Secure Programming

Canonicalization

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Learning objectives

- Understand that there are many ways of representing "addresses" and names, like a path to a file, but only one standard way: the canonical one
- Understand how canonicalization issues can result in directory traversal vulnerabilities
- Learn which OS-provided function calls help with canonicalization issues
- Learn how to use chroot to defend against directory traversal vulnerabilities

Canonicalization and Directory Traversal: Outline

- Importance of Directory Traversal Vulnerabilities
- Canonical names
- BearShare example
- How to canonicalize
- Mitigating solutions (e.g., chroot)
- Lab

Importance

- Directory traversal vulnerabilities are very common, but not as much as buffer overflows
  - They may allow remotely writing or reading files, depending. These may be executable files, or be secret or confidential documents.
- Canonicalization issues are more complex in Windows, due to the many ways of naming a file
  - short name (8.3)
  - long name
  - Unicode name
  - Streams
  - Trailing dots, forward slashes or backslashes
  - etc...

Directory Traversal Vulnerabilities

- Basic Idea: the characters '..' mean "Go up a directory"
- They can be inserted in file paths for
  - Browsing
  - Reading
  - Execution
- Often a network services problem (e.g., ftp)
  - Web sites
  - Web-enabled applications
  - Applications using networks

Synonyms

- “..” (“dot dot”) attacks
- Also “...” on Windows
  - Windows 95, 98
  - Goes up two directories

Definition of Canonical

- Canonical means *the* standard form or representation of something
  - Canonicalization: "process by which various equivalent forms of a name can be resolved to a single, standard name – the so-called canonical name.”
- Usually the simplest form
  - Without symlinks
- “/usr/../home/student” is the same as “/home/student”
- /home/student is the canonical path

Question

- Given that there is a symbolic link:

```
/home/alfred/sss -> /home/myhomebiz/accounting/spreadsheets/
```

What is the canonical path to:

```
"/home/bob/../mary/../alfred/.//sss/may.xls"
```
?

a) /home/alfred/sss/may.xls

b) /home/myhomebiz/accounting/spreadsheets/may.xls

c) /home/alfred/may.xls

The Problem

- If you forbid access to /home/private but enable access to /home/public, what do you do with a request for:
  - "/home/public/../private" ?
  - "/home/PRIVATE" ? (This one is dependent on the file system)

Answer

- “/home/public/../private” should of course be forbidden, but many programs are fooled by the presence of “..” and equivalent character encodings and obfuscations.
- Programs filtering out only “..” are still vulnerable.

Mismatched Object and Access Control

- The HFS+ file system is case insensitive. "/home/PRIVATE" == "/home/private"
- Apache directory access control is case sensitive, as it is designed for UFS (UNIX File System). It thinks that "/home/PRIVATE" is different from "/home/private".
- Join the two together and you have a canonicalization ("directory traversal") vulnerability, even though both systems alone are correct.
  - Fixed since

Url Vulnerabilities

- protocol://server/path
- Example:
  - http://www.host.com/path
  - path contains '..'; what do you do?

Symantec Example

- CVE-1999-0842
- Symantec Mail-Gear 1.0 web interface server allows remote users to read arbitrary files via a .. (dot dot) attack.

Example With Bad Patches (Instructive)

- BearShare
- Peer-to-peer file sharing service
- Also had a vulnerable web server component!

BearShare 2.2.2

- CVE-2001-0368
- http://vulnerable:6346/........../windows/win.ini
- This would download the win.ini file from the windows directory.
- This is a classic Directory Traversal vulnerability.

Wrong Way to Patch

- First attempt to patch, Apr 30 2001
- They forbid ‘{/\}.(.)*’ (unencoded) in the path
- Why is it bad?

BearShare 4.05 Vulnerability

- Attempt to fix previous exploit by filtering bad stuff
- New exploit:
  - http://127.0.0.1:6346/%5c..%5c..%5c..%5cwindows%5cwin.ini
    - %5c == '\'
    - This passes the filter
- Then it translates into: http://127.0.0.1:6346/\..\..\..\windows\win.ini
- Returning the win.ini file.

BearShare 4.06

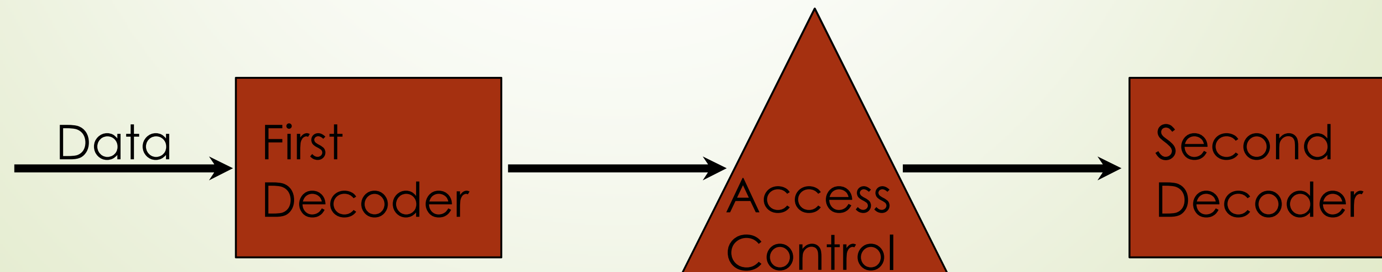
- http://127.0.0.1:6346/%5c..%5c..%5c..%5cwindows%5c win%2eini
  - %2e is "."
- Also returns the win.ini file.
- What went wrong twice?
  - Filter is a black list instead of white list
  - Filter is applied before canonicalization
- Good time to remind of "How to obscure any URL"
  - http://www.pc-help.org/obscure.htm

Other Character Encoding Example

- CAN-2004-0072
- Directory traversal vulnerability in Accipiter Direct Server 6.0 allows remote attackers to read arbitrary files via encoded \.. (backslash .., "%5c%2e%2e") sequences in an HTTP request.
- Hundreds of similar vulnerabilities

Double Encoding

- CVE-2001-0333
- Directory traversal vulnerability in IIS 5.0 and earlier allows remote attackers to execute arbitrary commands by encoding .. (dot dot) and "\" characters twice.
- How many in-series decoders are there?
- Are there any *after* the access control decisions have been made?



Repeated Mistake

- Attempt to cleanse '..' and things that have certain meanings ('.ini') directly from input
- These attempts to do semantic validation before resolving encoding and canonicalization will fail
- Too many ways to represent the same thing

How to Canonicalize Paths

- Goal: Find the absolute name of a file which contains no ".", ".." components nor any repeated path separators (/) or symlinks
- UNIX:
  - **realpath** (obsolescent but may be only available function)
    - Requires buffer allocation ahead of time
    - Buffer should be of length PATH_MAX
    - What if PATH_MAX is undefined because a system has no limit on path length?
  - **canonicalize_file_name** (new)
    - Allocates the needed memory

Canonical Names

- PHP:
  - string realpath (string path)
- Windows:
  - GetFullPathName
- Java:
  - File.getCanonicalPath() or File.getCanonicalFile()

Differences Between UNIX and Windows

- UNIX:
  - All but the last component of pathname must exist when realpath() is called.
- Windows:
  - "This function does not verify that the resulting path and file name are valid or that they see an existing file on the associated volume."
  - Need to standardize on either short or long file names
    - Long names are prefered

Things That Look Like Files But Aren't

- Devices (Windows, UNIX)
- Special cases (Linux)
  - /proc/self contains information reflecting the state of the process accessing the directory.
- Sockets
  Unix domain sockets can be bound to locations in the file system. While these cannot be opened like normal files, they can still be used to create things like lock files.
- NTFS Alternate Data Streams
- Named Pipes and Mailslots
- UNC (\\UNC\share\name\here)

Solutions Without Code

- Chroot "jail"
  - Confine a process to a specific directory
  - Independent microsphere
    - self-contained
  - Derivatives
    - FreeBSD "jail"
    - Solaris "zones"
- Subdomain (Immunix)
  - Applies an access control list to file references
  - No duplication of files
- Windows doesn't have equivalent (closest functionality is virtual machines)

Chroot

- Chroot changes the filesystem "root".
- The applications in a chroot jail can't use files outside the visible root of the filesystem
  - They are "jailed" down in a subdirectory
- Example
  - ```
    chdir("/foo/bar");
    chroot("/foo/bar");
    ```
- chroot [-u -user] [-g -group] [-G -group,group,...] newroot [command]
    ```

Chroot Can Fail

- Doesn’t work against root
  - Is service running as root?
  - If not, is there a vulnerability that yields root access?
  - Yes -> “Get Out of Jail”
  - http://www.bpfh.net/simes/computing/chroot-break.html
- Important to run with lowers privileges
  - Special users
- FreeBSD "jail" claims to have closed those loopholes

Lab

- Write an application that will:
  - Take as input two command-line arguments
    1) a path to a file or directory
    2) a path to a directory
  - Output the canonicalized path equivalent for the first argument.
    - If the path would not refer to a real path (UNIX semantics as described before), issue a warning.
  - Decide whether or not the first argument refers to a file inside the second argument
    - Think of the second argument as a filesystem root for a server of some kind (web, FTP)

Lab notes

- Use canonicalize_file_name
  - http://www.delorie.com/gnu/docs/glibc/libc_279.html
- Canonical path resolution always goes left to right