CSE 484 (Winter 2008)

Software Security: Attacks, Defenses, and Design Principles

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Goals for Today

- Defensive Mechanisms
  - Languages
  - System changes
- Software Development Design Principles
  - (Programming practices)

Preventing Buffer Overflow

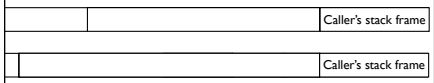
- Use safe programming languages, e.g., Java
  - What about legacy C code?
- Mark stack as non-executable
- Randomize stack location or encrypt return address on stack by XORing with random string
  - Attacker won't know what address to use in his or her string
- Static analysis of source code to find overflows
- Run-time checking of array and buffer bounds
  - StackGuard, libsafe, many other tools
- Black-box testing with long strings

Non-Executable Stack

- NX bit on every Page Table Entry
  - AMD Athlon 64, Intel P4 "Prescott"
  - Code patches marking stack segment as non-executable exist for Linux, Solaris, OpenBSD
- Some applications need executable stack
  - For example, LISP interpreters
- Does not defend against return-to-libc exploits
  - Overwrite return address with the address of an existing library function (can still be harmful)
- …nor against heap and function pointer overflows
- …nor changing stack internal variables (auth flag, ...)

Run-Time Checking: StackGuard

- Embed "canaries" in stack frames and verify their integrity prior to function return
  - Any overflow of local variables will damage the canary



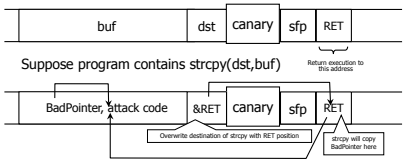
- Choose random canary string on program start
  - Attacker can't guess what the value of canary will be
- Terminator canary: "\0", newline, linefeed, EOF
  - String functions like strcpy won't copy beyond "\0"

StackGuard Implementation

- StackGuard requires code recompilation
- Checking canary integrity prior to every function return causes a performance penalty
  - For example, 8% for Apache Web server
- PointGuard also places canaries next to function pointers and setjmp buffers
  - Worse performance penalty
- StackGuard can be defeated!
  - Phrack article by Bulba and Kil3r

Defeating StackGuard (Sketch)

- Idea: overwrite pointer used by some strcpy and make it point to return address (RET) on stack
  - strcpy will write into RET without touching canary!



Run-Time Checking: Libsafe

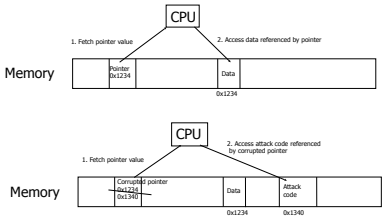
- Dynamically loaded library
- Intercepts calls to strcpy(dest,src)
  - Checks if there is sufficient space in current stack frame

    |frame-pointer – dest| > strlen(src)
  - If yes, does strcpy; else terminates application

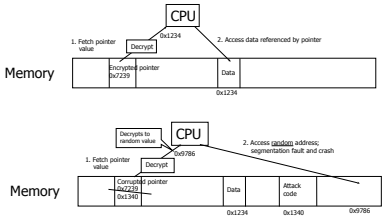
PointGuard

- Attack: overflow a function pointer so that it points to attack code
- Idea: encrypt all pointers while in memory
  - Generate a random key when program is executed
  - Each pointer is XORed with this key when loaded from memory to registers or stored back into memory
    - Pointers cannot be overflown while in registers
- Attacker cannot predict the target program's key
  - Even if pointer is overwritten, after XORing with key it will dereference to a "random" memory address

Normal Pointer Dereference [Cowan]



PointGuard Dereference [Cowan]



Fuzz Testing

- Generate "random" inputs to program
  - Sometimes conforming to input structures (file formats, etc)
- See if program crashes
  - If crashes, found a bug
  - Bug may be exploitable
- Surprisingly effective

- Now standard part of development lifecycle, e.g., for IE

Genetic Diversity

- Problems with Monoculture
- Steps toward diversity
  - Automatic diversification of compiled code
  - Address Space Randomization

Principles

- Check inputs

Principles

- Least privilege

Principles

- Check all return values

Principles

- Securely clear memory (passwords, keys, etc)

Principles

- Failsafe defaults

Principles

- Reduce size of TCB
- Simplicity
- Modularity

Principles

- Open design? Open source?
- Maybe...
- Linux Kernel Backdoor Attempt: http://www.freedom-to-tinker.com/?p=472

Vulnerability Analysis and Disclosure

- What do you do if you've found a security problem in a real system?
- Say
  - IM client?
  - Electronic voting machine?
  - ATM machine?
  - Hospital drug (morphine) pump