Backdoors, Endianness

CS 2130: Computer Systems and Organization 1

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Announcements

- Homework 4 due Friday at 11:59pm on Gradescope
  - Note the earlier deadline!
  - You have written most of this code already
  - Lab 6 may provide a fast way to get started

Backdoors

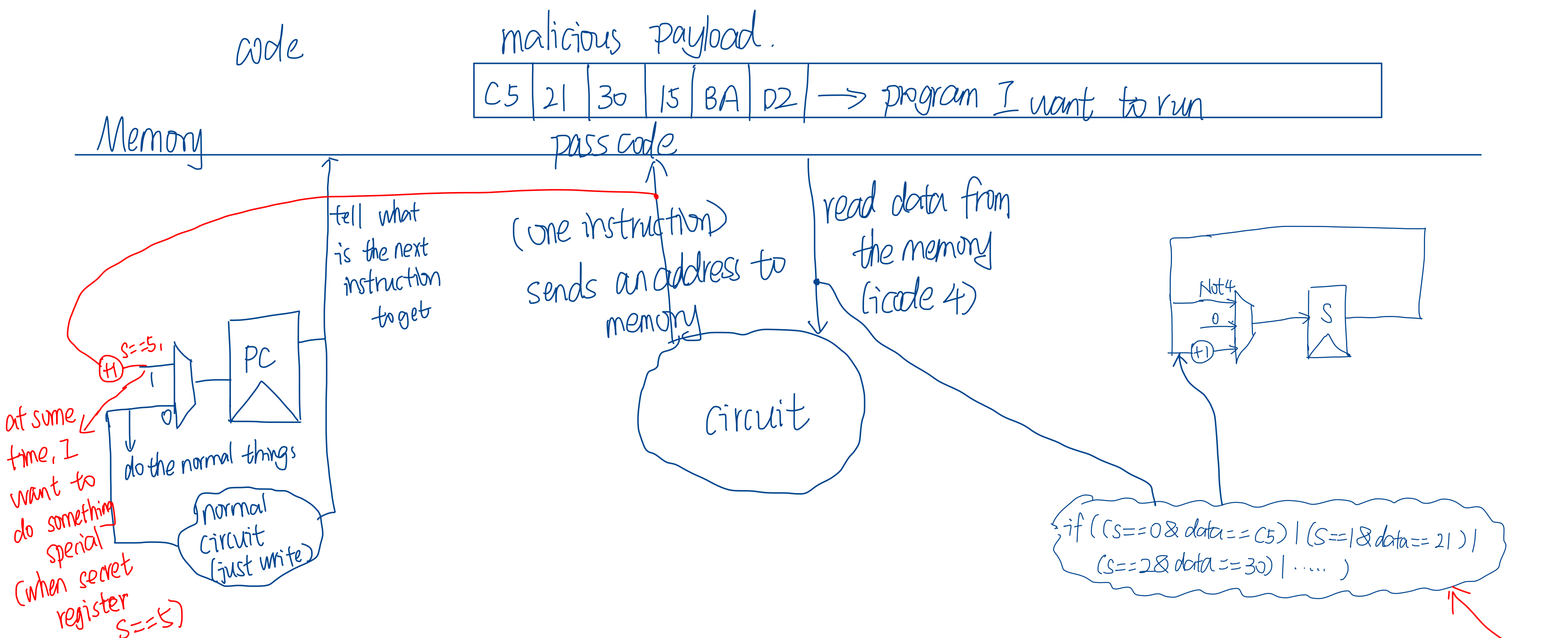
Backdoor: secret way in to do new unexpected things

- Get around the normal barriers of behavior
- Ex: a way in to allow me to take complete control of your computer

Exploit - a way to use a vulnerability or backdoor that has been created

- Our exploit today: a **malicious payload**
  - A passcode and program
  - If it ever gets in memory, run my program regardless of what you want to do

Our Hardware Backdoor



Something not icode 4: keep the original value

if it is icode4: ① reset counter if that's not part of my passcode

② increasmentor: under special condition

Our Hardware Backdoor

Will you notice this on your chip?

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- Modern chips have **billions** of transistors
- We're talking adding a few hundred transistors

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Will you notice this on your chip?

- Modern chips have **billions** of transistors
- We're talking adding a few hundred transistors
- Maybe with a microscope? But you'd need to know where to look!

If I had a microscope and I knew exactly where to look, I probably can find it.

Or, maybe, I'm very, very lucky.

But - Most exploits are going to be found after somebody tries to use them.

Our Hardware Backdoor

Have you heard about something like this before?

- Sounds like something from the movies
- People claim this might be happening
- To the best of my knowledge, no one has ever admitted to falling in this trap

Ethics, Business, Tech

Are there reasons to do this? Not to do this?

- No technical reason not to, it’s easy to do!

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Can we make a system where one bad actor can't break it?

- Code reviews, double checks, verification systems, automated verification systems, ...

Why does this work?

Why?

Why does this work?

- **It's all bytes!**
- Everything we store in computers are bytes
- We store code and data in the same place: memory

Von Neumann model

It's all bytes

Memory, Code, Data... It's all bytes!

- **Enumerate** - pick the meaning for each possible byte
- **Adjacency** - store bigger values together (sequentially)
- **Pointers** - a value treated as address of thing we are interested in

Enumerate

Enumerate - pick the meaning for each possible byte

Assign meaning to this byte.

What is 8-bit 0x54?

Unsigned integer	eighty-four
Signed integer	positive eighty-four
Floating point w/ 4-bit exponent	twelve
ASCII	capital letter T: `T`
Bitvector sets	The set $\{2, 3, 5\}$
Our example ISA	Flip all bits of value in r1

Adjacency

Adjacency - store bigger values together (sequentially)

- An array: build bigger values out of many copies of the same type of small values
  - – Store them next to each other in memory
  - – Arithmetic to find any given value based on index

We know: ①. The address of the first element. (addr)
②. The index of that element (i)
Then the address of that element: addr + (i * size_of_each_element).

Adjacency

Adjacency - store bigger values together (sequentially)

One row in a database table, like one line in a CSV file.

- Records, structures, classes
  - Classes have fields! Store them adjacently
  - Know how to access (add offsets from base address) addr + offset_of_x
  - If you tell me where object is, I can find fields

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Pointers

Pointers - a value treated as address of thing we are interested in

- A value that really points to another value
- Easy to describe, hard to use properly
- We'll be talking about these a lot in this class!

Those 3 things, we combine them all together. And this is kind of how we're storing the data in the memory.

Pointers

Pointers - a value treated as address of thing we are interested in

- Give us strange new powers (represent more complicated things), e.g.,
  - Variable-sized lists
  - Values that we don’t know their type without looking
  - Dictionaries, maps

Programs Use These!

How do our programs use these?

- Enumerated icodes, numbers
- Ajacently stored instructions (PC+1)
- Pointers of where to jump/goto (addresses in memory)

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ToyISA Instructions

So far, only dealing with 8-bit machine! → 8-bit instructions/values/memory addresses

icode	b	meaning
0		`rA = rB`
1		`rA &= rB`
2		`rA += rB`
3	0	`rA = ~rA`
	1	`rA = !rA`
	2	`rA = -rA`
	3	`rA = pc`
4		`rA` = read from memory at address `rB`
5		write `rA` to memory at address `rB`
6	0	`rA` = read from memory at `pc + 1`
	1	`rA` &= read from memory at `pc + 1`
	2	`rA` += read from memory at `pc + 1`
	3	`rA` = read from memory at the address stored at `pc + 1`
		For icode 6, increase `pc` by 2 at end of instruction
7		Compare `rA` as 8-bit 2's-complement to 0
		if `rA <= 0` set `pc = rB`
		else increment `pc` as normal

64-bit Machines

64-bit machine: The registers are 64-bits

- i.e., r0, but also PC

Important to have large values. Why?

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PC is wider

- Most important: PC and memory addresses We need space to do things.
- How much memory could our 8-bit machine access?

$2^8 = 256$ bytes. 00 – FF.

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- 80s - 32 bits:

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- 80s - 32 bits: ≈ 4 billion bytes (4 GiB)
- Today's processors - 64 bits:

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- How much memory could our 8-bit machine access? 256 Bytes
- Late 70s - 16 bits: 65536 Bytes
- 80s - 32 bits: ≈ 4 billion bytes
- Today's processors - 64 bits: 2^{64} addresses (2^{64} indices to memory)

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Aside: Powers of Two

Value	base-10	Short form	Pronounced
2^{10}	(10^3) 1024	Ki	Kilo
2^{20}	1,048,576	Mi	Mega
2^{30}	1,073,741,824	Gi	Giga
2^{40}	(10^{12}) 1,099,511,627,776	Ti	Tera
2^{50}	1,125,899,906,842,624	Pi	Peta
2^{60}	1,152,921,504,606,846,976	Ei	Exa

Example: 2^{27} bytes

If I have 2 to some power, it works out to be roughly equivalent to a power of 10.

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Example: 2^{27} bytes $= 2^7 \times 2^{20}$ bytes

$2^m \times 2^n = 2^{m+n}$

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Example: 2^{27} bytes $= 2^7 \times 2^{20}$ bytes $= 2^7$ MiB $=$ 128 MiB

64-bit Machines

How much can we address with 64-bits?

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- 16 EiB (2^{64} addresses = $2^4 \times \underbrace{2^{60}}_{\text{Exa}}$)

64-bit Machines

How much can we address with 64-bits?

- 16 EiB (2^{64} addresses = $2^4 \times 2^{60}$)
- But I only have 8 GiB of RAM

I have 16 EiB of addresses. We can address more space we actually have.

But it could be used for virtual memory.

We will talk about it in CSO-2.

A Challenge

There is a disconnect:

- Registers: 64-bits values
- Memory: 8-bit values (i.e., **1 byte** values) What we are storing is still 8 bits (1 byte).
  - – Each address addresses an 8-bit value in memory
  - – Each address points to a 1-byte slot in memory

A Challenge

There is a disconnect:

- Registers: 64-bits values
- Memory: 8-bit values (i.e., **1 byte** values)
  - Each address addresses an 8-bit value in memory
  - Each address points to a 1-byte slot in memory
- How do we store a 64-bit value in an 8-bit spot?

Rules

0x | 00 | AB | CD | EF (4 bytes)

0x600 0x601 0x602 0x603

starting from an address and going up.

Rules to break "big values" into bytes (memory)

1. Break it into bytes
2. Store them adjacently
3. Address of the overall value = smallest address of its bytes
4. Order the bytes
   - If parts are ordered (i.e., array), first goes in smallest address
   - Else, hardware implementation gets to pick (!!)
     – Little-endian
     – Big-endian

Ordering Values

0x|00|AB|CD|EF

Little-endian

- Store the low order part/byte first
- Most hardware today is little-endian

EF	CD	AB	00
0x600	0x601	0x602	0x603

Big-endian

- Store the high order part/byte first

00	AB	CD	EF
0x600	0x601	0x602	0x603

Why we want to talk about 2 ways?
Because people decided to do different things.
We write 00ABCDEF, but we calculate from F to 0,

Maybe that's the reason to see EF first?

Example

array of 2 numbers, each number should use 2 bytes.

Store [0x1234, 0x5678] at address 0xF00