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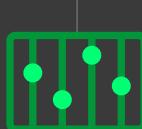
Stephen Corona

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nginx
A Practical Guide to High Performance

Stephen Corona

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nginx

by Stephen Corona

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Foreword

Nearly 20 years ago, I read my first O'Reilly book, *Learning Perl*. Like most developers, O'Reilly books have been a regular part of my life, helping me learn and make the most of the amazing technology developed by my peers. Back then I never would have dreamed that there would one day be a book written about software that I created, yet here we are today.

When I created NGINX, I did not seek to create an application that would be used worldwide. Even more than a decade ago, the problem of making our applications fast and reliable was keeping developers like me up late at night. While working at Rambler (a Russian search engine and web portal) back in 2002, I set out to solve for the C10K problem: how could we crack 10,000 simultaneous connections to a web server? NGINX was the first web server software to make 10,000 concurrent connections possible, and it saw rapid adoption after I open sourced it in 2004.

Fast forward 10 years, and the use of NGINX is remarkable. As of early 2015, we power 24% of all web servers and almost half of the world's busiest sites. Companies like Airbnb, Netflix, and Uber are using our software to invent the digital future, and the company we founded a few years ago to provide products and services for NGINX now has hundreds of customers, who have deployed thousands of instances of our load-balancing and application-delivery software, NGINX Plus.

This book is another remarkable milestone in our history. The journey here has not always been a smooth one. As with many popular products, NGINX has been developed iteratively and has evolved rapidly. Our users have faced challenges in making the most of what we built, and the absence of early documentation did not help matters. I am eternally grateful to our early community of users who helped translate and then extend our library of docs, and I hope that the release of this book now helps millions more adopt NGINX.

Thank you to everyone who has contributed so much to make NGINX what it is today. Whether you have contributed a patch or module, added to documentation or knowledge, or have simply used the product and provided feedback, you have helped

improve NGINX—together we have made the web better. I hope you continue to use NGINX, and in return I remain committed to providing you with powerful, light-weight software that lets you deliver amazing applications with performance, reliability, and scale.

Igor Sysoev, co-founder and CTO, NGINX

April, 2015

Preface

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic

Indicates new terms, URLs, email addresses, filenames, and file extensions.

Constant width

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

Constant width bold

Shows commands or other text that should be typed literally by the user.

Constant width italic

Shows text that should be replaced with user-supplied values or by values determined by context.



This element signifies a tip or suggestion.



This element signifies a general note.



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Acknowledgments

CHAPTER 1

Getting Started

nginx, pronounced “engine x” is a web server that’s gained incredible popularity among the most highly visited websites on the internet.

It isn’t fair to think of nginx as *just* a web server. It can do so much more— it can serve HTTP and HTTPS traffic, proxy to Rails, PHP or Node applications, run as a software load balancer, http cache, off-load ssl or even act as a SMTP, POP3, and IMAP mail server.

Most people think of nginx as a replacement to Apache. That’s true too, when looking at what the biggest websites on the internet are using today. According to Netcraft, as of March 2015, nginx is used by 21% of the top 1 million busiest websites on the internet.

As you’ll learn in this book, nginx is all of these things, but at the very core it’s an HTTP router, a living, breathing part of the web stack that gives developers the flexibility to build and deploy web apps easier than ever before.

Installing nginx

Let’s get the basics out of the way and get started with installing nginx. While it’s possible to run nginx on Windows, it’s not recommended, and the book operates under the assumption that you’re planning to install and run nginx on a common distribution of Linux.

You have two installation options, directly from source or a pre-built package for your operating system. While installing the package is much more convenient, it’s typically an outdated version. Fortunately, nginx.org publishes their own set of up-to-date packages for a variety of operating systems.



A note on nginx versions

As typical with open source projects, nginx has multiple version streams that run in parallel— *stable* and *mainline*.

The **stable version** (often, an even-numbered release, e.g., “1.4”, “1.6”) is the recommended production version. It lags behind any major feature development but gets critical bug fixes back ported to it. As of writing, the latest stable version is 1.6.2

The **mainline version** (often, an odd-numbered release), while still pretty stable, is where active development is done. It receives new features, faster bug fixes, and has an overall quicker cadence. That being said, mainline is not bleeding edge. Many people choose to run mainline in production for new features.

Installing from source

It’s very easy to build nginx from source, but first you’ll need to grab the code. Head to nginx.org and click the “download” link. You’ll need to choose whether to download the mainline or stable version, but building them is exactly the same.

For this example, I’m going to download the mainline version, 1.9.2. Once the file is downloaded (nginx-1.9.2.tar.gz), the next step is to uncompress it and enter the folder.

```
$ tar -zvxf nginx-1.9.2.tar.gz  
$ cd nginx-1.9.2
```

From here, building the source code is relatively simple if you have the basic build tools already installed.



Installing build tools

If you don’t have the basic build tools installed on your machine, you may need to refer to the documentation for your Linux distribution.

On Ubuntu or Debian, it’s as simple as installing the `build-essential` package.

```
apt-get install build-essential
```

On RedHat or CentOS, you’d just install the *Development Tools* package group.

```
yum group install "Development Tools"
```

```
$ ./configure  
$ make  
$ sudo make install
```



Installing nginx dependencies

For the most part, nginx is pretty lightweight and doesn't have very many library dependencies. That being said, the default build configuration depends on 3 libraries to be installed:

- **PCRE** (for the HTTP Rewrite module)
- **Zlib** (for the HTTP Gzip module)
- **OpenSSL** (for HTTPS protocol support)

These libraries can be installed from source or through the package manager.

On my Ubuntu machine, I was able to install these libraries with the following command:

```
$ apt-get install libpcre3-dev zlib1g-dev libssl-dev
```

By default, `make install` will install nginx and all related files into the folder `/usr/local/nginx/`.

The executable binary for nginx will be located at `/usr/local/nginx/sbin/nginx`.

You can test that everything went correctly and nginx works by running the command `nginx -V`. The `-V` flag will make nginx print the version number and compile-time build options. The output should look similar to this:

```
$ /usr/local/nginx/sbin/nginx -V  
nginx version: nginx/1.9.2  
built by gcc 4.8.2 (Ubuntu 4.8.2-19ubuntu1)  
configure arguments:
```

Specifying the install location

As mentioned above, the default installation path for nginx is `/usr/local/nginx/`. Often times, it's desirable to change the installation path to conform with the filesystem layout of the operating system distribution (i.e, to put all daemons in `/usr/sbin` or the configuration files in `/etc`).

To do this, you can specify the path of the base installation directory by passing it to the `configure` script with the `--prefix` flag.

Additionally, you can change the default location for the nginx configuration files (the default path is `/usr/local/nginx/conf`). This location can be passed to the `configure` script by using the `--conf-path` flag.

For instance, the most common nginx installation would have the nginx binary located in `/usr/sbin` and the configuration files in `/etc/nginx`. In order to make this happen, we'd run the configure script with the following flags:

```
$ ./configure --prefix=/usr --conf-path=/etc/nginx
```

Modules in nginx

nginx is an extremely modular piece of software. Even some of seemingly “built-in” pieces of the software, such as gzip or SSL, are actually built as modules that can be enabled and disabled during build time.

One of the benefits of building nginx from source is that you're able to specify exactly the modules you want, and which ones you don't. The downside is that if you don't include something that you later need, you'll have to rebuild nginx from source.

By default, nginx comes out of the box with the following modules— some enabled by default and some disabled by default.

Module Name	Flag	Description	Installed by Default?
Charset	<code>http_charset</code>	Adds the <i>Content-Type</i> header to the HTTP response	Yes
Gzip	<code>http_gzip</code>	Compresses the HTTP response	Yes
SSI	<code>http_ssi</code>	Processes Service-Side Includes	Yes
Userid	<code>http_userid</code>	Sets an HTTP Cookie suitable for Client Identification	Yes
Access	<code>http_access</code>	Allows limiting access to certain client IP addresses	Yes
Basic Auth	<code>http_auth_basic</code>	Allows limiting access by validating username and password using HTTP Basic Authentication	Yes
Auto Index	<code>http_autoindex</code>	Processes requests ending in “/” and produces a directory listing	Yes
Geo	<code>http_geo</code>	Creates variables with values depending on the IP address	Yes
Map	<code>http_map</code>	Creates variables whose values depend on other variable values	Yes
Split Clients	<code>http_split_clients</code>	Creates variables for use with split (A/B) testing	Yes
Referer	<code>http_referer</code>	Blocks access depending on the value of the HTTP Referer Header	Yes
Rewrite	<code>http_rewrite</code>	Changes the request URI using regular expressions	Yes
Proxy	<code>http_proxy</code>	Allows passing requests to another HTTP server	Yes
Fastcgi	<code>http_fastcgi</code>	Allows passing requests to a FastCGI server	Yes

uWSGI	<code>http_uwsgi</code>	Allows passing requests to a uWSGI server	Yes
SCGI	<code>http_scgi</code>	Allows passing requests to a SCGI server	Yes
Memcached	<code>http_memcached</code>	Used to obtain values from a Memcached server	Yes
Limit Conn	<code>http_limit_conn</code>	Limit the number of connections per IP address	Yes
Limit Req	<code>http_limit_req</code>	Limit the request processing rate per IP address	Yes
Empty GIF	<code>http_empty_gif</code>	Emits a single-pixel transparent GIF image	Yes
Browser	<code>http_browser</code>	Allows browser detection based on the User-Agent HTTP Header	Yes
Perl	<code>http_perl</code>	Implement location and variable handlers in Perl	No
SSL	<code>http_ssl</code>	Handle SSL traffic within nginx	No
SPDY	<code>http_spdy</code>	Provides experimental support for SPDY	No
RealIP	<code>http_realip</code>	Change the Client IP Address of the Request	No
Addition	<code>http_addition</code>	Adds text before and after the HTTP response	No
XSLT	<code>http_xslt</code>	Post-process pages with XSLT	No
Image Filter	<code>http_image_filter</code>	Transform images with libgd	No
GeoIP	<code>http_geoip</code>	Create variables with geo information based on the IP Address	No
Substitution	<code>http_sub</code>	Replace text in Pages	No
WebDAV	<code>http_dav</code>	WebDAV pass-through support	No
FLV	<code>http_flv</code>	Flash Streaming Video	No
MP4	<code>http_mp4</code>	Enables mp4 streaming with seeking ability	No
Gunzip	<code>http_gunzip</code>	On-the-fly decompression of gzipped responses	No
Gzip Precompression	<code>http_gzip_static</code>	Serves already pre-compressed static files	No
Auth Request	<code>http_auth_request</code>	Implements client authorization based on the result of a subrequest	No
Random Index	<code>http_random_index</code>	Randomize directory index	No
Secure Link	<code>http_secure_link</code>	Protect pages with a secret key	No
Degradation	<code>http_degradation</code>	Allow to return 204 or 444 code for some locations on low memory condition	No
Stub Status	<code>http_stub_status</code>	View server statistics	No

Enabling modules in nginx is as simple as passing an extra flag to the configuration script. For instance, if you wanted to enable the SSL module, you'd add the `--with-http_ssl_module` flag to enable it.

While the barebones build of nginx will get you through *most* of this book, I recommend that you re-build nginx with a few extra modules, specifically SSL, SPDY, RealIP, and Stub Status.

To accomplish this, re-run the configuration script with the extra flags listed below, as well as make and make install.

Remember, in order to build the SSL module, you'll need to have [OpenSSL](#) installed on your machine.

```
$ ./configure --with-http_ssl_module \
              --with-http_spdy_module \
              --with-http_realip_module \
              --with-http_stub_status_modul
$ make
$ sudo make install
```

After re-building nginx with the new modules, you may re-run `nginx -V` to verify that the new version of nginx, with the modules, have been properly installed.

You will notice in the output that *TLS SNI* has been enabled, as well as the configuration arguments we used above.

```
$ /usr/local/nginx/sbin/nginx -V
nginx version: nginx/1.9.2
built by gcc 4.8.2 (Ubuntu 4.8.2-19ubuntu1)
TLS SNI support enabled
configure arguments: --with-http_ssl_module --with-http_spdy_module
--with-http_realip_module --with-http_stub_status_module
```

Third party modules

In addition to many built-in modules, nginx also has a massive library of third party modules that aren't packaged with the main distribution.

You can find the modules on [wiki.nginx.org](#). There are over 100 third party modules, including everything from embedded lua scripting to upload progress bars.

Installing from a package

Installing nginx straight from your distributions package manager is easier and faster compared to building nginx from source.

The tradeoff is that your distribution's nginx packages are often outdated and you won't be able to install any of the 3rd party modules mentioned earlier.

That being said, nginx provides its own up-to-date pre-built packages for many of the most popular Linux distributions, including RedHat, CentOS, Debian, Ubuntu, and SLES.

Another advantage of installing nginx from your package manager is that the packages come with the necessary init or upstart scripts to easily run nginx as a daemon or automatically start after a reboot.

If you're just getting started, I highly recommend you take this path— the packages are built with sane default modules and generally involve less fuss.

Installing the RedHat/CentOS Package

```
$ sudo yum install nginx
```

Installing Ubuntu/Debian Package

```
$ sudo apt-get install nginx
```

Installing nginx.org Package (Ubuntu/Debian)

First, you'll need to grab the nginx signing key from their website so that the package manager can validate the authenticity of the packages.

```
$ wget http://nginx.org/keys/nginx_signing.key
```

Once that's done, the next step is to add the key you just downloaded from nginx.org to apt, using the `apt-key` command.

```
$ sudo apt-key add nginx_signing.key
```

Now, we need to find the codename of the Ubuntu/Debian release you're running. The easiest way to do this is to run `lsb_release -a` and look for the row labeled *Codename*.

```
$ lsb_release -a
No LSB modules are available.
Distributor ID: Ubuntu
Description:    Ubuntu 14.04.1 LTS
Release:        14.04
Codename:       trusty
```

In this case, the codename the Ubuntu release I'm using is *trusty*. We'll use this information for the next step.

For Debian, open the file `/etc/apt/sources.list` and add the entries below to the bottom of the file, replacing *codename*, with the one from running the `lsb_release` command.

```
deb http://nginx.org/packages/debian/ codename nginx
deb-src http://nginx.org/packages/debian/ codename nginx
```

For Ubuntu, open the file `/etc/apt/sources.list` and add the entries below to the bottom of the file, replacing *codename*, with the one from running the `lsb_release` command.

```
deb http://nginx.org/packages/ubuntu/ codename nginx
deb-src http://nginx.org/packages/ubuntu/ codename nginx
```

Great, almost there. The last step is to update apt and install the latest version of nginx.

```
$ apt-get update
$ apt-get install nginx
```

In all cases, no matter which route you chose, you can test the success by attempting to running `nginx -V`. You should see output should appear to be similar the output below:

```
$ nginx -V
nginx version: nginx/1.9.2 (Ubuntu)
built by gcc 4.8.2 (Ubuntu 4.8.2-19ubuntu1)
TLS SNI support
enabled configure arguments:
```


Basic Configuration

In this chapter, we'll cover the basics of configuring nginx— from getting it up and running for the first time, to configuring and running it in production.

The `nginx.conf` File

Like most software on Linux, the way that nginx works is specified in a configuration file called `nginx.conf`.

When nginx is built from source, the path to the configuration file can be specified by changing the `--conf-path` flag.

If nginx was installed from source, the default location of the `nginx.conf` file is `/usr/local/nginx/conf`.

If nginx was installed from a package, it may be located in `/etc/nginx` or `/usr/local/etc/nginx`, depending on the package maintainer and Linux distribution.

If you're not sure where to find the `nginx.conf` file, you can run `nginx -t` to determine the location.

```
$ /usr/sbin/nginx -t
nginx: the configuration file /etc/nginx/nginx.conf syntax is ok
nginx: configuration file /etc/nginx/nginx.conf test is successful
```

What does `nginx -t` do?

In addition to running as a web server, the nginx binary includes a few extra bits of utility functions that you can use.

Passing the `-t` command line flag just tests that the configuration file is valid and exits.

Here is a table for reference (this can be accessed by running `nginx -h`)

Option	Description
<code>-?, -h</code>	show the help
<code>-v</code>	show version and exit
<code>-V</code>	show version AND configure options then exit
<code>-t</code>	test configuration and exit
<code>-q</code>	suppress non-error messages during configuration testing
<code>-s signal</code>	send signal to master process: stop, quit, reopen, reload
<code>-p prefix</code>	set prefix path (default: /usr/share/nginx)
<code>-c filename</code>	set configuration file (default: /etc/nginx/nginx.conf)
<code>-g directives</code>	set global directives out of configuration file
<code>-T</code>	dumps the entire configuration to stdout

If you don't want to use the default path of the nginx configuration file, you can pass in your own location with `nginx -c filename`.

For instance, if you decided you wanted to use a nginx.conf file that was located in your home directory, the command would look something like this:

```
$ nginx -c /home/user/nginx.conf
```

Configuring and running nginx

The nginx configuration file is easy to understand and quite readable— the syntax reads somewhat like code.

The most basic nginx configuration that does *something* is shown in the block below.

```
events {  
}  
  
http {  
    server {  
    }  
}
```

You can paste this configuration into your nginx.conf file, but before anything happens, you need to run the nginx server. There are a few different ways to do that, depending on if you built nginx from source or installed it from a package.

If you used a package manager to install nginx, it was probably packaged with an init script that can be used—`service nginx start` will start the server.

If you installed nginx from source, you can simply run `nginx` to start the server.

You may not see any output when you start nginx, that's completely normal. To verify that nginx is running, you can use `ps` to check if the process is running or try to access the web server with `curl`.

Using `ps`, you grep the output for nginx, and should see a master and worker process running.

```
$ ps aux | grep nginx
root 24323 0.0 0.0 85772 1213 ? Ss 01:24 0:00 nginx: master process
nobody 24324 0.0 0.0 85992 2004 ? S 01:24 0:00 nginx: worker process
```

Using `curl`, you should see some HTML output if you try to access port 80 on localhost.

```
$ curl 127.0.0.1
<!DOCTYPE html>
<html>
<head>
<title>Welcome to nginx!</title>
```

Wait, that's right—with the simple 7-line configuration file nginx is actually serving up static files to the internet. By default (with this empty configuration), nginx will share the contents of the `/usr/share/nginx/html` directory on port 80.

If you add a file to this directory and try to access it from `curl`, the contents would be returned to you.

Filling in the blanks

Obviously, there must be something else going on or some default values if nginx is serving HTTP requests to `/usr/share/nginx/html` with a nearly blank configuration file.

Here is what that same configuration file *actually* looks like with the default values added.

Example 2-1. Basic configuration file, with defaults values

```
user nobody nogroup;
worker_processes 1;

events {
    worker_connections 512;
}
```

```
http {
    server {
        listen *:80;
        server_name "";
        root /usr/share/nginx/html;
    }
}
```

With this filled out configuration file, you can start to get a sense for what the nginx configuration syntax looks like and how it works.

The configuration file is made up of *directives*. There are two types of directives that you'll encounter.

Simple Directives

The most basic is called a *simple directive*. A simple directive is just a simple statement, like `listen *:80;`.

The simple directive is made up of a name (`listen`), the parameters (`*:80`), and a closing semicolon (`;`).

Simple directives often can take multiple parameters, some of which can be optional. When a directive has optional parameters, they are typically named parameters and passed into the directive as a key-value pair OR just the key name for true values.

For instance, the `listen` directive has 14 optional parameters, which can be specified in any order. Two of the optional parameters for the `listen` directive are “`ssl`” and “`backlog`”, which are turned on the example below.

```
listen *:80 ssl backlog=511;
```

Note that for `ssl`, the parameter was passed without a corresponding value. This indicates a true value and turns SSL on.

Context Directives

The *context directive* has a similar syntax as the simple directive except instead of ending in a semicolon, it wraps a group of directives inside of curly braces.

For example, the `server` block wraps the `listen`, `server_name`, and `root` directives.

Context directives can be nested, and provide somewhat of a configuration inheritance model within the configuration file.

Examples of context directives are `events`, `http`, and `server`. There are a handful of other contexts that you'll see presented in the next few chapters.

Typically, simple directives can only be included in specific context directives. For example, the *listen* directive can only be present in the server context. The list of contexts supported is shown in the documentation for each directive.

The last thing to note—there is an implied main context wrapping the configuration file. Putting something in the main context simply means that it's at the top-level of the configuration file and isn't included under any other context.

Directive Inheritance

nginx has a very lightweight inheritance model. Directives are always inherited downwards.

For example, you may overwrite previously defined directives in nested contexts.

```
server {  
    root /usr/share/nginx/html;  
  
    location /foo {  
        root /usr/share;  
    }  
}
```

While we haven't covered the location context yet, you can see in the example that we're overwriting the root directive.

If the root directive was not explicitly specified inside of the location block, the value would be inherited from the server context.

The more complex inheritance rules will be covered in the Advanced Configuration chapter.

So let's dig into the configuration file and talk about what's going on with each line, starting with the first two.

```
user nobody nogroup;  
worker_processes 1;
```

Lines 1 and 2 configure the *user* directive and the *worker_processes* directive. Since they aren't wrapped in a context directive, they are implicitly part of the main context.

The user directive sets the unix user and group that the nginx worker processes will run as. By default, the user is **nobody** and the group is **nogroup**.

Remember, in the unix world, every process needs to be run as an explicit user. Generally, with network facing services, you want the daemon to run with the least amount of privileges are possible.



Running nginx as a non-root user

If you choose to run nginx as a non-root user, the `user` directive will be ignored. nginx will also not be able to bind to ports below 1024.

This user will potentially need to have permission to read and write to the log files, store temporary data, and read data from static files.

You may notice that if you run `ps`, there are two nginx processes, a master running as root and a worker running as nobody.

```
$ ps aux | grep nginx
root  24484 0.0 0.0 85772 1312 ? Ss 1:38 0:00 nginx: master process
nobody 24485 0.0 0.0 85992 2004 ? S 1:38 0:00 nginx: worker process
```

On a Linux, only the root user is able to bind to port numbers below port 1024. Because of this, nginx is typically started as root to allow it to bind to port 80 and port 443.

The master process reads and executes the nginx configuration, binds the necessary ports, and runs the worker processes.

The worker process, running as the user specified in the configuration file, is where incoming HTTP requests are served from.

The number of worker processes is configured with the `worker_processes` directive. By default the value is 1, meaning that nginx will run 1 worker process.

It's common practice to set the number of worker processes to the same number of CPU cores that you have on your machine. The value of `auto` can be set on `worker_processes` to have nginx auto-detect the number of logical CPU cores. For example, a single Intel CPU core with Hyperthreading enabled will appear as 2 logical CPU cores.

Events Context

The `events context` is the next section of the configuration file. This context is used to configure parts of the connection processing part of nginx.

There can only ever be one events context and it must be in the main context.

```
events {
    worker_connections 512;
}
```

nginx is an *event* driven server. Each worker process is single-threaded and runs a non-blocking event loop to process requests very quickly.

The events context allows you to tweak and tune some of the settings that drive event loop.

The *worker_connections* directive sets the maximum number of simultaneous connections that can be opened by each worker process. The default is 512 connections per worker process.

This limit doesn't just include connections from clients (e.g, browsers making requests to nginx), but also any subsequent connections that nginx has to make to talk to your PHP or Rails application.

On Linux, each connection is counts as an open file, and there is an operating system limit on the maximum number of open files allowed per process. If you decide increase this value, you'll need to also increase the maximum number of open files allowed. More on tuning this in the future chapters.

HTTP and Server Contexts

The HTTP context is where you define your HTTP servers and any applicable directives.

Typically, the HTTP context and the server contexts go hand-in-hand. That is to say, the HTTP context is mostly a container for holding one or more server contexts.

Because it's possible to define multiple server contexts, it's often convenient to put shared directives inside of the HTTP context, since the nginx inheritance model will make these directives apply to all of the server contexts contained within.

The server context can only ever be specified within the HTTP context, and the HTTP context must always be part of the main context.

```
http {
    server {
        listen *:80;
        server_name "";
        root /usr/share/nginx/html;
    }
}
```

Let's look at what's going on here— very simply, we're creating an HTTP server to listen on port 80 of every network interface, with no HTTP Host specified, and a root path of /usr/share/nginx/html.

Listen Directive.

The listen directive tells the server which network interface and port to listen on, and defaults to `*:80`.

A listen directive may be specified multiple times in a single server block. For example, if you wanted a server to listen on two different ports—

```
server {  
    listen *:80;  
    listen *:81;  
}
```

Typically this is used when you turn on SSL on, for example, to listen for non-SSL traffic on port 80 and SSL traffic on port 443.

```
server {  
    listen *:80;  
    listen *:443 ssl;  
}
```

Server_name Directive. The *server_name* directive is used to determine which server context to use for an incoming request. This directive is very useful for virtual hosting, when you want to host multiple domain names on the same interface and port.

The *server_name* is matched against the HTTP Host header of the incoming request. The HTTP Host header is specified by the HTTP client to indicate which domain name that it's attempting to access.

For example, an HTTP request made to nginx may look something like this:

```
GET /foobar.html HTTP/1.0  
Host: example.org  
User-Agent: FakeUserAgent/1.0
```

The Host header (example.org) is used to match against the value in the *server_name* directive.

The *server_name* can be an exact domain name (including subdomains), a wildcard, or regular expression.

A value of “” means that no Host header is necessary.

Root Directive.

The root directive specifies the path of the directory to serve static files out of. Any and all files in the root directory will become publicly available over HTTP.

```
server {  
    listen *:80;  
    server_name "";  
    root /usr/share/nginx/html;  
}
```

Given the above configuration, any files in `/usr/share/nginx/html` can be accessed via HTTP by making a web request to `http://127.0.0.1`.

If you were to add the file `test.html` to this directory, it could be accessed over HTTP by hitting `http://127.0.0.1/test.html`.

Likewise, any directory in the URI is just appended to the root path, so a request to the URL `http://127.0.0.1/foo/test.html` would resolve to the filesystem path `/usr/share/nginx/html/foo/test.html`.

Reloading and Stopping nginx

Earlier in the chapter, we discussed how to start the nginx server. Depending on how you installed nginx, it's as simple as running the binary.

Depending on how you've installed nginx, it may have come with an init.d script, and you can start it by running a command line `service nginx start`.

Ultimately, though, you can just start nginx by running the binary directly, `nginx`.

When you make a change or modify the nginx configuration, nginx does not pick it up automatically—you need to reload the process.

You can reload nginx by sending it the standard unix signal, HUP. In order to send a unix signal to a process, you first need to know the *pid* (process id). When you start nginx, it writes the pid of the master process to the file `/var/run/nginx.pid`.

Putting it all together, to reload nginx, send the HUP signal with the command:

```
kill -HUP `cat /var/run/nginx.pid`
```

When you reload nginx, it will actually verify the syntax of your configuration file first, so you don't have to worry about accidentally killing nginx if you try to reload it with an invalid configuration file.

Reloading nginx actually starts new worker processes and kills off the old ones. It's able to do this completely gracefully, without dropping or killing any web requests. It does this by starting the new workers, discontinuing to send traffic to the old workers, and waiting for the old workers to complete all in-flight requests before killing them.

Likewise, you can also shutdown nginx gracefully without dropping any in-flight or processing requests by sending it the QUIT signal:

```
kill -QUIT `cat /var/run/nginx.pid`
```

The list of unix signals that nginx responds to (and the behavior) is listed below:

Signal	Description
TERM, INT	Quick shutdown
QUIT	Graceful shutdown

Signal	Description
KILL	Halts a stubborn process
HUP	Configuration reload
USR1	Reopen the log files (useful for log rotation)
USR2	Upgrade executable on the fly
WINCH	Gracefully shutdown worker processes



Making configuration changes

Anytime that you make a configuration change to your `nginx.conf` file, you'll have to explicitly tell nginx to reload the configuration with the `HUP` signal— nginx does **not** pick up configuration changes automatically.

Upgrading the nginx binary without Downtime

When you reload the nginx configuration, it starts new workers, but the master process does not change.

This works great if you're just updating the configuration, but what if you have a new version of nginx that you want to deploy?

No worries, nginx can actually upgrade itself on the fly without any downtime.

First, build or install the new version of nginx that you want to run.

Next, find the master process id by running checking the nginx pid file, located at `/var/run/nginx.pid`.

```
$ cat /var/run/nginx.pid
24484
```

In this example, the master PID is 24484. We need to send it the `USR2` signal, which starts the new master process and new workers.

```
$ kill -USR2 24484
```

After sending `USR2` to the old master process, nginx will start up a new master process and workers. These two processes will serve incoming requests together.

Next, we need to kill the children of the old nginx master. Since we don't want to drop any in-flight requests, we use the `WINCH` signal to tell the old nginx master to stop taking new requests and shutdown down the children once all in-flight requests are finished.

```
$ kill -WINCH 24484
```

After a short time, when all in-flight requests are complete, the old nginx children will shutdown and the upgraded version of nginx will be running and serving request.

There's still one last thing to do. The old nginx master is still running and hanging around.

If you need to bail out of the upgrade, you can actually ask the old master to spin up children and serve requests again by sending it the HUP signal.

Otherwise, you can go ahead and kill the old master by sending it the QUIT signal:

```
$ kill -QUIT 24484
```

Serving Static Files

Now that we've gone over a bit about the basic directives in the nginx.conf file, let's talk about how to do something practical with nginx so that you can begin using it.

The most basic case for nginx is serving static files. While nginx can do plenty of other things (dynamic web applications, reverse proxying, http caching), the foundation of nginx all builds on the http and server directives.

Typically, when you serve static files (html, css, javascript, images, etc) from a web server, all of the files are stored in a common directory called a *directory root*. The directory root is the base directory that you want to make available through the web server.

For example, if you have a document root of `/usr/share/nginx/html`, when someone requests the URL `http://example.org/test.html`, the server will attempt to locate the test.html file inside of the directory `/usr/share/nginx/html`.

Example 2-2. Nginx with a document root

```
server {  
    listen *:80;  
    root /usr/share/nginx/html;  
}
```

What happens when you access a URL without specifying a file, for example, `http://example.org/`? By default, nginx blesses a special file named index.html to be shown when a filename isn't specified in the URL.

It's possible to override this behavior and specify your own default index with the `index` directive.

Example 2-3. Make foobar.html the index

```
server {  
    listen *:80;  
    root /usr/share/nginx/html;  
    index ADifferentIndexFile.html;  
}
```

You may also pass multiple index files to the index directive. When you do this, nginx will check for the existence of each file and serve the first one that exists. The index file name can include nginx variables. The last file name in the list may also be an absolute path.

Example 2-4. Multiple index files

```
server {  
    listen *:80;  
    root /usr/share/nginx/html;  
    index maintenance.html index.html;  
}
```

In the example above, we're implicitly checking for the existence of the index file maintenance.html. If it exists, that file is served as the index. If it doesn't, we proceed as normal and serve the regular index.html page.

This mechanism is a common way to handle deployments or other scheduled downtime— before deploying or making changes, you create a maintenance.html page and have nginx serve that. When you're done, just delete the file and it'll go back to serving index.html.

The Location Block

It's typical to have more advanced needs when serving requests through nginx. The static file examples in the previous section depends on 1:1 mapping between the path of the HTTP Request and the filesystem.

For example, a request to `http://example.org/foo/bar.html` depends on the existence of `bar.html` within the directory `foo`. This works for simple cases, but often times it's not that simple.

This is where the *location* block shines— it allows us to provide a custom configuration for incoming request URI by matching it against a prefix string or regular expression.

If you're coming from Apache land, it's an easier and, in my opinion, more elegant rule to express similar functionality as Rewrite Rules.

Basic Location Blocks

The basic syntax for a location block looks like this:

Example 2-5. Basic location block syntax

```
location optional_modifier uri_matcher {  
    configuration_directives  
}
```

Let's look at a basic example.

Example 2-6. Basic location block example

```
location / {  
    root /var/www/html;  
}  
location /foobar/ {  
    root /data;  
}
```

The example above defines two prefix location blocks, one for the path `/` and the other for the path `/foobar/`.

The first location block simply serves request URIs matching the prefix `/` out of the directory `/var/www/html`. For example, `http://example.org/file.html` will be resolved to `/var/www/html/file.html`. This is the exact same behavior as completely skipping the location block and specifying the root directive within the server block.

The second location block does something different. It matches against the prefix `/foobar/` and serves it out of a different directory entirely. When a request URI begins with the prefix `/foobar/`, it will use the root directory `/data`.

So, for example, a request to `http://example.org/foobar/test.html` will resolve to the filesystem path `/data/foobar/test.html`.

Appending the path and replacing the path

Notice that in all of the examples so far, when we use the root directive, the request URI path is appended to the root directive.

Sometimes, instead of appending the URI to the root path, we want to replace it instead.

To accomplish this, we can use the *alias* directive instead. It's similar to root, except it replaces the specified location.

Example 2-7. Location block using alias

```
location /gifs/ {  
    alias /data/images/;  
}
```

In this example, a request to `http://example.org/gifs/business_cat.gif` will be resolved to the path `/data/images/business_cat.gif`.

If we had used root instead, the same request uri would resolve to the path `/data/images/gif/business_cat.gif` instead.

The trailing slash is important with alias, as without it, the path would end up being `/data/imagesbusiness_cat.gif`

When there are overlapping prefix location blocks, the most specific match is used. Let's look at the following example:

Example 2-8. Overlapping prefix location blocks

```
location /foobar/images {  
    ...  
}  
  
location /foobar/ {  
    ...  
}
```

In this case, a request URI for `http://example.org/foobar/images/gifs/file.gif` will use the `/foobar/images` location block, even though it matches both blocks. The order of prefix location blocks does not matter, the most specific match will be used regardless.

As you've noticed, the prefix location blocks match any request URI that are prefixed with the path specified. You can use the *exact match modifier* (=) to match an exact request URI.

Example 2-9. Matching an exact request URI

```
location = /foobar/images/business_cat.gif {  
    ...  
}
```

In this example, the location block will **only** match the exact request URI for the path `/foobar/images/business_cat.gif`. The fact that it matches a filename is not important, it can match any arbitrary request URI.

Example 2-10. Matching an exact request URI without a filename

```
location = /foobar/ {  
    ...  
}
```

This location block will only match an exact request URI to `/foobar/`. It won't match `/foobar/index.html` or anything besides an exact match.

Location blocks with an exact match modifier are the first blocks to be checked for a match and **will terminate the search and immediately be selected for use**.

Example 2-11. Example of = block being selected

```
location = /foobar/ {  
    ...  
}  
  
location /foobar/ {  
    ...  
}
```

In the example above, a request URI for `/foobar/` will always use the first location block, even though the prefix block also matches the same request URI.

Because the exact match modifier will immediately terminate the location block search, you can improve performance by creating exact match blocks for highly accessed URIs when you have a configuration with many location blocks (this becomes even more useful with regular expression blocks, discussed in the next section, as they are more intensive to process).

Regular Expression Location Blocks

In the previous section, we discussed prefix and exact match location blocks. These types of location blocks are very useful but they're not very dynamic— sometimes you need to match on more than just the prefix.

Regular expression location blocks give you that power. They allow you to specify a regular expression that's used to match the request URI.

Unlike using prefixes, the order of regular expression location blocks matters. Each block will be processed, in order of declaration, and the first to match the request URI will be used to serve the request.

Example 2-12. Basic regular expression example

```
location ~ \.(gif|jpg)$ {  
    ...  
}
```

This location block uses the regular expression `\.(gif|jpg)$` to match any URIs ending in the extension `.gif` or `.jpg`.

Notice how the location block also uses a modifier, `~`, before the regular expression. The `~` is the modifier to create a *case-sensitive regular expression* location block.

Because this example uses a case-sensitive matcher, it will match the URI `images/picture.gif` but not `images/picture.GIF`.

Creating a *case-insensitive regular expression* location block is almost the same, but uses the `~*` modifier instead.

Example 2-13. Example of a case-insensitive regular expression

```
location ~* \.(gif|jpg)$ {  
    ...  
}
```

Because regular expression are more processor intensive to process and match against, use them only when necessary! It will always be faster to process a location block that uses prefixes than one that uses regular expressions.

Skipping Regular Expressions

There's one more type of location block modifier that allows us to skip the processing of regular expressions, the *carat and tilde* (`^~`) modifier.

Let's look at an example where this type of modifier would be useful.

Example 2-14. Overlapping prefix and regular expressions

```
location /foobar/images {  
    root /var/www/foobar;  
}  
  
location ~* \.(gif|jpg)$ {  
    root /var/www/images;  
}
```

Because regular expressions are matched **after** the prefix locations, if there is a request URI for `/foobar/images/dog.gif`, the regular expression block will always be used. The two blocks are competing for the same paths.

One way to solve this would be to rewrite the regular expression to exclude the /foobar/images path, but this would make it more complicated and confusing.

Instead, we can change the /foobar/images location block to use the carat-tilde modifier.

Example 2-15. Example using the carat-tilde modifier

```
location ^~ /foobar/images {  
    root /var/www/foobar;  
}  
  
location ~* \.(gif|jpg)$ {  
    root /var/www/images;  
}
```

When the carat-tilde modifier is chosen as the best prefix for a URI, it is immediately selected and skips matching against the regular expression blocks.

Therefore, a URI for /foobar/images/dog.gif will use the first location block while /images/cat.gif will match the regular expression and use the second location block.

The Location Block Selection Algorithm

At this point, we've learned about all of the different types of modifiers that influence how a request URI is matched to a location block.

Modifier	Name	Description
(none)	Prefix	Matches on the prefix of a URI
=	Exact Match	Matches an exact URI
~	Case-Sensitive Regular Expression	Matches a URI against a case-sensitive regular expression
~*	Case-Insensitive Regular Expression	Matches a URI against a case-insensitive regular expression
^~	Non-Regular Expression Prefix	Matches a URI against a prefix and skips regular expression matching

The exact search algorithm that nginx uses to select the location block is described as follows:

1. The exact match location blocks are checked. If an exact match is found, the search is terminated and the location block is used.
2. All of the prefix location blocks are checked for the most specific (longest) matching prefix.
 - a. If the best match has the `^~` modifier, the search is terminated and the block is used.
3. Each regular expression block is checked in sequential order. If a regular expression match occurs, the search is terminated and block is used.
4. If no regular expression block is matched, the best prefix location block determined in step #2 is used.

Named Location Blocks

There's one last type of location block that I haven't mentioned yet—the named location block. These types of location blocks are a bit different in that they cannot be used directly for regular request processing and will never match the request URI. Instead, they are used for internal redirection. Named locations are denoted by the `@` prefix.

Example 2-16. Example of unused named location block

```
location @foobar {  
    ...  
}
```

In the above example, we declare a named location block. In its current form it does nothing! It will never be used unless it's called explicitly within the nginx configuration file. So how do we call it?

Example 2-17. Named locations for try_files

```
location / {  
    try_files maintenance.html index.html @foobar;  
}  
  
location @foobar {  
    ...  
}
```

The example above introduces a new directive, `try_files`, which checks for the existence of the file names provided, in order from left to right, and uses the first one found to service the request.

The last parameter to `try_files` may be either an internal redirect using a named location block (in this case, `@foobar`) or an explicit error code (shown in the next example).

When `try_files` can't find any of the files in its parameter list, it will redirect to the `@foobar` location block and allow the block handle the request.

We'll dig into `try_files` more in Chapter 3 (FastCGI) and Chapter 4 (Reverse Proxy), as it's commonly used when talking to dynamic backends, such as PHP and Ruby applications.

Example 2-18. try_files with an error code

```
location / {  
    try_files maintenance.html index.html =404  
}
```

If neither `maintenance.html` nor `index.html` are found, `try_files` will return the HTTP error code 404.

Location Block Inheritance

Section content goes here

Virtualhosts

So far, we've only talked about configuring a single server block, which limits us to running a single website within nginx.

Fortunately, nginx allows us to define as many server blocks to host as many websites as we want! This is called virtual hosting.

Example 2-19. Basic virtual hosts example

```
server {  
    listen 80;  
    server_name example.com;  
}  
  
server {  
    listen 80;  
    server_name foobar.com;  
}
```

In the above example, we define two server blocks, both listening on port 80, for the domain names `example.com` and `foobar.com`. These two blocks are completely independent and can define their own location directives.

Remember that `server_name` can contain subdomains, wildcards, and regular expressions. The first domain parameter to `server_name` is considered the primary server name.

All of these are valid `server_name` directives:

```
server_name example.com www.example.com;
```

Using wildcards:

```
server_name example.com *.example.com www.example.*;
```

Alternative way to match both `example.com` and `*.example.com`:

```
server_name .example.com;
```

You may use a regular expression by prefixing it with a tilde (~):

```
server_name ~^www[0-9]\.example\.com$;
```

Regular expressions may also contain captures, allowing you to set dynamic variables based on the match.

Example 2-20. Example using capture group

```
server {  
    listen 80;  
    server_name ~^(www\.)?(?<domain>.+)$;  
  
    location / {  
        root /sites/$domain;  
    }  
}
```

This example sets the `root` path dynamically based on the name of the domain.

Notice how the `server_name` regex contains the syntax `(?<domain>.+)?` This is the syntax for a *named capturing group*, the name being everything between the brackets.

When you use a named capturing group, you're basically saying “remember whatever data matches the regular expression between these two parenthesis”. In this case, that regular expression is matching everything after the “www.” in the domain name.

Because you've asked nginx to remember the data matched in the regular expression **and** you used a named capture group to name it “domain”, the variable `$domain` is set with that data and subsequently used a few lines lower to dynamically set the root path.

We'll dig into variables later in the chapter, but for now all you need to know is that they allow you pass dynamic data into various directives.

Default Server Block

When you have multiple server blocks, how does nginx decide which one to use? First, it matches the IP Address and Port that the request was received on and only considers server blocks that are listening on that IP Address and Port combination (by default, all IP Addresses and Port 80).

After that, nginx matches the HTTP Header "Host" from the request against the `server_name` directive in each server block.

If there are more than one `server_name` directives that match the Host header, the first matching one will be chosen, similar to how location blocks are chosen.

1. The exact name (`www.example.com`)
2. The longest wildcard name starting with an asterisk (`*.example.com`)
3. The longest wild card name ending with an asterisk (`www.*`)
4. The first matching regular expression, in the order defined in the configuration

If there **no** `server_name` directives that match the Host header (or the Host header is not present), nginx chooses the *default server block*. Out of the box, the default server block is the first one defined in the configuration file.

You may explicitly choose the default server block by setting the `default_server` parameter on the `listen` directive.

Example 2-21. Explicitly setting the `default_server` parameter

```
server {  
    listen 80;  
    server_name example.com;  
}  
  
server {  
    listen 80 default_server;  
    server_name foobar.com;  
}
```

In the above example, the second server block will match requests to `foobar.com` **and** any requests on port 80 that aren't to the domain `example.com`.

Dropping requests without a server name

You can choose to drop requests made to your server without a Host header set, as this usually signifies an invalid or misbehaving HTTP client.

The way you do this is by defining a server block with an empty `server_name` that returns a special nginx HTTP error code.

Example 2-22. Server that drops requests

```
server {  
    listen 80;  
    server_name "";  
    return 444;  
}
```

The `return` directive stops processing the request and returns the specified HTTP error code. In this case, we return a non-standard HTTP code, 444, which is special code that tells nginx to immediately close the connection.

Additionally, if you'd like to drop requests made to your server without an explicitly defined domain name, you can mark this server block as the `default_server`.

Configuring SSL

SSL (Secure Sockets Layer) is a way to create a secure connection between an HTTP Client and an HTTP(S) Server. nginx offers a very robust and high performance SSL implementation.

To get started with setting up SSL, you'll need to have an SSL certificate and key.

Example 2-23. Most basic SSL Configuration

```
server {  
    listen 80;  
    listen 443 ssl;  
    server_name www.foobar.com;  
    ssl_certificate www.foobar.com.crt;  
    ssl_certificate_key www.foobar.com.key;  
}
```

You'll notice a few new things here— first, there are two `listen` directives specified, one listening on port 80 and other on 443. This setup allows us to create a compact server block that server both non-SSL **and** SSL requests. We use the `ssl` parameter to tell nginx that we expect SSL traffic on this port.

The other two new directives are `ssl_certificate` and `ssl_certificate_key`. `ssl_certificate` tells nginx the path to find the signed certificate (in PEM format) for this domain. Likewise, `ssl_certificate_key` specifies the path to the key for the certificate

If you specify just a filename or relative path (i.e, `ssl/certificate.crt`), nginx will prefix the path with the configuration directory, `/etc/nginx`.

You may also specify an absolute path, i.e `/usr/share/ssl/foobar.com.crt`.



Beware outdated SSL information

In previous versions of nginx, there were substantially different ways to configure SSL that are no longer valid syntax or non-optimal.

For example, in previous versions (prior to 0.7.14) of nginx you had to configure separate server blocks, one for non-SSL and another for SSL.

Sharing a wildcard certificate

It's possible to generate a wildcard SSL certificate that is valid for multiple domains, or subdomains.

Perhaps we have a certificate for the domain name `*.example.com` and want to share it with several server directives that serve various subdomains on `example.com`.

Instead of having to configure the same `ssl_certificate` and `ssl_certificate_key` directives for each server block, we can set it at the `http` block level instead, and the server blocks will inherit the directives.

Example 2-24. Example sharing SSL directives

```
http {
    ssl_certificate star.example.com.crt;
    ssl_certificate_key star.example.com.crt;

    server {
        listen 80;
        listen 443 ssl;
        server_name www.example.com;
    }

    server {
        listen 80;
        listen 443 ssl;
        server_name billing.example.com;
    }
}
```

This also has the benefit of having a lighter memory footprint as the certificate data will only be loaded into nginx one time.

SNI and the future of SSL

Up until recently, HTTPS had the major disadvantage that each and every SSL server had to have its own dedicated IP Address.

The reason for this is that the *entire* HTTP Payload gets encrypted during the request, even the HTTP Host Header, which is how you determine which server block *and* SSL configuration to use. It's a catch-22—without the Host header, you don't know which SSL configuration to use, and without the SSL configuration, you can't decrypt the HTTP Payload to get the Host Header.

Thus, each HTTPS site was put on its own IP Address, so that you could determine which domain and SSL configuration it belonged to without having access to the HTTP Host Header.

Unfortunately, we're quickly running out of IPv4 IP Addresses. They're getting scarce and expensive. The one-IP-per-website thing doesn't scale anymore.

To address this problem, SNI (Server Name Indication) was created. Simply put, an SNI-enabled browser passes the domain name unencrypted so that we know which SSL certificate to use. It means that many websites can share a single IP Address and **still** have SSL.

That being said, SNI is only supported on modern browsers, specifically:

- Chrome (Windows version only Vista or newer)
- Safari 3.2.1 (Windows version only Vista or newer)
- Firefox 2.0
- MSIE 7.0 (only on Windows Vista or newer)
- Opera 8.0

CGI, FastCGI, and uWSGI

Until the mid-1990s, there wasn't an easy way to create dynamic pages for the web. If you wanted to do more than serve static HTML files or images, you'd have to write your own web server.

Writing your own web server for every application is clearly a case of "reinventing the wheel", so it was obvious that something better was needed—a way to extend the web server.

To serve that need, CGI (Common Gateway Interface) was officially born in 1997. CGI is an interface for web servers to communicate with programs (or scripts) on the web server. CGI gave programmers the ability to write their own dynamic web application by extending the web server software.

Because it's a *Common* Gateway Interface, CGI is a programming language independent.

Although plain CGI isn't used much in recent years (it's not even supported out-of-the box by nginx), it's worth understanding because the more modern replacements that we'll cover later in the chapter are built on it.

How CGI works

CGI works by executing the script or program, on demand, whenever it is requested by the HTTP client.

We've all seen the old school `http://example.com/cgi-bin/script.php` URLs. What's going on there? What's a *cgi-bin* anyways? Time for a deep dive.

When a web server receives a request for a CGI script, it simply executes the scripts directly and returns the output to the browser.

For example, for this hypothetical example, let's pretend we have the following PHP script that we want to run as a CGI script. The script will be saved to the file system as *script.php*.

```
#!/usr/bin/php

<?php

echo "Content-Type: text/plain\n";
echo "PHP-CGI Script! Woohoo<br>";
echo time();
```

If you wanted to run this script from the command line on the server yourself, you'd just type the name of the script, press enter, and it would execute.

```
$ ./script.php

Content-Type: text/plain
PHP-CGI Script! Woohoo<br>
1429629271
```

Well, what does that have to do with CGI? Remember, CGI is just a fancy way of saying “the web server executes the script directly”. When you access *script.php* from the web server, it's just running *./script.php* and returning the output to the browser.

You might be thinking, that seems **insecure**. What if you tried to run dangerous commands like *rm* to delete files? If the web server is just running the commands, couldn't you run anything? And you'd be right.

That's where the *cgi-bin* directory comes in to play. Typically, with CGI, there's a special directory that's used to designate which programs are safe to run. This directory can be named anything, but it's commonly named and referred to as the *cgi-bin* directory.

The other missing piece of CGI is the context, or environment, of the HTTP request. The CGI script needs a way to retrieve things like the Request URI, Client IP Address, or Server Host from the HTTP Request.

With CGI, these are all passed into the script as environment variables. For example, if we wanted our CGI script to output the Client IP Address, we might write the following:

```
#!/usr/bin/php

<?php

echo "Content-Type: text/plain\n";
echo "PHP-CGI Script! Woohoo<br>";
echo $_SERVER["REMOTE_IP"];
```

If we were executing this script from the command line, we'd have to pass in the REMOTE_IP environment variable, shown below.

```
$ REMOTE_IP=127.0.0.1 ./script.php
Content-Type: text/plain
PHP-CGI Script! Woohoo<br>
127.0.0.1
```

When accessed via CGI through the web server, the same thing is happening. There are a standard group of environment variables that are passed from the web server to the CGI script to provide context about the web request. These environment variables are listed in the table below.

Variable	Definition	Example
GATEWAY_INTERFACE	The version of the CGI protocol being used by the web server.	CGI/1.1
SERVER_SOFTWARE	The name of the web server software making the CGI call.	nginx
QUERY_STRING	The HTTP query string of the web request.	foo=bar&foobar=1
REQUEST_METHOD	The HTTP request method	POST
CONTENT_TYPE	The HTTP Content-Type	text/plain
CONTENT_LENGTH	The Length of the HTTP Request	100
SCRIPT_FILENAME	The path of the CGI script being executed	/var/www/cgi-bin/test.php
SCRIPT_NAME	The virtual path of the CGI script	/cgi-bin/test.php
REQUEST_URI	The path to the requested file by the client	/cgi-bin/test.php?foo=bar
DOCUMENT_URI	The path part of the URL to the cgi script	/cgi-bin/test.php
DOCUMENT_ROOT	The root path of the server	/var/www/html
SERVER_PROTOCOL	The type of protocol being used by the client/server	HTTP/1.0
REMOTE_ADDR	The IP Address of the client	108.22.12.23
REMOTE_PORT	The port of the client	9583
SERVER_ADDR	The IP Address of the server	192.168.10.1
SERVER_PORT	The port of the server	80
SERVER_NAME	The server hostname	app01

While serving up static html is easy, there's only so much that can be done with html and javascript. It's impossible to create rich applications without a backend or server-side component.

There's generally two different ways to use nginx with a backend web application—FastCGI is one of the ways. The other method, using a reverse proxy, will be covered in the next chapter.

Typically, FastCGI is only relevant if you're deploying PHP applications. Most other languages (Ruby, Node, Go, etc) have moved past CGI and it's best practice to use a Reverse Proxy Server.

What is FastCGI?

nginx does not support regular, old-school CGI. In the traditional CGI model, when the script is accessed, the web server actually has to fork and execute the script.

This has all of the disadvantages that you might imagine. The performance is relatively poor, since forking is a slow and an expensive system call to make.

The security model is also risky. If an attacker finds a way to upload a script to that blessed cgi-bin directory, they can run any script that they desire. You don't want the webserver to be able to execute any arbitrary script on your server.

However, CGI has one advantage: it's extremely simple. Plop a perl or php script into a special directory and you're good to go. No special servers, no deployment.

FastCGI Basics

FastCGI is a direct replacement for CGI. It solves the performance and security concerns but adds a little bit of complexity to the way that applications are run.

With CGI, the web server is executing the scripts directly. There is no layer between the two- they talk directly.

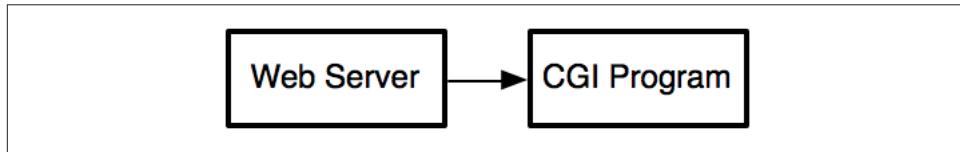


Figure 3-1. Web Server executing CGI program directly

With FastCGI, things change a little bit. Instead of the web server talking to the program directly, the web server talks to a FastCGI server instead. The FastCGI server is another daemon/background program, running on the computer, that handles the task of running the desired script.

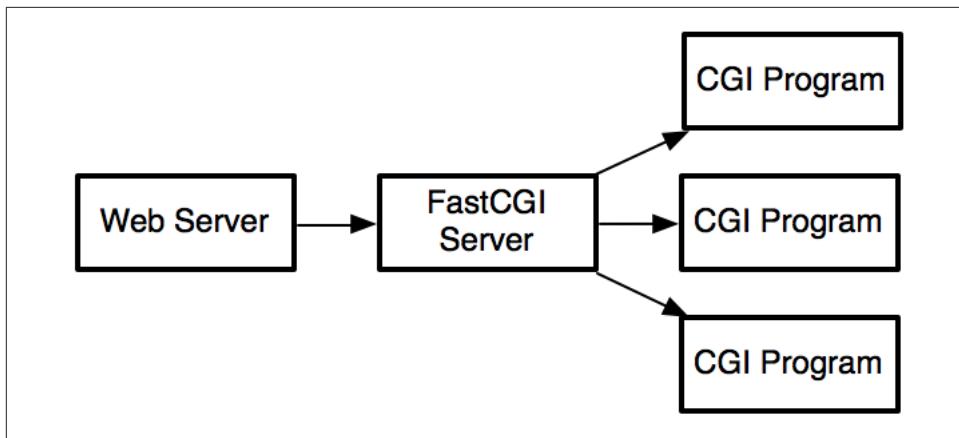


Figure 3-2. Web Server executing CGI program through FastCGI Server

When a request comes in, the webserver makes a TCP or Unix Socket request to the FastCGI server, which runs the script and returns the result to the web server.

The FastCGI server is typically long running, so it doesn't need to fork itself for each request, and can typically handle many connections.

This all seems really complex. It's not. In almost all cases, when you're writing or configuring php apps to work with nginx, you'll almost never have to deal with FastCGI directly, because PHP has PHP-FPM (PHP FastCGI Process Manager) built in. It does almost all of the work for you.

FastCGI Basic Config

Let's start off with the most basic (yet common) situation. You have a PHP script, `script.php`, that you want to run with nginx.

```

<?php
echo "Running a script from nginx<br>";
echo time();

```

The desired output for this script is something like

```

Running a script from nginx
2015-05-01 12:01:01

```

Configuring PHP-FPM for FastCGI

In order to run PHP as FastCGI, you need to make sure that you have PHP-FPM. Luckily, PHP-FPM has been bundled with PHP since PHP version 5.3.

If you're on Ubuntu, you can install PHP-FPM with the command `apt-get install php5-fpm`.

To configure php-fpm, you need to edit the configuration file. On Ubuntu, this file is located in `/etc/php5/fpm/pool.d/www.conf`

To start php-fpm on Ubuntu, you run the command `service php5-fpm start`.

```
location ~ script.php {  
    fastcgi_pass unix:/var/run/php5-fpm.sock;  
    fastcgi_index index.php;  
    include fastcgi_params;  
}
```

This location block matches a single PHP script, `script.php`. When a request comes in that matches this block (`http://example.org/script.php`), it will pass, or proxy, the request to the upstream FastCGI server.

The FastCGI server will use the `SCRIPT_FILENAME` FastCGI Parameter to determine which PHP script to execute.

By default, the `SCRIPT_FILENAME` parameter is set to the value below

```
$document_root$fastcgi_script_name
```

This value just concatenates the `$document_root`, which is the document root of the current request (specified by the `root` directive) and another variable called `$fastcgi_script_name`.

`$fastcgi_script_name` is a variable that's set automatically by nginx based on the path of the request URI.

If the request URI ends in a “/”, the value of the `fastcgi_index` directive is appended to the end of the URI and set to the `$fastcgi_script_name` variable. So, for example, if the request were `http://example.org/foobar/`, the `$fastcgi_script_name` would be set as `/foobar/index.php`.

Otherwise, `$fastcgi_script_name` is simply set as request URI.



Watch out for old syntax!

Please be warned about something important!

Many individual PHP Files, Directly Accessible

In the real world, there are two common FastCGI/PHP configuration that people typically want.

The first is when you have many individual PHP files in a single directory and want them to be all individually executable.

Route all requests through index.php

The other typical scenario, especially for modern web applications built on PHP frameworks such as Zend Framework or Laravel, is to have all requests go through a central index.php file.

The configuration for this scenario looks like this:

```
server {  
    location / {  
        try_files $uri $uri/ index.php$is_args$args;  
    }  
  
    location ~ \.php$ {  
        try_files $uri /index.php =404;  
        fastcgi_pass upstream;  
        fastcgi_index index.php;  
        fastcgi_split_path_info ^(.+\.php)(.*)$;  
        fastcgi_param SCRIPT_FILENAME $document_root$fastcgi_scriptName;  
    }  
}
```



Don't trust the nginx/PHP Tutorials!

Most websites and tutorials for configuring nginx and PHP are wrong.

More than wrong, in fact, they unknowingly expose you to a backdoor—a misconfigured nginx server can allow non-PHP files to be executed as PHP.

What that means that if your nginx server is misconfigured using one of the incorrect online tutorials, an attacker could upload their own PHP file (say, through an image uploader or contact form on your website) and convince PHP-FPM to execute it!

cgi.fix_pathinfo
fastcgi_split_path_info

Future Sections in this Chapter

1. Advanced FastCGI Configuration
2. FastCGI Params
3. PHP and FastCGI Security
4. Python and uWSGI

5. uWSGI vs FastCGI

CHAPTER 4

Reverse Proxy

One of the most popular reasons for running nginx is to serve a dynamic web application written in Ruby, PHP, Node.js, Python or one of the many web languages available today.

Unlike Apache, nginx does not have the ability to embed the programming language interpreter into the webserver, like Apache does with mod_php.

Instead, nginx takes a much lighter weight approach. It's **just** a webserver and generally tries to keep its footprint very small, running a web application is delegated to a separate server and proxies upstream.

Forward Proxy vs Reverse Proxy

To fully understand the concept of a reverse proxy, which will be foundational for the following chapters on Load Balancing and FastCGI, you first need to concept of a *forward proxy*.

Forward Proxy

A forward proxy, or sometimes just called *proxy*, is a common setup in a home or office network. Basically, the proxy sits between all outgoing internet connections and the internet. It looks something like this.

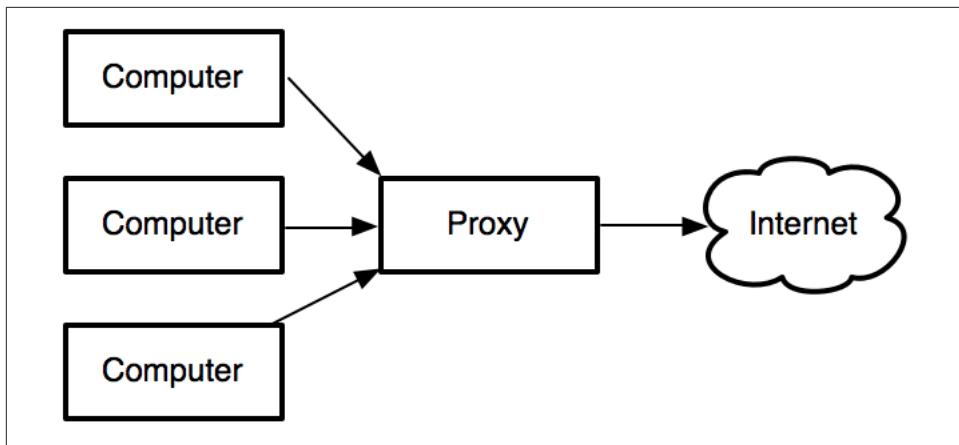


Figure 4-1. Example of a forward proxy configuration

The outgoing connections from the computers are captured and terminated by the Forward Proxy and forwarded to the Internet. To the Internet, all of the Computers appear to be coming from the same source—the Forward Proxy.

Reverse Proxy

A reverse proxy is the opposite of a forward proxy and is a common setup for serving dynamic web applications and load balancing.

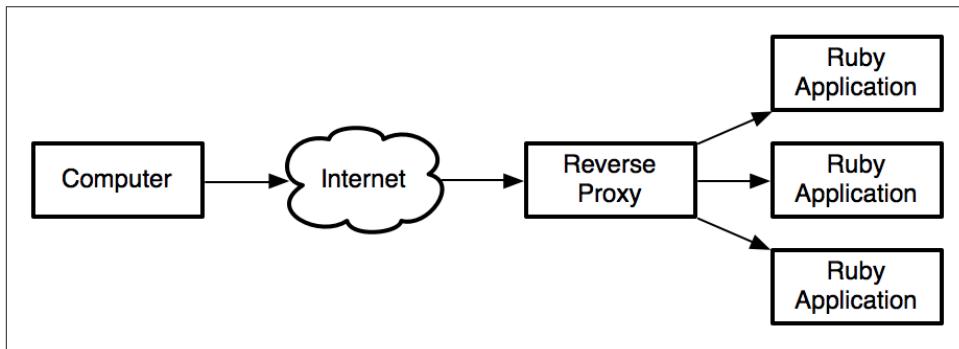


Figure 4-2. Example of a reverse proxy configuration

In this example, the reverse proxy multiplexes many connections from the internet to a dynamic ruby application. The reverse proxy terminates the request and forwards it to the ruby app.

This is the exact same concept as Load Balancing a Chapter 4—a Load Balancer is reverse proxy!

The only difference in the case of load balancing is that typically a load balancer is communicating upstream to another nginx or web server, located on a different physical machine, while the reverse proxy is often talking to a service on the same machine.

The terms are different but the underlying concepts are nearly identical. In fact, because reverse proxy just proxies HTTP, and most dynamic web applications speak HTTP, you can think of it as just a local load balancer.

Configuring a basic Rails Application

The way I like to start digging into advanced concepts is by dissecting a very basic example and building upon that.

Let's pretend we have the most basic Ruby on Rails application. You can set this up by creating a bare-bones Rails application with `rails new TestApp` and running `rails s` within the newly creating TestApp directory.

The `rails s` command starts a WEBrick listening on port 3000. The WEBrick server is great for development and testing, but isn't great for production. In production, I recommend using `puma`, `unicorn`, or `thin`, but WEBrick will suffice for this example (the nginx configuration is the same).

If you access `http://127.0.0.1:3000` in your browser, you'll see the stock "*Welcome to Rails*" page which looks something like this:

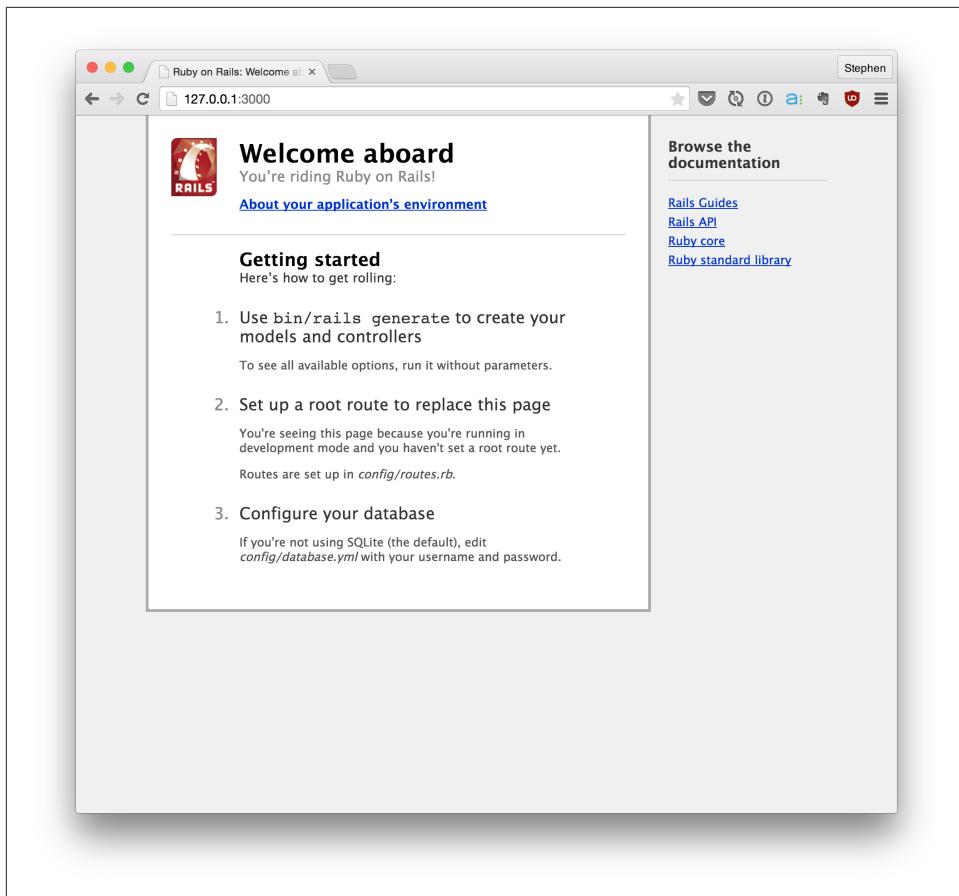


Figure 4-3. The basic “Welcome to Rails” page

That’s great, but you really want this running port 80, and you don’t want to expose WEBrick directly to the internet.

Rack-based server (like WEBrick, puma, and unicorn) are great for serving dynamic content from Rails, but are horribly slow when serving static content. Additionally, the web serving parts of these servers aren’t nearly as feature rich as nginx— their purpose is to serve Ruby applications, not be full-featured servers.

What we want to do is use nginx to listen on port 80 and act as a reverse proxy for this WEBrick server that’s running on port 3000.

It’s all just HTTP, so it doesn’t matter if you’re using Rails, Node.JS, Golang, or something else.

The most basic configuration would look something like this:

Example 4-1. Basic Reverse Proxy configuration

```
http {  
  
    upstream rails_app {  
        server 127.0.0.1:3000;  
    }  
  
    server {  
        listen *:80;  
        root /path/to/application/public;  
  
        location / {  
            proxy_pass http://rails_app;  
        }  
    }  
}
```

This configuration has nginx receiving every incoming request on port 80 and forwards it to our WEBrick server running on port 3000.

As simple as it is, you already get massive benefits from putting nginx in front of WEBrick.

First, it's much more scalable— WEBrick is single-threaded, so it can only process a single request at a time. With nginx in front, it can multiplex the incoming connections and accept them while it's waiting for earlier WEBrick to processes to finish.

Second, the error handling is much better. If the upstream server times out or goes down, nginx will gracefully return 503 Service Unavailable and 502 Bad Gateway respectively. While throwing a 500 error isn't exactly ideal, without the reverse proxy in place, there would be no response at all.

Our configuration still has a problem, however. Notice, that because of the single "catch-all" location block, we're still proxying **all** of the requests through to WEBrick,

What we'd actually prefer to serve all of the static assets (images, javascript, css) through nginx, since it's much better at doing that, and can reduce the load put on WEBrick.

To do that, all we need to do is add a new location block to the configuration for the / assets directory (which is where all assets are stored in a Rails application).

```
server {  
    listen *:80;  
    root /path/to/application/public;  
  
    location / {  
        proxy_pass http://rails_app;  
    }  
}
```

```
location /assets {  
}  
}
```

We've added a new location block to catch anything starting with the prefix `/assets`.

Because there's no `proxy_pass` directive specified in the location block, the default behavior is to fallback serve files statically from the root path, which is inherited from the server context, `/path/to/application/public/assets`.

One last tip— it's often common to set long lived HTTP cache headers for static assets. You can accomplish this by adding the `expires` and `add_header` directives.

```
location /assets {  
    expires max;  
    add_header Cache-Control public;  
}
```

The `expires` directive sets the `Expires` and `Cache-Control` HTTP headers. The value can be a specified date, relative time (e.g. `42d`), or the constant value `max`.

When set to `max`, nginx sets the `Expires` header to `"Thu, 31 Dec 2037 23:55:55 GMT"` and `Cache-Control` header to 10 years.

Even though `expires` sets a `Cache-Control` header for us, we still need to tweak it a bit. By default, the `Cache-Control` header marks the content as private, which means that intermediate HTTP caches will not cache the content. Since assets are typically public and shared across all users, we need to explicitly mark this header as public so that they have maximum cache-ability.

If you make a web request to a file in the `/assets` directory, you will see HTTP headers that look something like this.

```
$ curl -I 127.0.0.1/assets/test.jpg  
HTTP/1.1 200 OK  
Server: nginx/1.4.6 (Ubuntu)  
Expires: Thu, 31 Dec 2037 23:55:55 GMT  
Cache-Control: max-age=315360000  
Cache-Control: public
```

A more robust reverse proxy

Let's re-visit our reverse proxy configuration and take a look at a slightly more advanced and flexible configuration.

In Chapter 2, we quickly discussed using `try_files`, which gives you the ability to check for the existence of static files before falling back onto another location block.

This is a convenient way to gracefully take your application down for maintenance. For example, if you wanted to deploy a new version of your code but had to do a length database migrate, you might want to display a temporary “come back soon” page.

Example 4-2. Serving a dynamic application using try_files

```
server {  
    listen *:80;  
    root /path/to/application/public;  
  
    location / {  
        try_files maintenance.html @rails;  
    }  
  
    location @rails {  
        proxy_pass http://rails_app;  
    }  
}
```

With this configuration, we've moved the `proxy_pass` directive to it's own named location block and check for the existence of `maintenance.html`, which will short-circuit forwarding the request to the upstream if it exists.

A simplistic catch-all `proxy_pass` location block, like I demonstrated in the original example, also has the disadvantage of forwarding everything onward to the upstream application unless explicitly defined, like we did for the `/assets` folder.

What if there was a `videos` directory inside of the nginx root path that we wanted to have nginx serve directly? One way to would be to add yet-another location block to configuration, but that's kind of a pain. We can use `try_files` to solve this for us.

Example 4-3. Dynamically checking for file existence with try_files

```
server {  
    listen *:80;  
    root /path/to/application/public;  
  
    location / {  
        try_files $uri $uri/index.html @rails;  
    }  
  
    location @rails {  
        proxy_pass http://rails_app;  
    }  
}
```

Notice that we use `try_files`, but this time instead of using a static filename, we're using the nginx variable `$uri`, which contains the *normalized* (decoded and sanitized) URI of the web request.

This will allow any files and folders in the root path to be served up statically by nginx and **not** be forwarded to the upstream backend.

If you're coming from the Apache world, this is similar to checking for the existence of a file or directory with `RewriteCond` before forwarding to the upstream.

An equivalent Apache configuration would look something like this:

Example 4-4. Equivalent Apache configuration

```
<VirtualHost *:80>
    DocumentRoot /path/to/application/public
    RewriteEngine On

    # This is roughly the same as the behavior our try_files
    # configuration above
    RewriteCond %{DOCUMENT_ROOT}/ %{REQUEST_FILENAME} !-f
    RewriteRule ^/(.*)$ balancer://rails [P,QSA,L]

    # This is equivalent to upstream in nginx
    <Proxy balancer://rails>
        BalancerMember http://127.0.0.1:3000
    </Proxy>
</VirtualHost>
```

While using `try_files` to serve static files before falling back on the backend is best practice, it's important to notice that *everything* in the root path will be publicly accessible— so you need to make sure that you don't put anything sensitive or private in there.

It's for this reason that we always make sure the nginx root is our *public* directory. If we were set the root one level lower, for example, to `/path/to/application`, anyone would be able to read source code files directly from nginx by accessing the paths directly, by going to `http://example.org/app/config/secrets.yml`.

Upstream with Unix Domain Sockets

When you specify an upstream server with an IP Address, hostname, or port, you're telling nginx to use the TCP stack to communicate with it.

That works great when your upstream servers are on remote machines (for example, in the case of a load balancer), but it incurs a slight performance overhead.

In the case of a Reverse Proxy configuration where your upstream server is on the same machine, you can get better performance by skipping the TCP/Network stack and using Unix Domain Sockets.

A Unix Domain Socket is communication mechanism to do inter-process messaging within the operating system kernel, using the file system as the name space.

To enable Unix Domain Sockets, you need to first tell your upstream server to listen on a domain socket instead of TCP.

Unfortunately, WEBrick doesn't support Unix Domain Sockets, but most other servers (for Rails and otherwise), do. For this example, we'll have to use `thin`.

First, install `thin` with Rubygems by running the command `gem install thin`.

Next, instead of running `rails s` to start WEBrick, run `thin start --socket /tmp/rails.sock`. The path that we pass to the `--socket` flag is the location of the unix socket.

Once you do that, it's just a matter of changing your nginx upstream server to talk over the domain socket instead of TCP.

```
upstream rails_app {  
    server unix:/tmp/rails.sock;  
}
```

Custom Error Pages

It's a fact of life that sometimes our web applications return errors (of course, not from the code that *you* wrote).

Typically these errors surface in the form of the standard **HTTP status codes**. If you need a refresher, 2xx status codes are for success, 3xx to indicate a redirect, 4xx to indicate the *client* did something wrong, and 5xx to indicate that the *server* did something wrong.

For the purposes of discussing errors, we generally care about the 4xx and 5xx codes. The most common of which are `403 Forbidden`, `404 Not Found`, `500 Internal Server Error`, and `502 Bad Gateway`.

When you request a file that doesn't exist or that nginx doesn't have access to, it will return a very plain `404 Not Found` page that looks something like the one below.

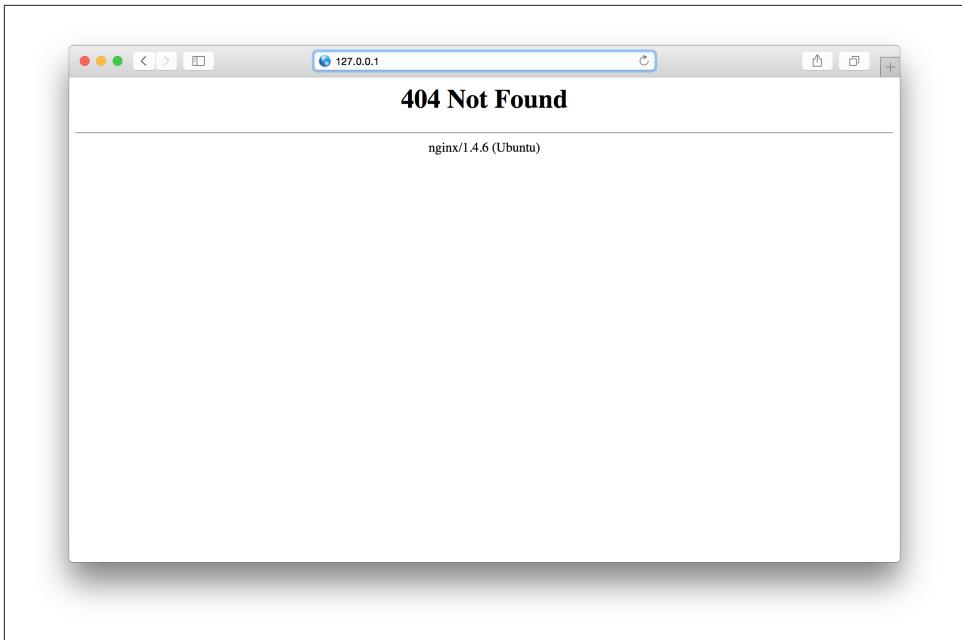


Figure 4-4. The default error page in nginx



Hiding the nginx version

If you notice, in the error page above, nginx returns the version and operating system that it's running on.

By default, nginx will also return the same information on every HTTP request in the Server HTTP Header.

While I don't think it gets you much in the way of security, some people like to hide these identifiers. You can turn them off by setting the value of the `server_tokens` directive to `off`.

```
server_tokens off;
```

Likewise, you will see a `500 Internal Server Error` if your code doesn't compile or hits some fatal error—usually this is returned by your upstream server (`thin`, `unicorn`, etc) as a last resort.

Typically, if you see a `502 Bad Gateway`, it's actually coming from nginx. When nginx returns this status code, it means that it can't reach the server inside of the `upstream` block.

Instead of having to use the (very unattractive) default error pages that come out of the box with nginx, we can define our own HTML error pages to use with the `error_page` directive.

The `error_page` directive takes a list of one or more error codes and a file to return as the body of the error. This is how Twitter made the fail whale page.

Example 4-5. Overriding default nginx error pages

```
server {  
    listen *:80;  
    root /path/to/application/public;  
  
    location / {  
        error_page 404 /404.html;  
        error_page 500 502 503 504 /50x.html;  
  
        try_files $uri $uri/index.html @rails;  
    }  
  
    location @rails {  
        proxy_pass http://rails_app;  
    }  
}
```

Other neat things you can do with `error_page`

The `error_page` directive has a few other tricks up its sleeve:

It can change the HTTP status code. For instance, if your upstream returned a `500 Internal Server Error`, you can change it to a `200 Ok!`

You probably shouldn't do this unless recovering with a static file is appropriate behavior—many applications and API clients depend on the status code to determine if there was an error.

The example below will change a `404 Not Found` into a `200` and return the static file, `index.html`.

```
error_page 404 =200 /index.html;
```

It can redirect to a completely different URL, sending back a `302 Found` with a redirect location that can be on any server.

The example below will cause any `500` error pages to actually return a `302 Found` with a redirect to `http://www.google.com`.

```
error_page 500 http://www.google.com;
```

It can internally redirect to a named location block, this is useful if you have a different upstream backend that you want to dynamically generate the error page from.

Note— If you're thinking about using this for redundancy or high-availability (i.e,

trying to re-run the request), you want the `proxy_next_upstream` directive, which is described in Chapter 7).

```
location / {
    error_page 404 = @fallback;
}

location @fallback {
    proxy_pass http://different_backend;
}
```

Adding headers to the upstream

Since the mechanics behind Reverse Proxying is just HTTP, that is to say, nginx is just re-opening a new connection to the backend and forwarding the HTTP data along, it's possible to modify the HTTP request within nginx.

This is typical if you want to add or remove some HTTP Headers from the original request.

A common use-case for this is to tell the backend whether the request came in HTTP or HTTPS—a secure or non-secure connection.

We can accomplish this with two pieces of knowledge—the first is the `proxy_set_header` directive which allows us to add new headers into the forwarded request to the backend.

The second is the fact that the variable `$scheme` contains the originating request scheme, either the value `http` or `https`.

Putting it together, we just need to set a new header (the commonly used name for this is `X-Forwarded-Proto`) with the value of `$scheme`! Easy!

Example 4-6. Setting X-Forwarded-Proto for a Reverse Proxy

```
server {
    listen *:80;
    root /path/to/application/public;

    location / {
        try_files $uri $uri/index.html @rails;
    }

    location @rails {
        proxy_set_header X-Forwarded-Proto $scheme;
        proxy_pass http://rails_app;
    }
}
```

By default, nginx will use `proxy_set_header` to dynamically set the `Host` header to the variable `$proxy_host`, which contains the name and port of the value passed to `proxy_pass`.

In the example above, nginx would proxy the request with the `Host` header set as `rails_app`.

This behavior might be undesirable if you want to know the actual host/domain that was used for the request, for example, if use use the subdomain to identify the account as is common in many SaaS applications.

You just need to override the `Host` header with `proxy_set_header` and pass it the value `$host` instead of `$proxy_host`.

```
proxy_set_header Host $host;
```

Real IP Module

A common problem that people often run into when reverse proxying is the inability to retrieve the client IP Address. Let's explore this problem for a second and understand what's happening under the hood when a request from a client is made to the load balancer.

A client, 203.0.113.1, makes a web request to an nginx server at example.com, which resolves to the IP Address 192.0.2.9.

Next, the load balancer at 192.0.2.9 reads the HTTP request from 203.0.113.1 and proxies the request to one of the app servers inside of its upstream directive.

The million dollar question: What client IP address does the backend think that the request came from?

The answer is 192.0.2.9— because nginx is proxying the request to the backend, from the perspective of the backend, it's technically the originator of the HTTP request.

The snag you run into is, what if, in your application, you'd like to access or log the IP Address of the client making the request? It's seemingly impossible because, to the app server, all of the requests appear to be coming from the load balancer.

The Real IP module in nginx solves this problem. This module is packaged with the nginx source code, but needs to manually enabled by passing the `--with-http_realip_module` flag to the build configuration script. If you're using a pre-build nginx package, it probably includes this module already.

How Real IP Works

Typically, with HTTP, the client IP Address is injected as the `REMOTE_ADDR` HTTP Header.

When a client (203.0.113.1) makes a request to nginx (192.0.2.9), the REMOTE_ADDR header is set to 203.0.113.1. When nginx proxies the request to the backend, the REMOTE_ADDR header is set to the new client, 192.0.2.9.

When Real IP is enabled on nginx, it injects a new HTTP header into the request—X-REAL-IP, that contains the original client IP Address (203.0.113.1).

Any applications (Rails, PHP, etc) will be able to access the origin client IP Address by accessing the REMOTE_ADDR HTTP Header.

How to enable Real IP

To enable Real IP, you need to configure it on your nginx server, and any nginx load balancers (discussed in Chapter 5).

On the load balancer, add the `real_ip_header` directive. This directive specifies the header to use (it's X-REAL-IP by default). While not mandatory (it's enabled as long as the module is installed), it's best practice to explicitly define it.

```
http {  
    real_ip_header X-Real-IP;  
  
    server {  
        ...  
    }  
}
```

On the reverse proxy's, you need to add the `real_ip_header` directive again, as well as specify the `set_real_ip_from` directive.

The `set_real_ip_from` directive takes a list of IP Addresses or CIDR blocks of trusted sources for the X-REAL-IP HTTP Header. Without this, anyone would be able to spoof their IP Address by making HTTP Requests with bogus values in the X-REAL-IP HTTP Header.

The value of `set_real_ip_from` should be the IP Address(es) or CIDR block of your load balancer, in the case of our example, 203.0.113.1.

```
http {  
    real_ip_header X-Real-IP;  
    set_real_ip_from 203.0.113.1;  
  
    server {  
        ...  
    }  
}
```

If there were multiple load balancers, you'd just have multiple `set_real_ip_from` statements. It can also take a CIDR block to cover an entire range of addresses.

```
http {  
    real_ip_header X-Real-IP;
```

```
set_real_ip_from 203.0.113.1;
set_real_ip_from 203.0.113.2;
set_real_ip_from 203.0.113.0/24;

server {
    ...
}
```



Real IP Module vs DIY Approach

It's possibly to cleverly implement similar functionality as the Real IP Module using `proxy_set_header`, something along the lines of:

```
proxy_set_header X-Real-IP $remote_addr;
```

Reverse Proxying Node.js & Websockets

In this section, I'll run through setting up a Reverse Proxy with Node.js instead of Rails.

The basic concepts are similar as with Rails but we'll learn a few new techniques, specifically how to use Websockets.

For this demo, I assume that you have already installed NodeJS and NPM.

First, let's start by creating the most basic Node application ever— go to a new directory and create a new file called `app.js`.

Example 4-7. Contents of app.js

```
var http = require('http');

http.createServer(function (request, response) {
    time = (new Date).getTime().toString();

    response.writeHead(200, {"Content-Type": "text/plain"});
    response.end(time);

}).listen(3000, "127.0.0.1");

console.log("Starting server running at http://127.0.0.1:3000");
```

This code starts up an HTTP server listening on port 3000 and will send back the current unix timestamp to any web request that it receives.

You can run this application directly by running `node app.js` from the command line and visiting `http://127.0.0.1:3000` in your browser.

Running Node to production

If you're running Node in product, you most likely want to be using some process supervisor instead of running the node cli directly.

While you can use the tried-and-true init scripts or `supervisord`, I highly recommend a tool such a `pm2`.

`pm2` is a process manager built specifically for running and supervising node applications and includes a very useful command line interface, monitoring tools, and log viewer.

[joni] ~/keymetrics/PM2 \$ pm2 list									
App name	id	mode	pid	status	restart	uptime	memory	watching	
API	0	cluster	26076	online	0	2m	22.582 MB	disabled	
API	1	cluster	26085	online	0	2m	22.527 MB	disabled	
API	2	cluster	26274	online	1	2m	22.566 MB	disabled	
API	3	cluster	26133	online	0	2m	22.563 MB	disabled	
Worker	4	fork	0	stopped	0	0	0 B	enabled	
Mailer	5	fork	26165	online	0	2m	15.125 MB	disabled	
Front	7	fork	26865	online	0	12s	14.465 MB	enabled	

Figure 4-5.

An example of the `pm2` user interface

You can install `pm2` with `npm` by running `npm install -g pm2`

Now, just like before, we want to put `nginx` in front of our `node.js` server. The configuration will look shockingly similar to how we configured the reverse proxy for rails.

Example 4-8. Basic Reverse Proxy for Node

```
http {  
    upstream node_app {  
        server 127.0.0.1:3000;  
    }  
  
    server {  
        listen *:80;  
        root /path/to/application/public;  
  
        location / {  
            try_files $uri $uri/index.html @node;  
        }  
    }  
}
```

```
location @node {
    proxy_pass http://node_app;
}
}
```

Reverse Proxy with WebSockets

WebSockets is a new HTTP protocol that allows for two-way communication over an HTTP connection and was standardized in 2011.

What this means is that WebSockets allow the browser and the server to have long-lived two-way connections, which dramatically changes the traditional HTTP model.

Of course, both the browser and the backend application need to support WebSockets before you can use it. At this point in time, almost all modern versions of all browsers support WebSockets and while *most* programming languages support WebSockets with additional libraries, Node.js has it natively built in. In fact, some would say that Node.js is built with WebSocket programming in mind.

The way that WebSockets works is that when the client makes an HTTP Request with two extra HTTP Headers— `Connection` and `Upgrade`.

The `Connection` Header is used to tell the server what do with the connection after the initial response, and is normally set to `Close` (to close the connection after the initial response) or `Keep-Alive` (to keep it open and re-use it). For WebSockets, the header value is set to `Upgrade`, requesting the server to *upgrade* the connection.

The `Upgrade` Header tells the server which protocol that the client wants to upgrade to when the `Connection` header asks for an upgrade. For WebSockets, the `Upgrade` Header is set to `websocket`.

To upgrade to WebSockets, the client will make a request similar to this:

```
GET /websocket HTTP/1.1
Host: www.example.org
Upgrade: websocket
Connection: Upgrade
```

If the server supports Websockets, it will respond with the HTTP status code `101 Switching Protocols` instead of the normal `200 Ok`, and begin speaking WebSockets.

The response would look something like this— after which, the client and server would begin communicating using the WebSocket protocol over the same TCP connection.

```
HTTP/1.1 101 Switching Protocols
Upgrade: websocket
Connection: Upgrade
```

You might think of WebSockets as switching to something similar to a 2-way chat session between the client and server, where both sides are able to send and receive messages for a long period of time.

Okay, so what's the point? Well, out of the box nginx supports WebSockets. Awesome. But, WebSockets gets a bit more complex with a Reverse Proxy because the upgrade handshake needs to be forwarded to the backend (not all backends support WebSockets— so even though nginx does, it can't assume the backend can too).

In addition to this, the default reverse proxy configuration uses very simple and stateless connections to the backend and every new request to nginx creates a new request to the backend server, 1 for 1— that is, it uses HTTP 1.0 and not HTTP 1.1, which is required for WebSockets.

Luckily, it's easy to enable this out of the box by switching the reverse proxy to use HTTP 1.1 and passing along the `Upgrade` and `Connection` headers (these types of HTTP headers are called hop-by-hop headers and explicitly forbidden by the HTTP 1.1 spec from being passed along by proxies or caches. Normally, headers are forwarded along by nginx automatically)

Example 4-9. Basic WebSocket Example

```
location /chat {
    proxy_pass http://node_app;
    proxy_http_version 1.1;
    proxy_set_header Upgrade $http_upgrade;
    proxy_set_header Connection "upgrade";
}
```

We first use `proxy_http_version` to explicitly set the HTTP version that nginx uses for communicating with the backend to be HTTP 1.1. Note that this has no impact on the HTTP version that the client/browser can use to communicate with nginx— even if this is not set, nginx will use HTTP 1.1 for communicating with the end client.

The next thing that we do is use `proxy_set_header` to set the two previously mentioned headers— `Upgrade` and `Connection`.

In the case of `Upgrade`, we're setting it to the variable `$http_upgrade` which is just the value of the `Upgrade` header from the original client request.

For the `Connection` header, we just hard code it as the string `upgrade`, asking the backend to upgrade to whatever protocol was passed along.

The problem with this configuration is that it will attempt to upgrade *every* HTTP connection that is made to it, which means that you'd need to have a specific location block for the WebSocket endpoint if you wanted to share it with a backend that also supports regular HTTP requests.

We can solve for this by dynamically setting the value of `Connection` based on the value of `Upgrade`, using a new nginx directive called `map`.

Example 4-10. Dynamically mapping Connection based on Upgrade

```
map $http_upgrade $connection_upgrade {
    'websocket' upgrade;
    default close;
}

location @node {
    proxy_pass http://node_app;
    proxy_http_version 1.1;
    proxy_set_header Upgrade $http_upgrade;
    proxy_set_header Connection $connection_upgrade;
}
```

Let's dissect the map bit, because I always think that these can be confusing at first glance if you haven't used it before.

If you were to write it in psuedo-programming language code, the logic would actually look something like this:

```
switch ($http_upgrade) {
    case "websocket":
        $connection_upgrade = "upgrade";
        break;
    default:
        $connection_upgrade = "close";
}
```

The map block maps between the value of the first variable passed, `$http_upgrade`, and uses it to set the values for any subsequent variables passed as parameters, in this case, `$connection_upgrade`.

So, when `$http_upgrade` equals “websocket”, we set `$connection_upgrade` to “upgrade”.

The default case sets the value of `$connection_upgrade` to “close” if it doesn't match anything.

Okay, so we've got nginx configured to use WebSockets, let's test this thing out by changing out Node.js dummy code to use WebSockets instead of plain old HTTP.

We need to install the websocket library for Node with npm. To do that, just run the command `npm install websocket`.

Now, change the `app.js` file to create a websocket server:

Example 4-11. Example Websocket Node.js Server

```
var WebSocketServer = require('websocket').server;
var http = require('http');

var server = http.createServer(function (request, response) {

    time = (new Date).getTime().toString();

    response.writeHead(200, {"Content-Type": "text/plain"});
    response.end(time);

});

server.listen(3000, "127.0.0.1");

console.log("Starting server running at http://127.0.0.1:3000/");

websocketServer = new WebSocketServer({
    httpServer: server,
    autoAcceptConnections: false
});

websocketServer.on('request', function(request) {
    console.log("Received connection");
    var connection = request.accept('echo-protocol', request.origin);

    time = (new Date).getTime().toString();
    connection.SendUTF(time);
});
```

Don't forget about timeouts!

Even when using WebSockets, you're still beholden to the all-mighty nginx timeout!

If a WebSocket sits idle for more than the value of `proxy_read_timeout` directive (default— 60 seconds), nginx will close the connection.

While some people recommend setting this value to a really high number, you'll see various sources on the internet tell you to set it to 999999 or something, a much better strategy is to implement a ping message that fires every 20 or 30 seconds to keep the connection alive.

Future Sections in this Chapter

1. nginx Buffering
2. Keepalive

CHAPTER 5

Load Balancing

One of the most common, and easiest, ways to scale a busy web application is to use *load balancing*. The idea behind load balancing is to distribute load, or web traffic, across multiple application servers.

Let's take an example—you've just created a Ruby on Rails application and deployed it to a single server. In order to show the world your Rails application, you modify the DNS zone of your website to point to the Rails app.

So far, all is good. Visitors type in your domain name and get routed straight to your single application server where nginx serves up your Ruby on Rails application.

That is, until, one of your biggest fans (mom) is so proud of your application that she submits it to the popular link sharing website, [Reddit](#). Others love your app too, and they upvote it to the front-page.

Now, there are thousands of people visiting your website, and a single server can't possibly handle the load. You know you need to scale out, maybe add some more servers, but how?

That's when the load balancer comes in to play—the load balancer receives all of the incoming traffic and distributes it across a pool of application servers.

There are many types of load balancers, both software (implemented in software) and hardware (implemented in hardware, typically installed as a device).

nginx has the ability to run as a software load balancer using the `http_proxy` module, and it's one of the most common and useful ways to use nginx in a web stack.

Your first load balancer

To get started, let's walk through the most basic configuration for a load balancer in nginx.

```
http {  
    upstream backend {  
        server 192.0.2.10;  
        server 192.0.2.11;  
    }  
  
    server {  
        listen 80;  
  
        location / {  
            proxy_pass http://backend;  
        }  
    }  
}
```

When run with the configuration above, nginx will take all traffic on port 80 and balance it across two servers, 192.0.2.10 and 192.0.2.11.

The key directives that make this work are the *proxy_pass* and the *upstream* directives.

The default configuration for an upstream is to balance requests using a round-robin method— for example, the first request will be sent to 192.0.2.10, the second to 192.0.2.11, the third to 192.0.2.10, and so on.

Round-robin load balancing is completely ignorant, so factors like the actual load of the server or number of connections is not considered.

The proxy_pass directive takes a host and causes nginx to proxy the request to that host. Since the example is passing in a named upstream (i.e., `http://backend`), nginx will pick which host to use depending on the load balancing strategy, round-robin in this case.

Load Balancing vs Reverse Proxy?

You might be saying to yourself— **this is exactly the same thing as reverse proxying**, and you'd be right! Load balancing is actually a form of reverse proxying with three fundamental differences:

1. Load Balancers typically reverse proxy across **many** backends while a traditional reverse proxy serving a dynamic web application will only reverse proxy to a single backend.

2. Load Balancers usually operate at either Layer 7 (Application Layer, i.e, HTTP) or Layer 4 (Transport Layer, i.e, TCP) while typically you will only operate at the Application Layer when reverse proxying a modern web application.
3. Scale is critical for load balancers— on busy sites, they will see 20x the amount of traffic that a single application server receives. For instance, a powerful application server will only need to handle 100-200 requests per second, while a load balancer may very well receive over 10,000 requests per second.

Handling Failure

What happens when a server goes away?

One important use case of load balancing is to handle failure, when a server crashes, someone trips over the power cord, or it just seems to go away.

By default, when a single request to a server inside of the upstream directive fails, the server will be removed from the pool for 10 seconds. These settings are configurable and will be discussed later in the chapter.

At the most basic, load balancers solve two problems for us:

Load balancers help us scale. They make horizontally scaling easy, by spreading the load across multiple backends. Instead of having a single very-powerful, very-expensive server, we can use load balancing to share the load across 5 cheap medium-powered instead.

Load balancers help us deal with failure. Even if you have plenty of power or only need a single server to serve your web application, that server will eventually go down. It will crash. The CPU will get fried. In the age of cloud computing, servers are ephemeral and not long-lived. Load balancers allow us to be highly available by providing redundant backends.

Who load balances to load balancers?

Are you really highly available if you have multiple backend application servers but only a single load balancer? Aren't you back into the same position, except now the load balancer is your single point of failure?

Yup.

You need to have multiple load balancers. But who load balancers to load balances?

The answer is DNS. When you have multiple nginx load balancers for your website, you can use DNS load balancing to present multiple IPs for a single A Record.

The DNS lookup would return something like the result below:

Example 5-1. DNS Load Balancing

```
> dig A example.com
; <>> DiG 9.7.3-P3 <>> A example.com

;; QUESTION SECTION:
;example.com.      IN  A

;; ANSWER SECTION:
example.com.    287  IN  A   208.0.113.36
example.com.    287  IN  A   208.0.113.34
example.com.    287  IN  A   208.0.113.38
```

In the example above, there are 3 load balancers for the website example.com, each with a different IP.

The drawback here is that although the clients are *supposed* to chose a random IP from the list, poorly implemented ones will always use first IP presented. Modern DNS providers (AWS Route 53 and Dynect come to mind) will randomize the ordering for each DNS request to help mitigate hotspots.

The other drawback is that DNS records are often cached for long periods of time. So, if a load balancer goes away, the IP Address may still be cached for some users, even if you remove it from your DNS entry.

Worst still, users get no indication that something is wrong, just a hard error that they could not connect. Even with DNS TTLs as low as 60s, this is unacceptable.

Therefore, a combination of DNS Load Balancing and a mechanism to re-assign IP Addresses is necessary to be highly-available. Depending on your provider, you can use something like **keepalived** to send heartbeats between servers and takeover the IP Address of a downed server by sending an ARP broadcast.

Traditionally, keepalived did not work on cloud providers like AWS because they usually filter broadcast traffic from the network for security. However, since version 1.2.8, keepalived supports unicast and makes a great way to build high availability nginx configurations— even on AWS.

Configuring the Upstream Directive

Before we move into more complex scenarios and examples with load balancing, let's deep dive into perhaps the most important tunable when using nginx as a load balancer, `upstream`.

We learned about the basic use of upstream in Chapter 4, where we used to connect to a single Rails or Node backend, but with load balancing, we'll use it to represent a group of servers.

For reference, the most basic multi-server upstream block looks something like this:

```
upstream backend {  
    server 192.0.2.10;  
    server 192.0.2.11;  
}
```

The servers in an upstream block can be IP addresses, hostnames, unix domain sockets, or a mix any of the above.

```
upstream backend {  
  
    # IP Address with Port  
    server 192.0.2.10:443;  
  
    # Hostname  
    server app1.example.com;  
  
    # Unix Socket  
    server unix:/u/apps/my_app/current/tmp/unicorn.sock  
}
```

Weighted Servers

Weighting alters the proportion of traffic that will be routed to a particular server in an upstream.

Weights are useful if you want to send more traffic to particular server because it has faster hardware, or, if you want to send less traffic to a particular server to test a change on it.

Example 5-2. Example upstream where one server receives 3x more traffic

```
upstream backend {  
    server app1.example.com weight=3;  
    server app2.example.com;  
    server app3.example.com;  
}
```

In the example above, the weight for app1.example.com is set as 3. When the weight is not specified, as is the case for app2 & app3, it is implied to be 1.

Since app1 has a weight of 3 and app2/app3 have a weight of 1, in the example above, app1 will have 3x more requests routed to it.

Example 5-3. Example upstream where one server receives half the traffic

```
upstream backend {  
    server app1.example.com weight=2;  
    server app2.example.com weight=2;  
    server app3.example.com weight=1;  
}
```

In this [example](#), we set the weight as 2 for both app1 & app2. The weight of app3 is set to 1. Because app3 has a lower weight, it will receive only 20% of the total traffic. This can be used as a great way to validate configuration changes or new deployments.

Health Checks

In the open-source version of nginx, health checks don't really exist. What you get out of the box are passive checks—checks that will remove a server from the pool if it causes an error a certain number of times.

The default handling is, if an incoming request to an upstream server errors out or times out once, the server will be removed from the pool for 10s.

The pitfalls with this type of health checking is—

1. It is passively activated, it does not actively check the health of a server except during the lifecycle of load balancing an incoming request.
2. It does not validate the response of the server. The server might be spewing out 500 errors, but as long as it responds to HTTP, nginx considers it healthy.

You can tweak the behavior of the health checks with three directives: `max_fails`, `fail_timeout`, and `proxy_next_upstream`.

max_fails

Max fails controls the number of times that the server can be marked as unhealthy before it is removed from the pool.

The conditions of what is considered “unhealthy” is determined by `proxy_next_upstream`.

The default setting is `max_fails=1` and is set per server directive within the `upstream` directive.

```
upstream backend {  
    server app1.example.com max_fails=2;  
    server app2.example.com max_fails=100;  
}
```

fail_timeout

This directive controls the behavior of two different settings.

1. The amount of time to remove the server from the upstream pool when it is marked as unhealthy.
2. The amount of time that the `max_fails` count is valid for. That is to say, if `max_fails=2` and `fail_timeout=10`, the server needs to fail 2 times in 10 seconds for it to be marked unhealthy.

The default setting is `fail_timeout=10` (implied as seconds) and, similar to `max_fails`, is set per server directive within the upstream.

```
upstream backend {
    server app1.example.com max_fails=2 fail_timeout=5;
    server app2.example.com max_fails=100 fail_timeout=50;
}
```

`proxy_next_upstream`

This directive controls the error conditions that will cause an unsuccessful request and increment the `max_fails` counter.

As mentioned earlier, the default setup is for nginx to only count complete failures (an error connecting to the server or a timeout) as a failed request. That behavior is controlled by this setting.

Below is a table all of the possible values (multiple may be set) for `proxy_next_upstream`.

It's worth noting that there are multiple uses (and settings) for this directive, but in this section, we'll only discuss the ones applicable to health checks.

Name	Meaning	Default?
error	An error occurred while communicating with an upstream server	Yes
timeout	A timeout occurred while communicating with an upstream server	Yes
invalid_header	A server returned an empty or invalid response	Yes
http_500	A server returned a 500 status code	No
http_502	A server returned a 502 status code	No
http_503	A server returned a 503 status code	No
http_504	A server returned a 504 status code	No

The values `error`, `timeout`, and `invalid_header` are set as the default for `proxy_next_upstream`. In fact, these three settings are not configurable and will always be set even if they aren't explicitly set.

For most production setups, I find it useful to also turn on `http_502`, `http_503`, and `http_504`, because they tend to be signs of an unhealthy server (typically meaning that the web application is unresponsive or out of workers).

Typically, I leave http_500 off, as this isn't always a sign of an unhealthy server and can be tripped by a broken code path in your web application.

The proxy_next_upstream directive is specified in the location block of the load balancer configuration.

In the example below, I turn on health checks for HTTP 502, 503, and 504 status codes. Note that even though I don't specify error, timeout, or invalid_header that they are enabled regardless.

```
location / {
    proxy_next_upstream http_502 http_503 http_504;
    proxy_pass http://backend;
}
```

Removing a server from the pool

Often times it is useful to remove a server from the upstream pool so that it no longer servers web traffic.

You may want to do this if you're testing a new configuration, performing upgrades, or debugging a problem in production.

While you can just remove a server directive from the upstream block completely, it's often advantageous to explicitly mark it as *down* instead. When a server is marked as down, it is considered completely unavailable and no traffic will be routed to it.

```
upstream backend {
    server app1.example.com;
    server app2.example.com down;
    server app3.example.com;
}
```

In the example upstream block above, app2 is marked as permanently down and will receive no traffic from the load balancer.

The reason that you'd use *down* to remove a server instead of commenting it out is to preserve hashes when using a load balancing algorithm such as *ip_hash* (described later in the chapter).

Backup Servers

It's possible to keep a set of backup servers within your pool that will only be used if **all** of the other servers in the pool go away.

To do so, simply mark the server with the *backup* parameter.

```
upstream backend {
    server app1.example.com;
    server app2.example.com;
    server app3.example.com;
    server app4.example.com backup;
```

```
    server app4.example.com backup;
}
```

In the example above, I've added a new server (app4) to be used as a backup server. Because it will only receive traffic if all of the hosts in the pool are marked as unavailable, its usefulness is limited to smaller workloads, as you'd need enough backup servers to handle the traffic for your entire pool.

Slow Start

The `server` directive supports a `slow_start` parameter, that tells nginx to dynamically adjust the weight over time, allowing it to ramp up and slowly begin receiving traffic after it has become recovered or became available.

This is incredibly useful if you're running a JIT (Just In Time) compiled language, such as the JVM, which can take several minutes to warm up and run at optimal speeds.

The `slow_start` parameter takes a time, in seconds, that it will use to ramp up the weight of the server.

Example 5-4. Example demonstrating the slow_start directive

```
upstream backend {
    server app1.example.com slow_start=60s;
    server app2.example.com;
}
```



DNS Resolution in nginx Upstream Directive

There is one huge gotcha with nginx upstreams that I've seen a few people get bitten by and it takes *forever* to debug.

The upstream directive allows you to define servers by IP Addresses or Hostnames.

When you set a server with a hostname, how is it resolved to an IP Address?

Well the answer is that when nginx first initializes and reads the configuration file, it resolves the hostnames with a DNS lookup and caches the IP Address for the lifetime of the process.

If you're using internal hosts, that's usually fine, as the IPs don't often change.

However, if your upstream is an external host or one that has a frequently changing IP Address, you're in trouble! Because nginx caches the IP Address forever, if the IP of a hostname used in a server directive ever changes, nginx will still use the old IP Address.

I've seen this problem manifest several times, with people configuring nginx to be a reverse proxy in-front of Amazon ELB (Elastic Load Balancer).

ELB re-maps IPs between clients *very frequently*, so it's incredibly unreliable to cache the ELB IP Address much longer than the DNS TTL. Anyways, nginx will be configured to act as a reverse proxy in-front of ELB and everything will work great, until the IP Address of the ELB is re-mapped to another client and suddenly nginx starts reverse proxying to another website! Oops!

Luckily, the fix is simple— we just need to tell nginx to obey the DNS TTL and re-resolve the hostname.

This can be done by setting the resolve parameter on the `server` directive and configuring the `resolver` directive.

Example 5-5. Example with dynamic DNS Resolution

```
http {  
    resolver 8.8.8;  
  
    upstream backend {  
        server loadbalancer.east.elb.amazonaws.com resolve;  
    }  
}
```

For the resolver, you want to pass it the IP Address of a DNS server that it can use to resolve domains. In the example, I use 8.8.8.8, which is Google's public DNS resolver, but it's preferable to use a DNS resolver or cache that's local to your network— I recommend

Load Balancing Methods

Out of the box, the open-source version of nginx ships with four algorithms for load balancing traffic.

Weighted Round Robin (Default)

The round robin method is the default load balancing algorithm for nginx. It chooses a server from the upstream list in sequential order and, once it chooses the last server in the list, resets back to the top.

If there are weights associated with the servers, they are taken into account during the round-robin selection and servers with a higher weight will receive proportionately more traffic.

Least Connections

The least connections load balancing algorithm picks the server that has the least number of active connections from nginx.

Many often choose this thinking that it's the fairest or most balanced option, however, often times the number of active connections is not a reliable indicator of server load.

In my experience, this method tends to cause overwhelming and spiky floods of traffic to particular servers, especially during times of failure when servers are marked unavailable by the health check and come back online with 0 active connections.

Turn on this algorithm by specifying the `least_conn` directive within the `upstream` context.

```
upstream {
    least_conn;
    server app1.example.com;
    server app2.example.com;
}
```

IP Hash

With round robin and least connection load balancing, when a user makes an HTTP request and is load balanced to a particular server, they are not guaranteed to have their request served by the same server for the future requests.

Often times this is desirable, but in some cases, you want the same users to always hit a particular server, perhaps because of session or file locality.

This method of load balancing is often called *sticky sessions*— meaning that, once a user is routed to a server, they are stuck to it and subsequent requests will be served by the same server.

Honestly, I don't recommend using sticky sessions and often it is a symptom of an unscalable application.

The open-source version of nginx implements sticky sessions by hashing based on the IP Address of the user. If the IP of the user changes, they will unstick, and the server they're routed to may change.

Turn on IP hashing by specifying the `ip_hash` directive within the upstream context.

```
upstream {
    ip_hash;
    server app1.example.com;
    server app2.example.com;
}
```

Because this load balancing algorithm uses a hashing function to determine the server for a user, all sticky sessions will be remapped if you add or remove any servers from the pool. The `down` parameter should be used when removing servers to preserve the session hashing.

In other words, don't bet the farm on always having users routed to the same server, all of the time.

Hash

The Hash algorithm is very similar to `ip_hash`, except it allows to hash to a particular server based on any arbitrary variable in nginx. For example, this can be used to hash based on the URL or Host.

Hash was originally part of the commercial nginx plus version, but is now available in the open-source version of nginx.

Example 5-6. Hashing based on the URI

```
upstream {
    hash $uri consistent;
    server app1.example.com;
    server app2.example.com;
}
```

In fact, you could implement `ip_hash` using the `hash` directive—

Example 5-7. Implementing IP Hash with Hash

```
upstream {
    hash $remote_addr consistent;
    server app1.example.com;
    server app2.example.com;
}
```

The `consistent` parameter tells nginx to use the ketama hashing algorithm, which is almost always desirable, as it prevents a full hash remap when servers are added or removed.

Sticky Sessions (Cookie Based)

Cookie based sticky sessions are available as part of the commercial nginx plus and are covered in Chapter 10.

C10K with nginx

Using nginx as a load balancer is all about scalability. Because you typically only have a handful of load balancers for 10s or 100s of application servers, they see a much larger number of connections and requests per second.

With load balancers, latency and scalability is much more important and you want to make sure that you get it right.

The “C10K Problem” is the idea of serving 10,000 simultaneous, concurrent connections through a web server.

Since nginx is incredibly scalable, with a bit of tuning (both nginx and the linux kernel), it can scale to 10,000 connections without much difficulty. In fact, it's not unheard of to even scale it to 100,000 or more connections.

The ability for your application to be able to handle it, though, is an entirely different problem!

Scalable Load Balancer Configuration

Example 5-8. Scalable Load Balancer Configuration

```
worker_processes auto;

events {
    worker_connections 16384;
}

http {

    sendfile on;
    tcp_nopush on;
    keepalive_timeout 90;

    server {
        listen *:80 backlog=2048 reuseport;
        listen *:443 ssl backlog=2048 reuseport;
    }
}
```

```
ssl_session_cache shared:SSL:20m;
ssl_session_timeout 10m;
ssl_session_tickets on;

ssl_stapling on;
ssl_stapling_verify on;
ssl_trusted_certificate /etc/nginx/cert/trustchain.crt;
resolver 8.8.8.8 8.8.4.4 valid=300s;

}
```

Tuning Linux for a Network Heavy Load

You can have the most-optimized nginx configuration, but without tuning your linux kernel for a network heavy load, you won't see most of the results.

This is not *optional*, it's essential for high performance. The linux kernel offers some crazy tunables that are hard for even experts to fully understand. While you can find handfuls of sysctl settings online, it's usually not a good idea to copy them onto your machine blindly without fully understanding the (often complicated) implications.

The handful of settings that I'm going to share below are well understood and non-risky. They also make up over 80% of the performance gains. I'll also share some settings to do your own research on.

These kernel flags can be set with the `sysctl` tool, but will be lost upon reboot. In order to persistent the changes across reboot, you must add them to `/etc/sysctl.conf` or `/etc/sysctl.d/`.

Listen queue for new connections (`net.core.somaxconn`)

The `net.core.somaxconn` flag defines the size of the kernel queue for accepting new TCP connections and most Linux distributions have it set extremely low, at 128 connections.

The listen queue defines the maximum number of new, pending connections that can sit in the socket backlog before the kernel starts rejecting them. Clients that are rejected will see a very unhelpful Connection Refused error.

One common tell-tale sign of an undersized listen queue is the “possible SYN flooding” error log. If you see something like this in your syslog files, you need to increase the size of your listen queue:

```
[73920] possible SYN flooding on port 80. Sending cookies.
```

What's a good value to set? Well, it totally depends on the level of traffic that you're load balancing will be receiving, but I recommend setting it high enough to handle the highest amount of burst traffic that you'll be able to handle.

That is, if you have enough capacity to handle 10,000 requests per second, set it to 10,000.

You can set the value with the `sysctl` tool, like so:

```
sysctl -w net.core.somaxconn=10000
```

Afterwards, make sure to edit `/etc/sysctl.conf` and add the following line to the file:

```
net.core.somaxconn=10000
```

nginx vs ELB vs HAProxy

Over the years, I've seen many debates on nginx versus other platforms. Because nginx does so many things— it's a web server, http router, reverse proxy, load balancer, and http cache, so it naturally competes with many other specialized pieces of software.

The list is long, but is nginx a better choice than AWS ELB, HAProxy, Varnish, or Apache?

The answer in my mind is a resounding yes.

In my first book on scaling, I even recommended using HAProxy as the load balancer instead of nginx, but I've changed my position.

The reason is that nginx is so incredibly powerful and fast. It doesn't come with much bloat and will be easiest part of your infrastructure stack to scale.

Technically, on paper, HAProxy and Varnish may be 5-10% faster than nginx for load balancing and http caching, respectively. But, you can accomplish the same things with a much simpler nginx stack and only have to become an expert in one piece of software. I'd trade that over a marginal gain in speed.

Many people on AWS choose to use ELB out of convenience and because it's so cheap. While ELB scales automagically, it's not very robust in terms of features compared to nginx. For example, it does not support URI-based routing, HTTP caching, or `VirtualHosts`.

Outside of basic setups, if doing anything serious on AWS, I highly recommend using nginx as your http routing layer.

HTTP and TCP Load Balancing

So far, we've talked about reverse proxying and load balancing in terms of the OSI Layer 7—the application layer. That is to say, when nginx is acting as a reverse proxy, it's actually parsing the HTTP request, processing the headers and body, and creating a new HTTP request to the backend server. It fully understands the application protocol.

Layer 7 load balancing is great from a convenience stand-point. It's easy to understand, allows you to add or modify HTTP headers, and allows you to route to custom locations or server blocks depending on the hostname.

However, this type of load balancing also comes with some disadvantages.

- It can *only* be used to load balance HTTP
- SSL must terminate at the load balancer
- It's slower due to the overhead of parsing and repacking the HTTP request

The alternative to Layer 7 load balancing is Layer 4 (TCP) load balancing, which just forwards the raw TCP packets onwards. There is no parsing of the data, no dependences on HTTP, and SSL can pass-thru to the backend application servers transparently.

Up until April 2015, the only way to do TCP load balancing with nginx was to pay for the commercial license or use an open-source competitor like HAProxy.

Fortunately, nginx has made TCP Load Balancing part of their open-source offering as of nginx 1.9.0 and now everyone has access to it for free!

Performance aside, this opens up many new use cases for nginx, such as using it to load balance database servers or really anything that speaks TCP.

Example 5-9. Example showing TCP Load Balancing

```
stream {
    server {
        listen *:80;
        proxy_pass backend;
    }

    upstream backend {
        server app01;
        server app02;
        server app03;
    }
}
```

Two things worth noting— TCP load balancing introduces the `stream` block that's used instead of the `http` block to define TCP-based servers.

The second thing is that the `proxy_pass` directive is not contained inside of a location block, it's at the top level server block. Location blocks (and many of the other `http` specific features) no longer make sense with TCP load balancing.

For instance, you can't use `proxy_set_header` to inject an HTTP header. With simplicity comes faster performance but less robust features.

TCP PROXY Protocol

While most people can live with the reduced feature set of TCP load balancing for HTTP, the major missing feature is that you can no longer access the IP Address of the client.

That is, once the load balancer forwards the TCP packets to the backend, the packets appear to be coming from the load balancer's IP Address. Because you can no longer modify the HTTP Headers to inject `X-Real-Ip` or overwrite `Remote-Addr`, you're kind of stuck.

Fortunately, HAProxy solved this problem by adding the **Proxy Protocol** to TCP, which allows reverse proxies to inject the originating source address into the TCP connection.

To enable this, you'll have to make a change on both your nginx load balancer and your reverse proxy servers.

On your load balancer:

```
stream {
    server {
        listen *:80;
        proxy_pass backend;
        proxy_protocol on;
    }
}
```

On the backend servers:

```
server {
    listen *:80 proxy_protocol;
    proxy_set_header X-Real-IP $proxy_protocol_addr;
}
```

Future Sections

1. Caching static content at the Load balancer

2. Keep-Alive for Load balancers

