CSE 484 / CSE M 584: Computer Security and Privacy

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Announcements / Answers

• Ethics form: Due Wednesday (10/3).
• Homework #1: Due Friday (10/5). Groups formed? Aim to finish by Thursday.
• Lab #1: Aiming for out this week. Quiz section this week is critical!
• In-class worksheet pick up @ Office Hours starting next-week.
TOWARDS DEFENSES
Approaches to Security

• Prevention
  – Stop an attack

• Detection
  – Detect an ongoing or past attack

• Response
  – Respond to attacks

• The threat of a response may be enough to deter some attackers
Whole System is Critical

• Securing a system involves a whole-system view
  – Cryptography
  – Implementation
  – People
  – Physical security
  – Everything in between

• This is because “security is only as strong as the weakest link,” and security can fail in many places
  – No reason to attack the strongest part of a system if you can walk right around it.
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- People
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Whole System is Critical

- Securing a system involves a whole-system view—Cryptography, Implementation, People, Physical security, and everything in between.

- This is because "security is only as strong as the weakest link," and security can fail in many places. No reason to attack the strongest part of a system if you can walk right around it.
Attacker’s Asymmetric Advantage
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- Attacker only needs to win in one place
- Defender’s response:
  - Threat Model
  - Defense in Depth
From Policy to Implementation

- After you’ve figured out what security means to your application, there are still challenges:
  - Requirements bugs
    - Incorrect or problematic goals
  - Design bugs
    - Poor use of cryptography
    - Poor sources of randomness
    - ...
  - Implementation bugs
    - Buffer overflow attacks
    - ...
  - Is the system usable?
Many Participants

• Many parties involved
  – System developers
  – Companies deploying the system
  – The end users
  – The adversaries (possibly one of the above)

• Different parties have different goals
  – System developers and companies may wish to optimize cost
  – End users may desire security, privacy, and usability
  – But the relationship between these goals is quite complex
    (will customers choose features or security?)
Better News

• There are a lot of defense mechanisms
  – We’ll study some, but by no means all, in this course

• It’s important to understand their limitations
  – “If you think cryptography will solve your problem, then you don’t understand cryptography... and you don’t understand your problem” -- Bruce Schneier
SOFTWARE SECURITY
Adversarial Failures

• Software bugs are bad
  – Consequences can be serious
• Even worse when an intelligent adversary wishes to exploit them!
  – Intelligent adversaries: Force bugs into “worst possible” conditions/states
  – Intelligent adversaries: Pick their targets
• Buffer overflows bugs: Big class of bugs
  – Normal conditions: Can sometimes cause systems to fail
  – Adversarial conditions: Attacker able to violate security of your system (control, obtain private information, ...)
BUFFER OVERFLOWS
A Bit of History: Morris Worm

• Worm was released in 1988 by Robert Morris
• Worm was intended to propagate slowly and harmlessly measure the size of the Internet
• Due to a coding error, it created new copies as fast as it could and overloaded infected machines
• $10-100M worth of damage
A Bit More History

• Morris: Graduate student at Cornell, son of NSA chief scientist
• Convicted under Computer Fraud and Abuse Act, sentenced to 3 years of probation and 400 hours of community service
• Now an EECS professor at MIT
Morris Worm and Buffer Overflow

• One of the worm’s propagation techniques was a buffer overflow attack against a vulnerable version of fingerd on VAX systems
  – By sending special string to finger daemon, worm caused it to execute code creating a new worm copy
Famous Internet Worms

• Buffer overflows: very common cause of attacks
  – Still today!
• Morris worm (1988): overflow in *fingerd*
  – 6,000 machines infected
• CodeRed (2001): overflow in MS-IIS server
  – 300,000 machines infected in 14 hours
• SQL Slammer (2003): overflow in MS-SQL server
  – 75,000 machines infected in 10 minutes (!!!)
• Sasser (2005): overflow in Windows LSASS
  – Around 500,000 machines infected
... And More

• Conficker (2008-09): overflow in Windows RPC
  – Around 10 million machines infected (estimates vary)

• Stuxnet (2009-10): several zero-day overflows + same Windows RPC overflow as Conficker
  – Windows print spooler service
  – Windows LNK shortcut display
  – Windows task scheduler

• Flame (2010-12): same print spooler and LNK overflows as Stuxnet
  – Targeted cyberespionage virus

• Still ubiquitous, especially in embedded systems
  – E.g., our car work (OnStar, Bluetooth, CD player)
Attacks on Memory Buffers

• **Buffer** is a pre-defined data storage area inside computer memory (stack or heap)

• Typical situation:
  – A function takes some input that it writes into a pre-allocated buffer.
  – The developer *forgets to check* that the size of the input isn’t larger than the size of the buffer.
  – Uh oh.
    • “Normal” bad input: crash
    • “Adversarial” bad input: take control of execution
Stack Buffers

• Suppose Web server contains this function

```c
void func(char *str) {
    char buf[126];
    ...
    strcpy(buf, str);
    ...
}
```

• No bounds checking on `strcpy()`

• If `str` is longer than 126 bytes
  – Program may crash
  – Attacker may change program behavior
Example: Changing Flags

- Suppose Web server contains this function
  ```c
  void func(char *str) {
      char buf[126];
      ...
      strcpy(buf,str);
      ...
  }
  ```
- **Authenticated** variable non-zero when user has extra privileges
- Morris worm also overflowed a buffer to overwrite an authenticated flag in fingerd
Memory Layout

- **Text region:** Executable code of the program
- **Heap:** Dynamically allocated data
- **Stack:** Local variables, function return addresses; grows and shrinks as functions are called and return
Stack Buffers

- Suppose Web server contains this function:

```c
void func(char *str) {
    char buf[126];
    strcpy(buf, str);
}
```

- When this function is invoked, a new frame (activation record) is pushed onto the stack.
What if Buffer is Overstuffed?

• Memory pointed to by str is copied onto stack...

```c
void func(char *str) {
    char buf[126];
    strcpy(buf, str);
}
```

• If a string longer than 126 bytes is copied into buffer, it will overwrite adjacent stack locations.

strcpy does NOT check whether the string at *str contains fewer than 126 characters

This will be interpreted as return address!
Executing Attack Code

• Suppose buffer contains attacker-created string
  – For example, str points to a string received from the network as the URL

• When function exits, code in the buffer will be executed, giving attacker a shell ("shellcode")
  – Root shell if the victim program is setuid root
Buffer Overflows Can Be Tricky...

• Overflow portion of the buffer must contain correct address of attack code in the RET position
  – The value in the RET position must point to the beginning of attack assembly code in the buffer
    • Otherwise application will (probably) crash with segfault
  – Attacker must correctly guess in which stack position their buffer will be when the function is called
Problem: No Bounds Checking

• strcpy does not check input size
  – strcpy(buf, str) simply copies memory contents into buf starting from *str until “\0” is encountered, ignoring the size of area allocated to buf

• Many C library functions are unsafe
  – strcpy(char *dest, const char *src)
  – strcat(char *dest, const char *src)
  – gets(char *s)
  – scanf(const char *format, …)
  – printf(const char *format, …)
Does Bounds Checking Help?

- `strncpy(char *dest, const char *src, size_t n)`
  - If `strncpy` is used instead of `strcpy`, no more than `n` characters will be copied from `*src` to `*dest`
    - Programmer has to supply the right value of `n`

- Potential overflow in `htpasswd.c` (Apache 1.3):
  ```
  strcpy(record, user);
  strcat(record, "":"");
  strcat(record, cpw);
  ```
  Copies username ("user") into buffer ("record"), then appends ":" and hashed password ("cpw")

- Published fix:
  ```
  strncpy(record, user, MAX_STRING_LEN-1);
  strcat(record, ":" );
  strcat(record, cpw, MAX_STRING_LEN-1);
  ```
Misuse of strncpy in htpasswd “Fix”

• Published “fix” for Apache htpasswd overflow:

```c
strncpy(record,user,MAX_STRING_LEN-1);
strcat(record,":")
strncat(record,cpw,MAX_STRING_LEN-1);
```

MAX_STRING_LEN bytes allocated for record buffer

- Put up to MAX_STRING_LEN-1 characters into buffer
- Put ":" contents of *cpw
- Again put up to MAX_STRING_LEN-1 characters into buffer
- Put up to MAX_STRING_LEN-1 characters into buffer
What About This?

- Home-brewed range-checking string copy

```c
void mycopy(char *input) {
  char buffer[512]; int i;

  for (i=0; i<=512; i++)
    buffer[i] = input[i];
}
void main(int argc, char *argv[]) {
  if (argc==2)
    mycopy(argv[1]);
}
```
Off-By-One Overflow

• Home-brewed range-checking string copy

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void mycopy(char *input) {
    char buffer[512]; int i;
    for (i=0; i<=512; i++)
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}
void main(int argc, char *argv[]) {
    if (argc==2)
        mycopy(argv[1]);
}
```

• 1-byte overflow: can’t change RET, but can change pointer to previous stack frame...

This will copy 513 characters into buffer. Oops!
Frame Pointer Overflow

![Diagram of Frame Pointer Overflow]

- **Fake FP**
- **Fake RET**
- **ATTACK CODE**
- **buf**
- **Saved FP**
- **ret/IP**
- **str**
- **Local variables**
- **Args**
- **Caller’s frame**
- **Addr 0xFF...F**

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Other Overflow Targets

• Function pointer, format strings in C
  – More details next time

• Heap management structures used by malloc()
  – More details in section

• These are all attacks you can look forward to in Lab #1 😊
To Do

• Ethics form (due Wed Oct 3 – do it soon!)
• Homework #1 (due Fri Oct 5)
  – Now: Groups formed? Think about events and technologies you’d like to review, ideally finish before Thursday.
• Quiz section this week critical for Lab 1
• Guest lecture on Wednesday
• In-class worksheet pick up @ Office Hours starting next-week