CSci 5271
Introduction to Computer Security
Transient Execution, OS Assurance, and Networks

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Outline

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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"

Minimizing trust

- Kernel $\rightarrow$ microkernel $\rightarrow$ nanokernel
- Reference monitor concept
- TCB size: measured relative to a policy goal
- Reference monitor $\subseteq$ TCB
  - But hard to build monitor for all goals

How to gain assurance

- 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
  - B1<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)

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Transient execution covert channels (cont'd)

OS trust and assurance

Announcements intermission

Brief introduction to networking

Some classic network attacks

Second half of course

Common Criteria 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.

Midterm exam Monday

- Arrive slightly early to start exam promptly at 1pm
- Erasable writing instrument recommended
  - E.g., mechanical pencil with separate eraser
- Open book, notes, printouts, but no electronics
- Rest of today's material is not covered

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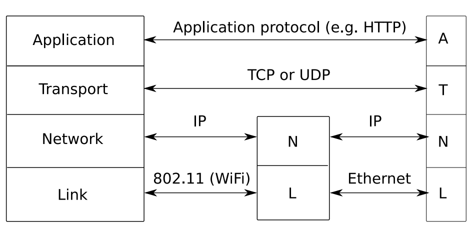
The Internet

- A bunch of computer networks voluntarily interconnected
- Capitalized because there's really only one
- No centralized network-level management
  - But technical collaboration, DNS, etc.

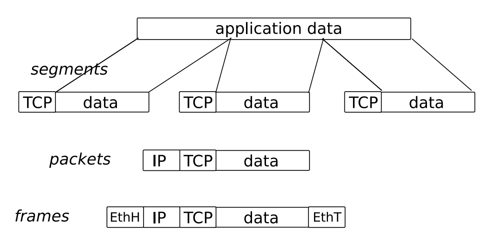
Layered model (OSI)

7. Application (HTTP)
6. Presentation (MIME?)
5. Session (SSL?)
4. Transport (TCP)
3. Network (IP)
2. Data-link (PPP)
1. Physical (10BASE-T)

Layered model: TCP/IP



Packet wrapping



IP(v4) addressing

- Interfaces (hosts or routers) identified by 32-bit addresses
  - Written as four decimal bytes, e.g. 192.168.10.2
- First k bits identify network, $32 - k$ host within network
  - Can't (anymore) tell k from the bits
- We'll run out any year now

IP and ICMP

- Internet Protocol (IP) forwards individual packets
- Packets have source and destination addresses, other options
- Automatic fragmentation (usually avoided)
- ICMP (I Control Message P) adds errors, ping packets, etc.

UDP

- User Datagram Protocol: thin wrapper around IP
- Adds source and destination port numbers (each 16-bit)
- Still connectionless, unreliable
- OK for some small messages

TCP

- Transmission Control Protocol: provides reliable bidirectional stream abstraction
- Packets have sequence numbers, acknowledged in order
- Missed packets resent later

Flow and congestion control

- Flow control: match speed to slowest link
  - "Window" limits number of packets sent but not ACKed
- Congestion control: avoid traffic jams
  - Lost packets signal congestion
  - Additive increase, multiplicative decrease of rate

Routing

- Where do I send this packet next?
  - Table from address ranges to next hops
- Core Internet routers need big tables
- Maintained by complex, insecure, cooperative protocols
  - Internet-level algorithm: BGP (Border Gateway Protocol)

Below IP: ARP

- Address Resolution Protocol maps IP addresses to lower-level address
  - E.g., 48-bit Ethernet MAC address
- Based on local-network broadcast packets
- Complex Ethernets also need their own routing (but called switches)

DNS

- Domain Name System: map more memorable and stable string names to IP addresses
- Hierarchically administered namespace
  - Like Unix paths, but backwards
- `.edu` server delegates to `.umn.edu` server, etc.

DNS caching and reverse DNS

- To be practical, DNS requires caching
  - Of positive and negative results
- But, cache lifetime limited for freshness
- Also, reverse IP to name mapping
  - Based on special top-level domain, IP address written backwards

Classic application: remote login

- Killer app of early Internet: access supercomputers at another university
- Telnet: works cross-OS
  - Send character stream, run regular login program
- rlogin: BSD Unix
  - Can authenticate based on trusting computer connection comes from
  - (Also rsh, rcp)

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Packet sniffing

- Watch other people's traffic as it goes by on network
- Easiest on:
  - Old-style broadcast (thin, "hub") Ethernet
  - Wireless
- Or if you own the router

Forging packet sources

- Source IP address not involved in routing, often not checked
- Change it to something else!
- Might already be enough to fool a naive UDP protocol

TCP spoofing

- Forging source address only lets you talk, not listen
- Old attack: wait until connection established, then DoS one participant and send packets in their place
- Frustrated by making TCP initial sequence numbers unpredictable
  - But see Oakland'12, WOOT'12 for fancier attacks, keyword "off-path"

ARP spoofing

- Impersonate other hosts on local network level
- Typical ARP implementations stateless, don't mind changes
- Now you get victim's traffic, can read, modify, resend

rlogin and reverse DNS

- rlogin uses reverse DNS to see if originating host is on whitelist
- How can you attack this mechanism with an honest source IP address?

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- Remember, ownership of reverse-DNS is by IP address

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Cryptographic primitives

- Core mathematical tools
- Symmetric: block cipher, hash function, MAC
- Public-key: encryption, signature
- Some insights on how they work, but concentrating on how to use them correctly

Cryptographic protocols

- Sequence of messages and crypto privileges for, e.g., key exchange
- A lot can go wrong here, too
- Also other ways security can fail even with a good crypto primitive

Crypto in Internet protocols

- How can we use crypto to secure network protocols
- E.g., rsh $\rightarrow$ ssh
- Challenges of getting the right public keys
- Fitting into existing usage ecosystems

Web security: server side

- Web software is privileged and processes untrusted data: what could go wrong?
- Shell script injection (Ex. 1)
- SQL injection
- Cross-site scripting (XSS) and related problems

Web security: client side

- JavaScript security environment even more tricky, complex
- More kinds of cross-site scripting
- Possibilities for sandboxing

Security middleboxes

- Firewall: block traffic according to security policy
- NAT box: different original purpose, now de-facto firewall
- IDS (Intrusion Detection System): recognize possible attacks

Malware and network DoS

- Attacks made possible by the network
- Viruses, trojans, bot nets
  - Detection?
  - Mitigation?
- Distributed denial of service (DDoS)

Adding back privacy

- Every Internet packet has source and destination addresses on it
- So how can network traffic be private or anonymous?
- Key technique: overlay a new network
- Examples: onion routing (Tor), anonymous remailing

Usability of security

- Prevent people from being the weakest link
- Usability of authentication
- “Secure” web sites, phishing
- Making decisions about mobile apps

Electronic money (Bitcoin)

- Current payment systems have strong centralized trust
  - US Federal Reserve and mint
  - Banks, PayPal
- Could they be replaced by a peer-to-peer distributed system?
- Maybe

Electronic voting

- Challenging: hard versions of many hard problems:
  - Trust in software
  - Usability
  - Simultaneously public and private
- Some deployed systems arguably worse than paper
- Can do better with crypto and systems approaches

Next time

- Symmetric crypto primitives