATELORE.1

10.3.1 NAME

lore - convert documentations formats

10.3.2 SYNOPSIS

lore [-l *linkrel*] [-d *docsdir*] [-i *input*] [-o *output*] [–config attribute[=value] [...]] [-p] [file [...]]
lore –help

10.3.3 DESCRIPTION

The *–help* prints out a usage message to standard output.

-p, –plain Use non-flashy progress bar - one file per line.

-n, –null Do not report progress at all.

-l, –linkrel Where non-document links should be relative to.

-d, –docsdir Where to look for *.html* files if no files are given.

-i, –input Input format. New input formats can be dynamically registered. Lore itself comes with “lore” (the standard format), “mlore” (allows LaTeX equations) and “man” (man page format). If the input format is not registered as a plugin, a module of the named input will be searched. For example, *–i* twisted.lore.defaultis equivalent to using the default Lore input.

-o, –output Output format. Available output formats depend on the input. For the core formats, lore and mlore support html, latex and lint, while man allows lore.

–config Add input/output-specific information. HTML output allows for ’ext=<extension>’, ’template=<template>’ and ’baseurl=<format string for API URLs>’. LaTeX output allows for ’section’ or ’chapter’ in Lore, and nothing in Math-Lore. Lore output allows for ’ext=<extension>’. Lint output allows nothing. Note that disallowed *–config* options are merely ignored, and do not cause errors.

10.3.4 DESCRIPTION

If no files are given, all *.html documents in docsdir are processed.

10.3.5 SEE ALSO

doc/howto/lore.xhtml, doc/howto/doc-standard.xhtml, doc/howto/extend-lore.xhtml

10.3.6 AUTHOR

Written by Moshe Zadka

10.3.7 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.3.8 COPYRIGHT

10.4 IM.1

10.4.1 NAME

im - run Instance Messenger, the Tkinter twisted.words client

10.4.2 SYNOPSIS

im

10.4.3 DESCRIPTION

Run Instance Messenger, the Tkinter twisted.words client

10.4.4 AUTHOR

Written by Moshe Zadka, based on im's help messages

10.4.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.4.6 COPYRIGHT

10.5 MANHOLE.1

10.5.1 NAME

manhole - Connect to a Twisted Manhole service

10.5.2 SYNOPSIS

manhole

10.5.3 DESCRIPTION

manhole is a GTK interface to Twisted Manhole services. You can execute python code as if at an interactive Python console inside a running Twisted process with this.

10.5.4 AUTHOR

Written by Chris Armstrong, copied from Moshe Zadka's "faucet" manpage.

10.5.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.5.6 COPYRIGHT

10.6 MKTAP.1

10.6.1 NAME

mktap - create twisted.servers

10.6.2 SYNOPSIS

mktap [*options*] *apptype* [*application_option*]...
mktap –help *apptype*

10.6.3 DESCRIPTION

The *–help* prints out a usage message to standard output.

–uid, -u<uid> Application belongs to this uid, and should run with its permissions.

–gid, -d<gid> Application belongs to this gid, and should run with its permissions.

–append, -a<file> Append given servers to given file, instead of creating a new one. File should be be a tap file.

–appname, -n<name> Use the specified name as the process name when the application is run with *twistd(1)*. This option also causes some initialization code to be duplicated when *twistd(1)* is run.

–xml, -x Output as a .tax XML file rather than a pickle.

–source, -s Output as a .tas (AOT Python source) file rather than a pickle.

apptype Can be 'web', 'portforward', 'toc', 'coil', 'words', 'manhole', 'im', 'news', 'socks', 'telnet', 'parent', 'sibling', 'ftp', and 'mail'. Each of those support different options.

10.6.4 portforward options

-h, –host<host> Proxy connections to <*host*>

-d, –dest_port<port> Proxy connections to <*port*> on remote host.

-p, –port<port> Listen locally on <*port*>

10.6.5 web options

-u, –user Makes a server with ~/public_html and ~/.twistd-web-pb support for users.

–personal Instead of generating a webserver, generate a ResourcePublisher which listens on ~/.twistd-web-pb

–path<path> <path> is either a specific file or a directory to be set as the root of the web server. Use this if you have a directory full of HTML, cgi, php3, epy, or rpy files or any other files that you want to be served up raw.

-p, –port<port> <port> is a number representing which port you want to start the server on.

-m, –mime_type<***mimetype***> <mimetype> is the default MIME type to use for files in a –path web server when none can be determined for a particular extension. The default is 'text/html'.

–allow_ignore_ext Specify wether or not a request for 'foo' should return 'foo.ext'. Default is off.

-t, –telnet<***port***> Run a telnet server on <port>, for additional configuration later.

-i, –index<***name***> Use an index name other than "index.html"

–https<***port***> Port to listen on for Secure HTTP.

-c, –certificate<***filename***> SSL certificate to use for HTTPS. [default: server.pem]

-k, –privkey<***filename***> SSL certificate to use for HTTPS. [default: server.pem]

–processor<***ext***>=<***class name***> Adds a processor to those file names. (Only usable if after *–path)*

–resource-script<***script name***> Sets the root as a resource script. This script will be re-evaluated on every request.

This creates a web.tap file that can be used by twistd. If you specify no arguments, it will be a demo webserver that has the Test class from twisted.web.test in it.

10.6.6 toc options

-p<***port***> <port> is a number representing which port you want to start the server on.

10.6.7 mail options

-r, –relay<***ip***>,<***port***>=<***queue directory***> Relay mail to all unknown domains through given IP and port, using queue directory as temporary place to place files.

-d, –domain<***domain***>=<***path***> generate an SMTP/POP3 virtual maildir domain named "domain" which saves to "path"

-u, –username<***name***>=<***password***> add a user/password to the last specified domains

-b, –bounce_to_postmaster undelivered mails are sent to the postmaster, instead of being rejected.

-p, –pop<***port***> <port> is a number representing which port you want to start the pop3 server on.

-s, –smtp<***port***> <port> is a number representing which port you want to start the smtp server on.

This creates a mail.tap file that can be used by twistd(1)

10.6.8 telnet options

-p, –port<***port***> Run the telnet server on <port>

-u, –username<***name***> set the username to <name>

-w, –password<***password***> set the password to <password>

10.6.9 socks options

-i, –interface<***interface***> Listen on interface <interface>

-p, –port<***port***> Run the SOCKSv4 server on <port>

-l, –log<***filename***> log connection data to <filename>

10.6.10 ftp options

-a, –anonymous Allow anonymous logins

-3, –thirdparty Allow third party connections

–otp Use one time passwords (OTP)

-p, –port<***port***> Run the FTP server on <port>

-r, –root<***path***> Define the local root of the FTP server

–anonymoususer<***username***> Define the the name of the anonymous user

10.6.11 manhole options

-p, –port<***port***> Run the manhole server on <port>

-u, –user<***name***> set the username to <name>

-w, –password<***password***> set the password to <password>

10.6.12 words options

-p, –port<***port***> Run the Words server on <port>

-i, –irc<***port***> Run IRC server on port <port>

-w, –web<***port***> Run web server on port <port>

10.6.13 AUTHOR

Written by Moshe Zadka, based on mktap's help messages

10.6.14 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.6.15 COPYRIGHT

10.6.16 SEE ALSO

twistd(1)

10.7 IM.1

10.7.1 NAME

t-im - run Instance Messenger, the GTK+ twisted.words client

10.7.2 SYNOPSIS

t-im

10.7.3 DESCRIPTION

Run Instance Messenger, the GTK+ twisted.words client

10.7.4 AUTHOR

Written by Moshe Zadka, based on t-im's code

10.7.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.7.6 COPYRIGHT

10.8 TAP2DEB.1

10.8.1 NAME

tap2deb - create Debian packages which wrap .tap files

10.8.2 SYNOPSIS

tap2deb [options]

10.8.3 DESCRIPTION

Create a ready to upload Debian package in ".build"

-u, –unsigned do not sign the Debian pacakge

-t, –tapfile<***tapfile***> Build the application around the given .tap (default twistd.tap)

-y, –type<***type***> The configuration has the given type . Allowable types are *tap*, *source*, *xml* and *python*. The first three types are *mktap(1)* output formats, while the last one is a manual building of application (see *twistd(1)*, the *-y* option).

-p, –protocol<***protocol***> The name of the protocol this will be used to serve. This is intended as a part of the description. Default is the name of the tapfile, minus any extensions.

-d, –debfile<***debfile***> The name of the debian package. Default is 'twisted-'+protocol.

-V, –set-version<***version***> The version of the Debian package. The default is 1.0

-e, –description<***description***> The one-line description. Default is uninteresting.

-l, –long_description<***long_description***> A multi-line description. Default is explanantion about this being an automatic package created from tap2deb.

-m, –maintainer<***maintainer***> The maintainer, as "Name Lastname <email address>". This will go in the metafiles, as well as be used as the id to sign the package.

-v, –version Output version information and exit.

10.8.4 AUTHOR

Written by Moshe Zadka, based on twistd's help messages

10.8.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.8.6 COPYRIGHT

10.8.7 SEE ALSO

mktap(1)

10.9 TAPCONVERT.1

10.9.1 NAME

tapconvert - convert Twisted configurations from one format to another

10.9.2 SYNOPSIS

tapconvert -i *input* -o *output* [-f *input-type*] [-t *output-type*] [-d] [-e]
tapconvert –help

10.9.3 DESCRIPTION

The *–help* prints out a usage message to standard output.

–in, -i<input file> The name of the input configuration.

–out, -o<output file> The name of the output configuration.

–typein, -f<input type> The type of the input file. Can be either 'guess', 'python', 'pickle', 'xml', or 'source'. Default is 'guess'.

–typeout, -t<output type> The type of the output file. Can be either 'python', 'pickle', 'xml', or 'source'. Default is 'source'.

–decrypt, -d Decrypt input.

–encrypt, -e Encrypt output.

10.9.4 AUTHOR

Written by Moshe Zadka, based on tapconvert's help messages

10.9.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.9.6 COPYRIGHT

10.9.7 SEE ALSO

mktap(1)

10.10 TRIAL.1

10.10.1 NAME

trial - run unit tests

10.10.2 SYNOPSIS

trial [-b] [-v—-o—-j] [-r *reactor*] [-l *logfile*] [-m *module* [-m *module* ...]] [-p *package* [-p *package* ...]] *file—module—package—TestCase—testMethod* ...
trial –help

10.10.3 DESCRIPTION

trial loads and executes a suite of unit tests, obtained from modules and packages listed on the command line. The *–help* option prints out a usage message to standard output.

-s, –summary Print out just a machine-parseable summary of the results.

-v, –verbose Be more verbose. Without this option, trial prints out a single character for each test. (e.g. An 'F' for a failure, A '.' for a success). With this option, trial prints a single line for each test. This is especially useful for gauging how long each test takes.

-o, –bwverbose Be verbose, but do not attempt to use colors (more log-file friendly)

-j, –jelly Report results in a machine-readable jelly stream.

-m, –module<**module**> Module containing test cases.

-p, –package<**package**> Package containing modules that contain test cases. trial loads modules named 'test_' within the given package.

-l, –logfile<**logfile**> Log exceptions (and other things) to the given logfile.

-r, –reactor<**reactor**> Use this reactor for running the tests.

-b, –debug Run the tests in the Python debugger.

10.10.4 AUTHOR

Written by Jonathan M. Lange

10.10.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.10.6 COPYRIGHT

10.11 TWISTD.1

10.11.1 NAME

twistd - run twisted.internet.app.Application pickles

10.11.2 SYNOPSIS

twistd [options]

10.11.3 DESCRIPTION

Read an twisted.internet.app.Application out of a file and runs it.

-n, –nodaemon Don't daemonize (stay in foreground)

-q, –quiet be a little more quiet

-p, –profile Run profiler

-b, –debug Run the application in the Python Debugger (implies nodaemon option). Sending a SIGINT signal to the process will drop it into the debugger.

-o, –no_save Do not save shutdown state

–originalname Behave as though the specified Application has no process name set, and run with the standard process name (the python binary in most cases).

-l, –logfile<***logfile***> Log to a specified file, - for stdout (default twistd.log). The log file will be rotated on SIGUSR1.

–pidfile<***pidfile***> Save pid in specified file (default twistd.pid)

–chroot<***directory***> Chroot to a supplied directory before running (default – don't chroot). Chrooting is done before changing the current directory.

-d, –rundir<***directory***> Change to a supplied directory before running (default .)

-r, –reactor<***reactor***> Choose which ReactorCore event loop to use, such as 'poll' or 'gtk'.

–spew Write an extremely verbose log of everything that happens. Useful for debugging freezes or locks in complex code.

-f, –file<***tap file***> Read the given .tap file (default twistd.tap)

-x, –xml<***tax file***> Load an Application from the given .tax (XML) file.

-s, –source<***tas file***> Load an Application from the given .tas (AOT Python source) file.

-y, –python<***python file***> Use the variable "application" from the given Python file. This setting, if given, overrides *-f*.

-g, –plugin<***plugin name***> Read config.tac from a plugin package, as with *-y*.

–syslog Log to syslog, not to file.

–prefix<***prefix***> Use the specified prefix when logging to logfile. Default is "twisted".

10.11.4 AUTHOR

Written by Moshe Zadka, based on twistd's help messages

10.11.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.11.6 COPYRIGHT

10.11.7 SEE ALSO

mktap(1)

10.12 WEBSETROOT.1

10.12.1 NAME

websetroot - set the root of a Twisted web server

10.12.2 SYNOPSIS

websetroot {-f *tapfile* — -y *codefile* — -x *XML* — -s *AOT* } {–pickle *pickle* — –script *script* } [-e] [–port *port*]
websetroot –help

10.12.3 DESCRIPTION

The *–help* prints out a usage message to standard output.

-e, –encrypted The specified tap/aos/xml file is encrypted.

-p, –port<**port**> The port the web server is running on [default: 80]

-f, –file<**file**> read the given .tap file [default: twistd.tap]

-y, –python<**file**> read an application from within a Python file

-x, –xml<**file**> Read an application from a .tax file (Marmalade format).

-s, –source<**file**> Read an application from a .tas file (AOT format).

–script<**file**> Read the root resource from the given resource script file

–pickle<**file**> Read the root resource from the given resource pickle file

10.12.4 AUTHOR

Written by Moshe Zadka, based on websetroot's help messages

10.12.5 REPORTING BUGS

Report bugs to <twisted-python@twistedmatrix.com>.

10.12.6 COPYRIGHT

10.12.7 SEE ALSO

mktap(1)

Chapter 11

Appendix

11.1 The Twisted FAQ

11.1.1 General

What is "Twisted"?

Please see Twisted[1]

Why should I use Twisted?

See The Twisted Advantage[2]

I have a problem "getting" Twisted.

Did you check the HOWTO collection? There are so many documents there that they might overwhelm you... try starting from the index, reading through the overviews and seeing if there seems to be a chapter which explains what you need to. You can try reading the PostScript or PDF formatted books, inside the distribution. And, remember, the source will be with you... always.

Why is Twisted so big?

Twisted is a lot of things, rolled into one big package. We're not sure if it'll stay this way, yet, but for now, if you have only specific needs, we recommend grabbing the big Twisted tarball, and if you want, you can run the 'setup.py' script with a modified config file to generate a package with only certain Twisted sub-packages. Twisted as a whole makes it into many operating system distributions (FreeBSD, Debian and Gentoo, at least) so size shouldn't be an issue for the end developer or user. In addition, packaging Twisted as a whole makes sure the end users do not have to worry about versioning parts of Twisted and inter-version compatibility.

If you are distributing Twisted to end-users, you can base your distribution on the "Nodocs" packages, which are signficantly smaller.

[1] http://twistedmatrix.com/products/twisted
[2] http://twistedmatrix.com/services/twisted-advantage

But won't Twisted bloat my program, since it's so big?

No. You only need to import the sub-packages which you want to use, meaning only those will be loaded into memory. So if you write a low-level network protocol, you'd only import twisted.internet, leaving out extraneous things like twisted.web, etc. Twisted itself is very careful with internal dependancies, so importing one subpackage is not likely to import the whole twisted package.

11.1.2 Versioning

Does the 1.0 release mean that all of Twisted's APIs are stable?

No, only specific parts of Twisted are stable, i.e. we only promise backwards compatibility for some parts of Twisted. While these APIs may be extended, they will not change in ways that break existing code that uses them.

While other parts of Twisted are not stable, we will however do our best to make sure that there is backwards compatibility for these parts as well. In general, the more the module or package are used, and the closer they are to being feature complete, the more we will concentrate on providing backwards compatibility when API changes take place.

Which parts of Twisted 1.0 are stable?

Only modules explictily marked as such can be considered stable. Semi-stable modules may change, but not in a large way and some sort of backwards-compatibily will probably be provided. If no comment about API stability is present, assume the module is unstable.

In Twisted 1.0, *most of twisted.internet is completely stable*, other than:

1. UDP support
2. twisted.internet.win32eventreactor - will be replaced with win32support in future.

But as always, the only accurate way of knowing a module's stability is reading the module's docstrings.

11.1.3 Installation

I run mktap (from site-packages/twisted/scripts/mktap.py) and nothing happens!

Don't run scripts out of `site-packages`. The Windows installer should install executable scripts to someplace like `C:\Python22\scripts\`, *nix installers put them in `$PREFIX/bin`, which should be in your $PATH.

11.1.4 Core Twisted

How can I access self.factory from my Protocol's __init__?

You can't. A Protocol doesn't have a Factory when it is created. Instead, you should probably be doing that in your Protocol's `connectionMade` method.

Similarly you shouldn't be doing "real" work, like connecting to databases, in a Factory's `__init__` either. Instead, do that in `startFactory`.

See *Writing Servers* (page 68) and *Writing Clients* (page 72) for more details.

Where can I find out how to write Twisted servers?

Try Writing Servers[3].

When I try to install my reactor, I get errors about a reactor already being installed. What gives?

Here's the rule - installing a reactor should always be the *first* thing you do, and I do mean first. Importing other stuff before you install the reactor can break your code.

Tkinter and wxPython support, as they do not install a new reactor, can be done at any point, IIRC.

twistd won't load my .tap file!

When the pickled application state cannot be loaded for some reason, it is common to get a rather opaque error like so:

```
% twistd -f test2.tap

Failed to load application: global name 'initRun' is not defined
```

The rest of the error will try to explain how to solve this problem, but a short comment first: this error is indeed terse – but there is probably more data available elsewhere – namely, the `twistd.log` file. Open it up to see the full exception.

To load a `.tap` file, as with any unpickling operation, all the classes used by all the objects inside it must be accessible at the time of the reload. This may require the PYTHONPATH variable to have the same directories as were available when the application was first pickled.

A common problem occurs in single-file programs which define a few classes, then create instances of those classes for use in a server of some sort. If the class is used directly, the name of the class will be recorded in the `.tap` file as something like `__main__.MyProtocol`. When the application is reloaded, it will look for the class definition in `__main__`, which probably won't have it. The unpickling routines need to know the module name, and therefore the source file, from which the class definition can be loaded.

The way to fix this is to import the class from the same source file that defines it: if your source file is called `myprogram.py` and defines a class called `MyProtocol`, you will need to do a `from myprogram import MyProtocol` before (and in the same namespace as) the code that references the MyProtocol class. This makes it important to write the module cleanly: doing an `import myprogram` should only define classes, and should not cause any other subroutines to get run. All the code that builds the Application and saves it out to a `.tap` file must be inside an `if __name__ == '__main__'` clause to make sure it is not run twice (or more).

When you import the class from the module using an "external" name, that name will be recorded in the pickled `.tap` file. When the `.tap` is reloaded by `twistd`, it will look for `myprogram.py` to provide the definition of `MyProtocol`.

Here is a short example of this technique:

```
#

from twisted.internet.protocol import Protocol, Factory
from twisted.internet import reactor
```

[3] http://www.twistedmatrix.com/documents/howto/servers

```
### Protocol Implementation

# This is just about the simplest possible protocol
class Echo(Protocol):
    def dataReceived(self, data):
        """As soon as any data is received, write it back."""
        self.transport.write(data)

def main():
    f = Factory()
    f.protocol = Echo
    reactor.listenTCP(8000, f)
    reactor.run()

if __name__ == '__main__':
    main()
```

doc/examples/echoserv.py — *echoserv.py*

11.1.5 Web

Is the Twisted web server a toy?

No. It is a production grade server. It is running continously on several sites and has been proven quite stable. The server can take loads of up to 3000 users at a time and still keep churning several million requests a day, even on low end hardware. It can serve static files or dynamically rendered pages.

But can Twisted Web do PHP?

Yes. It works out-of-the-box, so long as you've got the standalone php interpreter installed. You might also want to take a look at Woven, Twisted's native web templating system.

And can Twisted Web do virtual hosting?

Can it ever!

You can decide to go with one big process for all of them, a front server and a seperate server for each virtual host (for example, for permission reasons), and you can even mix-and-match between Apache and Twisted (for example, put Apache in the front and have Twisted handle some subset of the virtual host).

How do I use twisted.web to do complex things?

See *the Twisted.Web Howto* (page 23).

I've been using Woven since before it was called Woven. I just upgraded and now I'm getting a confusing traceback talking about INodeMutator. What gives?

You probably have code that's survived the upgrade from PyXML's `minidom` to Twisted's `microdom`. Try deleting any `.pxp` files that you have lying around and the error will probably go away.

11.1.6 Requests and Contributing

Twisted is cool, but I need to add more functionality.

Great! Read our the docs, and if you're feeling generous, contribute patches.

I have a patch. How do I maximize the chances the Twisted developers will include it?

Use unified diff. Either use `cvs diff -u` or, better yet, make a clean checkout and use `diff -urN` between them. Make sure your patch applies cleanly. In your post to the mailing list, make sure it is inlined and without any word wrapping.

And to whom do I send it?

To the mailing list[4]. If no one picks it up after a few days, it's recommended that you add it to the bug tracker[5] so that it doesn't get lost.

My company would love to use Twisted, but it's missing feature X, can you implement it?

You have 3 options:

- Pay one of the Twisted developers to implement the feature.
- Implement the feature yourself.
- Add a feature request to our bug tracker. We will try to implement the feature, but there are no guarantees when and if this will happen.

11.1.7 Documentation

Twisted really needs documentation for X, Y or Z - how come it's not documented?.

We are doing the best we can, and there is documentation in progress for many parts of Twisted. There is a limit to how much we can do in our free time. See also the answer to the next question.

Wow the Twisted documentation is nice! I want my docs to look like that too!

Now you can, with `twisted.lore`. See the manual page for `lore`. For source format documentation, see *the documentation standard description* (page 218). For a more comprehensive explanation, see *the Lore HOWTO* (page 202).

[4] http://twistedmatrix.com/cgi-bin/mailman/listinfo/twisted-python
[5] http://sourceforge.net/tracker/?group_id=49387&atid=456015

11.1.8 Communicating with us

There's a bug in Twisted. Where do I report it?

Unless it is a show-stopper bug, we usually won't fix it if it's already fixed in CVS[6], so you would do well to look there. Then send any pertinent information about the bug (hopefully as much information needed to reproduce it: OS, CVS versions of any important files, Python version, code you wrote or things you did to trigger the bug, etc.) to the mailing list[7]. If no one answers immediately, you should add it to the bug tracker[8].

Where do I go for help?

Ask for help where the Twisted team hangs out[9]

How do I e-mail a Twisted developer?

First, note that in many cases this is the wrong thing to do: if you have a question about a part of Twisted, it's usually better to e-mail the mailing list. However, the preferred e-mail addresses for all Twisted developers are listed in the file "CREDITS" in the CVS repository.

11.2 Twisted Glossary

Absolute submodel paths The full path to a *Model* (page 251) object, starting at the root. For example, `/foo/bar/baz`

adaptee An object that has been adapted, also called "original". See *Adapter* (this page).

`Adapter` An object whose sole purpose is to implement an Interface for another object. See *Interfaces and Adapters* (page 61).

`Application` A `twisted.internet.app.Application`. There are HOWTOs on *creating and manipulating* (page 21) them as a system-administrator, as well as *using* (page 38) them in your code.

`Authorizer` An object responsible for managing *Identities* (page 250). See `twisted.cred.authorizer`.

`Banana` The low-level data marshalling layer of *Twisted Spread* (page 252). See `twisted.spread.banana`.

`Broker` A `twisted.spread.pb.Broker`, the object request broker for *Twisted Spread* (page 252).

cache A way to store data in readily accessible place for later reuse. Caching data is often done because the data is expensive to produce or access. Caching data risks being stale, or out of sync with the original data.

COIL "COnfiguration ILlumination". It is a (stagnant and incomplete) end-user interface for configuring Twisted applications. See `twisted.coil`.

component A special kind of (persistent) `Adapter` that works with a `twisted.python.components.Componentized`. See also *Interfaces and Adapters* (page 61).

[6] http://twistedmatrix.com/developers/cvs
[7] http://twistedmatrix.com/cgi-bin/mailman/listinfo/twisted-python
[8] http://sourceforge.net/tracker/?group_id=49387&atid=456015
[9] http://twistedmatrix.com/services/online-help

`Componentized` A Componentized object is a collection of information, separated into domain-specific or role-specific instances, that all stick together and refer to each other. Each object is an `Adapter`, which, in the context of Componentized, we call "components". See also *Interfaces and Adapters* (page 61).

`conch` Twisted's SSH implementation.

Connector Object used to interface between client connections and protocols, usually used with a `twisted.internet.protocol.ClientFactory` to give you control over how a client connection reconnects. See `twisted.internet.interfaces.IConnector` and *Writing Clients* (page 72).

Consumer An object that consumes data from a *Producer* (page 251). See `twisted.internet.interfaces.IConsumer`.

controller (In *Woven* (page 253)) an object which accepts input from the user in the form of mouse clicks, keypresses, and web form submissions, and updates the *Model* (page 251) component.

Cred Twisted's authentication API, `twisted.cred`. See *Introduction to Twisted Cred* (page 17) and *Twisted Cred usage* (page 133).

CVSToys A nifty set of tools for CVS, available at http://twistedmatrix.com/users/acapnotic/wares/code/CVSToys/.

`Deferred` A instance of `twisted.internet.defer.Deferred`, an abstraction for handling chains of callbacks and error handlers ("errbacks"). See the *Deferring Execution* (page 82) HOWTO.

Enterprise Twisted's RDBMS support. It contains `twisted.enterprise.adbapi` for asynchronous access to any standard DB-API 2.0 module, and `twisted.enterprise.row`, a "*Relational Object Wrapper* (page 252)". See *Introduction to Twisted Enterprise* (page 14) and *Twisted Enterprise Row Objects* (page 51) for more details.

errback A callback attached to a *Deferred* (this page) with `.addErrback` to handle errors.

`Factory` In general, an object that constructs other objects. In Twisted, a Factory usually refers to a `twisted.internet.protocol.Factory`, which constructs *Protocol* (page 251) instances for incoming or outgoing connections. See *Writing Servers* (page 68) and *Writing Clients* (page 72).

`Failure` Basically, an asynchronous exception that contains traceback information; these are used for passing errors through asynchronous callbacks.

`Identity` A *Cred* (this page) object that represents a single user with a username and a password of some sort.

im, t-im Abbreviation of "(Twisted) *Instance Messenger* (this page)".

Instance Messenger Instance Messenger is a multi-protocol chat program that comes with Twisted. It can communicate via TOC with the AOL servers, via IRC, as well as via *PB* (page 251) with *Twisted Words* (page 252). See `twisted.im`.

`Interface` A class that defines and documents methods that a class conforming to that interface needs to have. A collection of core twisted.internet interfaces can be found in `twisted.internet.interfaces`. See also *Interfaces and Adapters* (page 61).

Jelly The serialization layer for *Twisted Spread* (page 252), although it can be used seperately from Twisted Spread as well. It is similar in purpose to Python's standard `pickle` module, but is more network-friendly, and depends on a separate marshaller (*Banana* (page 249), in most cases). See `twisted.spread.jelly`.

Lore `twisted.lore` is Twisted's documentation system. The source format is a subset of XHTML, and output formats include HTML and LaTeX. See *lore(1)* (page 228) and the *Twisted Documentation Standard* (page 218).

Manhole A debugging/administration interface to a Twisted application. See *Debugging with Manhole* (page 31).

Marmalade An XML-based serialisation module. See `twisted.persisted.marmalade`.

Microdom A partial DOM implementation using *SUX* (page 252). It is simple and pythonic, rather than strictly standards-compliant. See `twisted.web.microdom`.

model An object that contains data and business logic for manipulating this data.

model stack A stack of *Model* (this page) instances which keeps track of the Model that is currently in scope during the *Woven* (page 253) Page rendering process.

Names Twisted's DNS server, found in `twisted.names`.

overrides (In *Woven* (page 253)) A way to add data to cached data. Overrides are not replaced when base data is updated.

pattern A node in a *Woven* (page 253) HTML template whose sole purpose is to be copied and filled with data by a View component.

relative submodel path A partial path to a *Model* (this page) object, relative to the top of the Model stack.

PB Abbreviation of "*Perspective Broker* (this page)".

`Perspective` A *Cred* (page 250) object; an *Identity* (page 250)'s "perspective" (or "view") onto a Service. There may be many Perspectives associated with an Identity, and an Identity may have multiple Perspectives onto the same *Service* (page 252).

Perspective Broker The high-level object layer of Twisted *Spread* (page 252), implementing semantics for method calling and object copying, caching, and referencing. See `twisted.spread.pb`.

Producer An object that generates data a chunk at a time, usually to be processed by a *Consumer* (page 250). See `twisted.internet.interfaces.IProducer`.

`Protocol` In general each network connection has its own Protocol instance to manage connection-specific state. There is a collection of standard protocol implementations in `twisted.protocols`. See also *Writing Servers* (page 68) and *Writing Clients* (page 72).

PSU There is no PSU.

Reactor The core event-loop of a Twisted application. See *Reactor Basics* (page 67).

Reality See "*Twisted Reality* (page 252)"

`Resource` A `twisted.web.resource.Resource`, which are served by Twisted Web. Resources can be as simple as a static file on disk, or they can have dynamically generated content.

ROW *R*elational *O*bject *W*rapper, an object-oriented interface to a relational database. See *Twisted Enterprise Row Objects* (page 51).

Service A `twisted.cred.service.Service`. See *Twisted Cred usage* (page 133) for a description of how they relate to *Applications* (page 249), *Perspectives* (this page) and *Identities* (page 250).

Spread Twisted Spread[10] is Twisted's remote-object suite. It consists of three layers: *Perspective Broker* (page 251), *Jelly* (page 251) and *Banana*. (page 249) See *Writing Applications with Perspective Broker* (page 14).

Sturdy A persistent reference manager for *PB* (page 251). See `twisted.spread.sturdy`.

submodel paths A path to a *Model* (page 251) object. A way of referring to a piece of data in a *Woven* (page 253) template that allows Python to locate the data in a tree of python objects.

SUX *S*mall *U*ncomplicated *X*ML, Twisted's simple XML parser written in pure Python. See `twisted.protocols.sux`.

TAP *T*wisted *A*pplication *P*ickle, or simply just a *T*wisted *AP*plication. A serialised application that created with `mktap` and runnable by `twistd`. See *Using the Utilities* (page 21).

Tendril A bridge between *Twisted Words* (this page) and IRC. See `twisted.words.tendril`.

Trial `twisted.trial`, Twisted's unit-testing framework, modelled after pyunit[11]. See also Twisted's *Test Standard* (page 221).

Twisted Matrix Laboratories The team behind Twisted. http://twistedmatrix.com/.

Twisted Reality In days of old, the Twisted Reality[12] multiplayer text-based interactive-fiction system was the main focus of Twisted Matrix Labs; Twisted, the general networking framework, grew out of Reality's need for better network functionality. Twisted Reality has since been broken off into a separate project.

`usage` The `twisted.python.usage` module, a replacement for the standard `getopt` module for parsing command-lines which is much easier to work with. See *Parsing command-lines* (page 54).

`wcfactory` A *factory* (page 250) method for producing *Controller* (page 250) objects when a `controller=` directive is encountered in a *Woven* (page 253) Template.

`wchild` In *Woven* (page 253), a *factory* (page 250) method for producing objects which represent URL segments below the current object.

widgets In *Woven* (page 253), a `View` subclass which specializes in rendering a fragment of the DOM tree.

`wmfactory` A *factory* (page 250) method for producing *Model* (page 251) objects when a `model=` directive is encountered in a *Woven* (page 253) Template.

Words Twisted Words is a multi-protocol chat server that uses the *Perspective Broker* (page 251) protocol as its native communication style. See `twisted.words`.

[10] http://twistedmatrix.com/products/spread
[11] http://pyunit.sourceforge.net/
[12] http://twistedmatrix.com/products/reality

Woven *W*eb *O*bject *V*isualization *En*vironment. A web templating system based on XML and the Model-View-Controller design pattern. See *Developing Componentized Applications using Woven* (page 160).

`wvfactory` A *factory* (page 250) method for producing View objects when a `view=` directive is encoutered in a *Woven* (page 253)Template.

Zoot Twisted's Gnutella implementation (currently very incomplete). See `twisted.zoot`.

11.3 Banana Protocol Specifications

11.3.1 Introduction

Banana is an efficient, extendable protocol for sending and receiving s-expressions. A s-expression in this context is a list composed of byte strings, integers, large integers, floats and/or s-expressions.

11.3.2 Banana Encodings

The banana protocol is a stream of data composed of elements. Each element has the following general structure - first, the length of element encoded in base-128, least signficant bit first. For example length 4674 will be sent as `0x42 0x24`. For certain element types the length will be omitted (e.g. float) or have a different meaning (it is the actual value of integer elements).

Following the length is a delimiter byte, which tells us what kind of element this is. Depending on the element type, there will then follow the number of bytes specified in the length. The byte's high-bit will always be set, so that we can differentiate between it and the length (since the length bytes use 128-base, their high bit will never be set).

11.3.3 Element Types

Given a series of bytes that gave us length N, these are the different delimiter bytes:

List – 0x80 The following bytes are a list of N elements. Lists may be nested, and a child list counts as only one element to its parent (regardless of how many elements the child list contains).

Integer – 0x81 The value of this element is the positive integer N. Following bytes are not part of this element. Integers can have values of 0 <= N <= 2147483647.

String – 0x82 The following N bytes are a string element.

Negative Integer – 0x83 The value of this element is the integer N * -1, i.e. -N. Following bytes are not part of this element. Negative integers can have values of 0 >= -N >= -2147483648.

Float - 0x84 The next 8 bytes are the float encoded in IEEE 754 floating-point "double format" bit layout. No length bytes should have been defined.

Large Integer – 0x85 The value of this element is the positive large integer N. Following bytes are not part of this element. Large integers have no size limitation.

Large Negative Integer – 0x86 The value of this element is the negative large integer -N. Following bytes are not part of this element. Large integers have no size limitation.

Large integers are intended for arbitary length integers. Regular integers types (positive and negative) are limited to 32-bit values.

Examples

Here are some examples of elements and their encodings - the type bytes are marked in bold:

1 0x01 0x81

-1 0x01 0x83

1.5 0x84 0x3f 0xf8 0x00 0x00 0x00 0x00 0x00 0x00

"hello" 0x05 0x82 0x68 0x65 0x6c 0x6c 0x6f

[] 0x00 0x80

[1, 23] 0x02 0x80 0x01 0x81 0x17 0x81

1234567891234567 89 0x15 0x3e 0x41 0x66 0x3a 0x69 0x26 0x5b 0x01 0x85

[1, ["hello"]] 0x02 0x80 0x01 0x81 0x01 0x80 0x05 0x82 0x68 0x65 0x6c 0x6c 0x6f

11.3.4 Profiles

The Banana protocol is extendable. Therefore, it supports the concept of profiles. Profiles allow developers to extend the banana protocol, adding new element types, while still keeping backwards compatability with implementations that don't support the extensions. The profile used in each session is determined at the handshake stage (see below.)

A profile is specified by a unique string. This specification defines two profiles - `"none"` and `"pb"`. The `"none"` profile is the standard profile that should be supported by all Banana implementations. Additional profiles may be added in the future.

The "none" Profile

The `"none"` profile is identical to the delimiter types listed above. It is highly recommended that all Banana clients and servers support the `"none"` profile.

The "pb" Profile

The `"pb"` profile is intended for use with the Perspective Broker protocol, that runs on top of Banana. Basically, it converts commonly used PB strings into shorter versions, thus minimizing bandwidth usage. It does this by adding an additional delimiter byte, 0x87. This byte should not be prefixed by a length. It should be followed by a single byte, which tells us to which string element to convert it:

0x01 'None'

0x02 'class'

0x03 'dereference'

0x04 'reference'

0x05 'dictionary'

0x06 ’function’

0x07 ’instance’

0x08 ’list’

0x09 ’module’

0x0a ’persistent’

0x0b ’tuple’

0x0c ’unpersistable’

0x0d ’copy’

0x0e ’cache’

0x0f ’cached’

0x10 ’remote’

0x11 ’local’

0x12 ’lcache’

0x13 ’version’

0x14 ’login’

0x15 ’password’

0x16 ’challenge’

0x17 ’logged_in’

0x18 ’not_logged_in’

0x19 ’cachemessage’

0x1a ’message’

0x1b ’answer’

0x1c ’error’

0x1d ’decref’

0x1e ’decache’

0x1f ’uncache’

11.3.5 Protocol Handshake and Behaviour

The initiating side of the connection will be referred to as “client”, and the other side as “server”.

Upon connection, the server will send the client a list of string elements, signifying the profiles it supports. It is recommended that `"none"` be included in this list. The client then sends the server a string from this list, telling the server which profile it wants to use. At this point the whole session will use this profile.

Once a profile has been established, the two sides may start exchanging elements. There is no limitation on order or dependencies of messages. Any such limitation (e.g. “server can only send an element to client in response to a request from client”) is application specific.

Upon receiving illegal messages, failed handshakes, etc., a Banana client or server should close its connection.