CSci 5271 Introduction to Computer Security Capabilities, side channels, OS assurance

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Preview question

What's "common" about the Common Criteria?

- A. Every kind of product is evaluated against the same "protection profile."
- B. Anyone can perform the certification, without special government approval.
- C. The certification applies to devices used in everyday civilian life, rather than in government or the military.
- D. A single certification is recognized by the governments of many countries.
- E. A single certification can be used for products from different vendors.

Outline

Capability-based access control (cont'd)

Side and covert channel basics

Announcements intermission

Transient execution covert channels

OS trust and assurance

(Object) capabilities

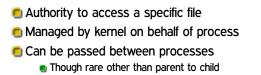
- A capability both designates a resource and provides authority to access it
- Similar to an object reference Unforgeable, but can copy and distribute
- Typically still managed by the kernel

Capability slogans (Miller et al.)

No designation without authority

- Dynamic subject creation
- Subject-aggregated authority management
- No ambient authority
- Composability of authorities
- Access-controlled delegation
- Dynamic resource creation

Partial example: Unix FDs



Unix not designed to use pervasively

Distinguish: password capabilities

- Bit pattern itself is the capability
 - No centralized management
- Modern example: authorization using cryptographic certificates

Revocation with capabilities

- Use indirection: give real capability via a pair of middlemen
- $\blacksquare A \to B \text{ via } A \to F \to R \to B$
- Retain capability to tell R to drop capability to B
- Depends on composability

Confinement with capabilities

- A cannot pass a capability to B if it cannot communicate with A at all
- Disconnected parts of the capability graph cannot be reconnected
- Depends on controlled delegation and data/capability distinction

OKL4 and seL4

- Commercial and research microkernels
- Recent versions of OKL4 use capability design from seL4
- Used as a hypervisor, e.g. underneath paravirtualized Linux
- Shipped on over 1 billion cell phones

Joe-E and Caja

- Dialects of Java and JavaScript (resp.) using capabilities for confined execution
- E.g., of JavaScript in an advertisement
- Note reliance on Java and JavaScript type safety

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More confidentiality problems

- Careful access control prevents secret data from "leaking" though normal OS-mediated communication channels
- Residual problem: channels not designed for communication
- A major theme of ongoing computer security research

Side channel vs. covert channel

- Side channel: information leaks from an unsuspecting victim
- Covert channel: information intentionally leaked by a adversarial sender
 - Violating an isolation property
 - Sender and receiver work together
- Distinction sometimes unclear or not observed

Kinds of channels

- Software channels: undesired feature of program behaviors
- Physical channels: channels mediated by the real world
- Hardware channels: undesired feature of hardware behaviors

Classic software covert channels

Storage channel: writable shared state
 E.g., screen brightness on mobile phone
 Timing channel: speed or ordering of events
 E.g., deliberately consume CPU time

Remote timing and traffic analysis

- Timing of events can also leak over the network
 Classic example: time taken to process encrypted data
 Encrypted network traffic still reveals information via
 - pattern and timing of packets
 - Classic example: keystrokes over SSH
 - Modern: "website fingerprinting" against HTTPS and Tor

Examples of physical side channels

- EM emissions and diffuse reflections from CRTs
- Power usage of computers and smart cards
- Smartphone accelerometer picks up speaker vibrations

Common hardware channel: cache timing

- Memory cache shared by processes and sometimes cores
- Cache state depends on pattern of previous accesses
- Cache hit or miss affects code execution speed

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Multiple BCMTA vulnerabilities found!

Format string vulnerability in logging
 Race condition on file ownership check
 Instruction whitelist was too permissive

Midterm exam next Monday

- Usual class time and location
- Covers up through today's lecture material
- Mix of short-answer and exercise-like questions
- Open books/notes/printouts, no computers or other electronics
- Sample exams (2013-2019) posted, solutions Wednesday

Exercise set 2

- Due Wednesday evening
- Join pre-created groups in Canvas
- Remember to cite any outside sources you used
- May not be graded before midterm, so ask questions early

Reversing the stack

```
void func(char *str) {
   char buf[128];
   strcpy(buf, str);
   do_something();
   return;
}
```

Payment app

Reverse range

```
void reverse_range(int *a, int from, int to) {
    unsigned int *p = &a[from];
    unsigned int *q = &a[to];
    while (!(p == q + 1 || p == q + 2)) {
        *p += *q;
        *q = *p - *q;
        *p = *p - *q;
        p++; q--;
    }
}
```

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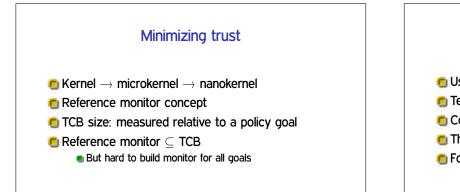
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Trusted and trustworthy

- Part of your system is trusted if its failure can break your security
- 🖲 Thus, OS is almost always trusted
- Real question: is it trustworthy?
- Distinction not universally observed: trusted boot, Trusted Solaris, etc.

Trusted (I/O) path

- How do you know you're talking to the right software?
- And no one is sniffing the data?
- 🖲 Example: Trojan login screen
 - Or worse: unlock screensaver with root password
 - Origin of "Press Ctrl-Alt-Del to log in"





Use for a long time
Testing
Code / design review
Third-party certification
Formal methods / proof

Evaluation / certification

- Testing and review performed by an independent party
- Goal: separate incentives, separate accountability
- Compare with financial auditing
- Watch out for: form over substance, misplaced incentives

Orange book OS evaluation

- Trusted Computer System Evaluation Criteria
- D. Minimal protection
- C. Discretionary protection C2 adds, e.g., secure audit over C1
- B. Mandatory protection BI<B2<B3: stricter classic MLS
- A. Verified protection

Common Criteria

- International standard and agreement for IT security certification
- Certification against a protection profile, and evaluation assurance level EAL 1-7
- Evaluation performed by non-government labs
- Up to EAL 4 automatically cross-recognized

Common Criteria, Anderson's view

- Many profiles don't specify the right things
- OSes evaluated only in unrealistic environments
 E.g., unpatched Windows XP with no network attacks
 "Corruption, Manipulation, and Inertia"
 - Pernicious innovation: evaluation paid for by vendor
 - Labs beholden to national security apparatus

Formal methods and proof

- Can math come to the rescue?
- Checking design vs. implementation
- Automation possible only with other tradeoffs E.g., bounded size model
- Starting to become possible: machine-checked proof

Proof and complexity

- Formal proof is only feasible for programs that are small and elegant
- If you honestly care about assurance, you want your TCB small and elegant anyway
- Should provability further guide design?

Some hopeful proof results

seL4 microkernel (SOSP'09 and ongoing)

 7.5 kL C, 200 kL proof, 160 bugs fixed, 25 person years
 CompCert C-subset compiler (PLDI'06 and ongoing)
 RockSalt SFI verifier (PLDI'12)