Architecture
Web Servers and Security

- The Web is the most visible part of the net
- Two web servers — Apache (open source) and Microsoft’s IIS — dominate the market
  - Apache has 37%; IIS has 34%. (Nginx, another open source web server, is in third place with 14%.) (source: http://news.netcraft.com/archives/web_server_survey.html)
- Both major servers have lots of functionality
- Are they secure? Let’s look at Apache.
Warning

- You’re going to hear about web server security issues — and problems
- Some of these issues apply to www.cs.columbia.edu
- You do not have permission to explore these holes
Metanote on Program Complexity

- Both Apache and IIS are very large, complex programs
- Large, complex programs are often buggy; these are no exception
- Both have had security problems
- IIS used to be very insecure:

  Using Internet-exposed IIS Web servers securely has a high cost of ownership. Nimda has again shown the high risk of using IIS and the effort involved in keeping up with Microsoft's frequent security patches.

  —The Gartner Group, 2001

- (They canceled that warning in 2004)
- Web servers are still large and complex...
Important Web Server Features

- Access control
- User behavior
- CGI (Apache) or ASP (IIS) scripts (often via special scripting languages)
- Plug-ins
- Back-end databases
- Cryptography
- (Does this remind you of an operating system?)
Access Control

- Many different forms
- Many different types of authentication
- Many interactions
Document Root

- All files served must reside under a certain directory
- Watch out for “.” in URLs (gee, we’ve seen that before)
- For convenience, some “subtrees” can reside somewhere else:
  
  ScriptAlias /mailman/ "'/usr/pkg/lib/mailman/cgi-bin/'"
  Alias /pipermail/ "'/var/db/mailman/archives/public/'"
  Alias /mailman-icons/ "'/usr/pkg/lib/mailman/icons/'"

- If the Web server supports “virtual hosting”, each “host” gets its own subtree
  
  With virtual hosting, a single machine and web server can offer up several different web sites
**Explicit Access Control**

- Access control lists settable by the webmaster for any directory tree
- Passwords or certificates can be configured as well
- Permission can be granted or withheld based on client IP address
- If a directory has no `index.html` file, should the web server just list its contents?
- Applications can do their own authentication and access control
- All of these interact; combinations can be used
A Sample Configuration

Here is a .htaccess file for a directory:

```html
<Files *
  AuthUserFile /home/smb/pwdir/.htpasswd
  AuthGroupFile /dev/null
  AuthName "File Access"
  AuthType Basic
  Require valid-user
</Files>
```

The string File Access is displayed to the user. Logins and passwords are stored in /home/smb/pwdir/.htpasswd.
Web Authentication

A web password file:

user1:eO3rzWPNjjZFo
user2:CqkaeLJSVcRpI
Operating System Access Control

- Can the web server benefit from OS access control?
- What UIDs does the server run under?
- What permissions can/should be used for the files being served?
“Privileged” Ports versus Security

• Most Unix systems reserve ports < 1024 for root
• Web servers listen on port 80; therefore, they have to run as root
• Do we really want such a large, complex program running as root? Not if we can help it...
Shedding Privileges

- Apache starts as root
- Note: it is *not* setuid; it must be invoked by root. (Why is that the right choice?)
- It opens the socket and some log files, then forks and sheds privileges
- Serving web pages is done as non-privileged user “www”
File Permissions

- If the web server isn’t root, it can’t open protected files
- All pages served must be readable by the web server, its group, or “other”
- Don’t make them owned by www; that way, a compromised web server can’t overwrite them
- In other words, the web server itself has as few privileges as possible
Design Philosophy

- Use the OS to protect the system against the web server
- Assume the web server can enforce its own access control mechanisms
User Behavior

- Who creates web content?
- Can ordinary users supply web pages?
- At many sites, the answer is yes
- This complicates things
User Directories

- Can users export things they shouldn’t?
  - Is that a software problem or a management problem?

- Where does user content live? Under DocumentRoot, or under the user’s home directory?

- Can user-configured access control (.htaccess) override system access control settings?

- Scripts...
Users versus Web Access Control

• Suppose there’s a `.htaccess` file to restrict web access to some directory
• The directory and its contents probably have to be world-readable
• Other users on that machine can read the files in that directory, without satisfying the requirements of the `.htaccess` file
• Oops…
Can We Lock Things Away?

- We don’t want content owned by user www
- We could try putting user content under some lock directory, with a setuid helper program to let people publish web pages
- That doesn’t work well if user-written scripts are allowed
- We can protect a few resources by using group read permissions — make the content group-readable but not other-readable, and let the web server run with several groups’ permissions

Unfortunately, Apache doesn’t seem to support that
- There’s still a problem with scripts
Scripts

- Retrieving static files is ok, but scripts make life interesting
- Scripts are *programs*
- Each script is a separate network service
- Is each one correct?
- From the Apache Security Guide: “Always remember that you must trust the writers of the CGI script/programs or your ability to spot potential security holes in CGI, whether they were deliberate or accidental.”
Script Permissions

• In general, all scripts run with the same permissions
• This uid shouldn’t own any files; see above for OS access controls
• Scripts can interfere with each other: “All the CGI scripts will run as
  the same user, so they have potential to conflict (accidentally or
deliberately) with other scripts e.g. User A hates User B, so he writes
a script to trash User B’s CGI database.”
User-Written Scripts

- Can ordinary users supply scripts?
- Translation: can ordinary users write secure programs that will do the right thing given arbitrary input?
- From the Apache Security Guide:

  Allowing users to execute CGI scripts in any directory should only be considered if:

  1. You trust your users not to write scripts which will deliberately or accidentally expose your system to an attack.

  2. You consider security at your site to be so feeble in other areas, as to make one more potential hole irrelevant.

  3. You have no users, and nobody ever visits your server.
Restricting Scripts

• Allow scripts only in certain directories
• That way, the administrator has some control over what scripts are run
• Use suEXEC to switch uids
suEXEC

- suEXEC runs user CGI scripts as that user
- A dangerous operation: let an unprivileged user — www — tell a setuid-root program to run some arbitrary program as some user
- Very difficult to get right!
- suEXEC performs 20 different checks; see http://httpd.apache.org/docs/2.4/suexec.html for details
- Sample check: Is the directory NOT writable by anyone else?
- Make sure that suEXEC is only executable by group www
- Watch out for race condition attacks!
- Caution: the CGI script owns itself; if subverted, it can overwrite itself (and other files belonging to that user)
Design Philosophy

- Use Apache access controls to isolate the dangerous stuff
- Use OS permission mechanisms — as invoked by Apache — to isolate CGI scripts from each other
- Separation isn’t as strong as for the base Apache system, because of the overwrite scenario
Plug-Ins

- Scripting languages are often available as Apache *modules*
- This means that they run as part of the Apache process
- Modules are an efficiency hack: save the expense of fork()/exec()
- Modules run with the full permissions (and address space) of Apache
- Very dangerous!
User-Written Plug-in Scripts

• In the standard installation, user-written scripts run with the web server’s permission

• Again, all such scripts, even if written by different, mutually hostile users, run with the same UID

• Do the plug-in languages provide access control? Some do
PHP’s Safe Mode

- PHP, if `safe_mode` is turned on, restricts scripts to opening files owned by the script owner.
- This in an application — PHP — enforcing something resembling OS permissions.
- Did they get it right? Are there race condition attacks?
- Still does not protect against attacks from on-machine.
Other Script Languages

- Java can be configured to be secure
- To my knowledge, neither Perl nor TCL — two other languages that can run as plug-ins — have such a feature
- There is no way to confine C or C++
Invoking Scripts

• Scripts are often invoked with client-supplied parameters

• Magic shell characters aren’t as big a problem for parameters, because they’re passed to scripts via an environment variable, not on the command line

• But — what about magic shell characters in the script name?

• Example: http://www.example.com/cgi-bin/`rm-rf/`

• After all, if it’s in `cgi-bin` it’s executable...
Administrator Strategy

- Use a complex local scheme
- Provide a setuid program to copy user content to the web server
- Do not allow user programs to execute on that server
- Permit only “safe” scripting languages with their own access control
- Do not permit execution of C or C++ programs!
- Use web server access controls to restrict other access
Uploading Files

- If all scripts run with the same permissions, and if local users have read-access to user content, how can you do safe upload?
- Example: suppose I wanted to write a PHP script for homework submission
- Create an upload directory owned by me that is mode `rwx, -wx, -wx`: anyone can write to it or trace a search path, but not read it
- Use a true-random string for part or all of the filename
- For instance, store smb2132.0.tar as 158cb5864f2c7662b-smb2132.0.tar (generated from `/dev/urandom`)
- No one will guess that to retrieve it or overwrite it
- Note: I’ll be able to list the directory and read the files (if I set the file permissions correctly), but I won’t own the files; www will
Back-End Databases

- Scripts are often front-ends to databases
- Does the database have its own access control? Where is the password stored?
- How does the script supply the password?
- Remember that any file on the server is readable by all other users or script writers...
Design Issues

- Neither the OS nor Apache’s access controls can help us much
- We have to rely on the script language’s access controls
- Even that may not protect us from subverted scripts
Cryptography

• TLS encryption used for most e-commerce
• TLS uses hybrid public key/symmetric crypto
• Where does the web server get its private key?
• Again, how do we store a key on a computer?
Key Storage

• Ideally, it’s stored in encrypted form, or in some tamper-resistant device

• We can’t store it encrypted — how is the decryption key supplied at Apache startup?

• A few large sites use TLS front-end/load-balancer devices, but these aren’t common

• We must store the key in the clear, on the web server machine
Protecting the Key

- Of course, it’s stored mode `r--,-,-,-`
- It’s also owned by root, and read in at startup before changing UIDs
- Why? To provide maximum OS protection against subversion
Authentication

- Two basic types: passwords and client-side certificates
- Passwords can be for the built-in Web browser authentication or for application-specific authentication
- Passwords should *never* be used without encrypting the network connection
- Client-side certificates are more secure, but they’re rare
- They’re also less convenient: how does the user carry around a private key to multiple machines?
- Ultimately, the client’s identity feeds into Apache’s access control mechanisms
Phishing

- Trick people into sending their passwords to the wrong site
- People *could* check the site’s certificate — but very few people do that
- Legitimate site should *never* email clickable links — but many do
- What good is a strong web password?
Password Managers

- Store passwords for many web sites
- Protect them with a master password
- The code matches the web site name against the stored password; it won’t be fooled by phishing email
Lessons

- Web servers are *very* hard to secure
- We need all of our tools: OS permissions, application ACLs, script language security, cryptography, and more
- There are often residual issues even then