CSci 4271W
Development of Secure Software Systems
Day 20: Network protocols

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Outline

Brief introduction to networking, cont'd

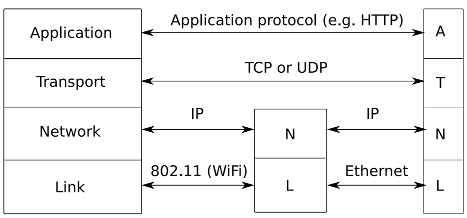
One slide of logistics

Some classic network attacks

Cryptographic protocols, pt. 1

Key distribution and PKI

Layered model: TCP/IP



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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Problem set 1 due Friday

- Problem set 1 due 11:59pm Friday on Canvas
- Piazza has a comment expanding on what makes a "high-level" policy
  - Also a good place for remaining questions or clarifications

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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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A couple more security goals

- Non-repudiation: principal cannot later deny having made a commitment
  - I.e., consider proving fact to a third party
- Forward secrecy: recovering later information does not reveal past information
  - Motivates using Diffie-Hellman to generate fresh keys for each session

Abstract protocols

- Outline of what information is communicated in messages
  - Omit most details of encoding, naming, sizes, choice of ciphers, etc.
- Describes honest operation
  - But must be secure against adversarial participants
- Seemingly simple, but many subtle problems

Protocol notation

$A \to B : N_B, \{T_0, B, N_B\}_{K_B}$

- $A \to B$: message sent from Alice intended for Bob
- B (after :): Bob's name
- $\{\cdots\}_K$: encryption with key K

Example: simple authentication

$A \to B : A, \{A, N\}_{K_A}$

- E.g., Alice is key fob, Bob is garage door
- Alice proves she possesses the pre-shared key K_A
  - Without revealing it directly
- Using encryption for authenticity and binding, not secrecy

Nonce

$A \to B : A, \{A, N\}_{K_A}$

- N is a *nonce*: a value chosen to make a message unique
- Best practice: pseudorandom
- In constrained systems, might be a counter or device-unique serial number

Replay attacks

- A nonce is needed to prevent a verbatim replay of a previous message
- Garage door difficulty: remembering previous nonces
  - Particularly: lunchtime/roommate/valet scenario
- Or, door chooses the nonce: *challenge-response* authentication

Middleperson attacks

- Older name: man-in-the-middle attack, MITM
- Adversary impersonates Alice to Bob and vice-versa, relays messages
- Powerful position for both eavesdropping and modification
- No easy fix if Alice and Bob aren't already related

Chess grandmaster problem

- Variant or dual of middleperson
- Adversary forwards messages to simulate capabilities with his own identity
- How to win at correspondence chess
- Anderson's MiG-in-the-middle

Anti-pattern: "oracle"

- Any way a legitimate protocol service can give a capability to an adversary
- Can exist whenever a party decrypts, signs, etc.
- "Padding oracle" was an instance of this at the implementation level

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Public key authenticity

- Public keys don't need to be secret, but they must be right
- Wrong key $\rightarrow$ can't stop middleperson
- So we still have a pretty hard distribution problem

Symmetric key servers

- Users share keys with server, server distributes session keys
- Symmetric key-exchange protocols, or channels
- Standard: Kerberos
- Drawback: central point of trust

Certificates

- A name and a public key, signed by someone else
  - $C_A = \text{Sign}_S(A, K_A)$
- Basic unit of transitive trust
- Commonly use a complex standard "X.509"

Certificate authorities

- "CA" for short: entities who sign certificates
- Simplest model: one central CA
- Works for a single organization, not the whole world

Web of trust

- Pioneered in PGP for email encryption
- Everyone is potentially a CA: trust people you know
- Works best with security-motivated users
  - Ever attended a key signing party?

CA hierarchies

- Organize CAs in a tree
- Distributed, but centralized (like DNS)
- Check by follow a path to the root
- Best practice: sub CAs are limited in what they certify

PKI for authorization

- Enterprise PKI can link up with permissions
- One approach: PKI maps key to name, ACL maps name to permissions
- Often better: link key with permissions directly, name is a comment
  - More like capabilities

The revocation problem

- How can we make certs "go away" when needed?
- Impossible without being online somehow

1. Short expiration times
2. Certificate revocation lists
3. Certificate status checking