CSci 5271
Introduction to Computer Security
Day 4: Low-level attacks

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Outline

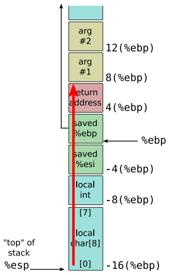
Classic code injection attacks

Announcements intermission

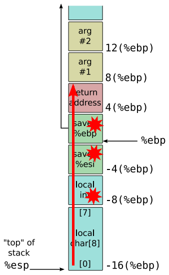
Shellcode techniques

Exploiting other vulnerabilities

Overwriting the return address



Collateral damage



Collateral damage

- Stop the program from crashing early
- ‘Overwrite’ with same value, or another legal one
- Minimize time between overwrite and use

Other code injection targets

- Function pointers
  - Local, global, on heap
- `longjmp` buffers
- GOT (PLT) / import tables
- Exception handlers

Indirect overwrites

- Change a data pointer used to access a code pointer
- Easiest if there are few other uses
- Common examples
  - Frame pointer
  - C++ object vtable pointer

Non-sequential writes

- E.g. missing bounds check, corrupted pointer
- Can be more flexible and targeted
  - E.g., a *write-what-where* primitve
- More likely needs an absolute location
- May have less control of value written

Unexpected-size writes

- Attacks don't need to obey normal conventions
- Overwrite one byte within a pointer
- Use mis-aligned word writes to isolate a byte

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Note to early readers

- This is the section of the slides most likely to change in the final version
- If class has already happened, make sure you have the latest slides for announcements

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Basic definition

- Shellcode: attacker supplied instructions implementing malicious functionality
- Name comes from example of starting a shell
- Often requires attention to machine-language encoding

Classic execve `/bin/sh`

- `execve(fname, argv, envp)` system call
- Specialized syscall calling conventions
- Omit unneeded arguments
- Doable in under 25 bytes for Linux/x86

Avoiding zero bytes

- Common requirement for shellcode in C string
- Analogy: broken 0 key on keyboard
- May occur in other parts of encoding as well

More restrictions

- No newlines
- Only printable characters
- Only alphanumeric characters
- "English Shellcode" (CCS'09)

Transformations

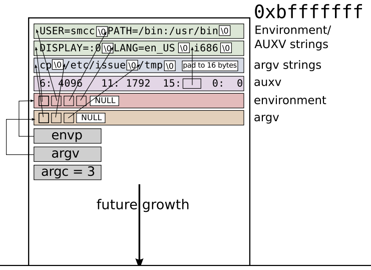
- Fold case, escapes, Latin1 to Unicode, etc.
- Invariant: unchanged by transformation
- Pre-image: becomes shellcode only after transformation

NOP sleds

- Goal: make the shellcode an easier target to hit
- Long sequence of no-op instructions, real shellcode at the end
  - x86: 0x90 0x90 0x90 0x90 0x90 … shellcode

Where to put shellcode?

Environment variables


0xbfffffff
USER=smcc \0 PATH=/bin:/usr/bin \0
DISPLAY=:0 \0 LANG=en_US \0 i686 \0
cp \0 /etc/issue \0 /tmp \0 pad to 16 bytes
6: 4096 11: 1792 15: 0: 0
NULL
NULL
envp
argv
argc = 3
Environment/ AUXV strings
argv strings
auxv
environment
argv
future growth

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Multi-stage approach

- Initially executable portion unpacks rest from another format
- Improves efficiency in restricted environments
- But self-modifying code has pitfalls

Where to put shellcode?

- In overflowed buffer, if big enough
- Anywhere else you can get it
  - Nice to have: predictable location
- Convenient choice of Unix local exploits:

Code reuse

- If can't get your own shellcode, use existing code
- Classic example: `system` implementation in C library
  - "Return to libc" attack
- More variations on this later

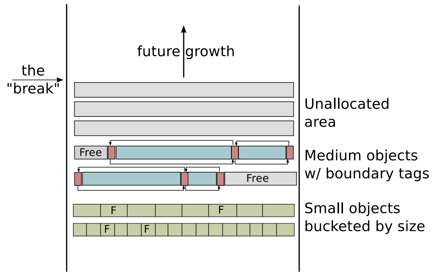
Non-control data overwrite

- Overwrite other security-sensitive data
- No change to program control flow
- Set user ID to 0, set permissions to all, etc.

Heap meta-data

- Boundary tags similar to doubly-linked list
- Overwritten on heap overflow
- Arbitrary write triggered on `free`
- Simple version stopped by sanity checks

Heap meta-data


future growth
the "break"
Unallocated area
Free
Free
Medium objects w/ boundary tags
F
F
F
F
Small objects bucketed by size

Use after free

- Write to new object overwrites old, or vice-versa
- Key issue is what heap object is reused for
- Influence by controlling other heap operations

Integer overflows

- Easiest to use: overflow in small (8-, 16-bit) value, or only overflowed value used
- 2GB write in 100 byte buffer
  - Find some other way to make it stop
- Arbitrary single overwrite
  - Use math to figure out overflowing value

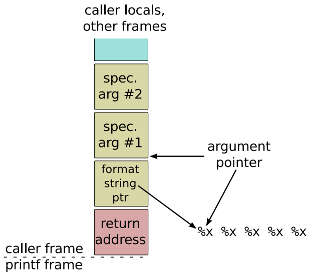
Null pointer dereference

- Add offset to make a predictable pointer
  - On Windows, interesting address start low
- Allocate data on the zero page
  - Most common in user-space to kernel attacks
  - Read more dangerous than a write

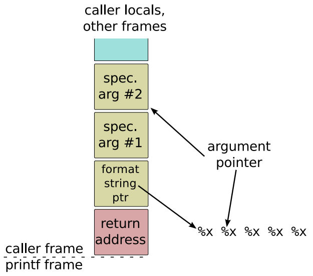
Format string attack

- Attacker-controlled format: little interpreter
- Step one: add extra integer specifiers, dump stack
  - Already useful for information disclosure

Format string attack layout



Format string attack layout



Format string attack: overwrite

- `%n` specifier: store number of chars written so far to pointer arg
- Advance format arg pointer to other attacker-controlled data
- Control number of chars written with padding
- On x86, use unaligned stores to create pointer

Next time

- Defenses and counter-attacks