CSE 484 (Winter 2008)

Network Security

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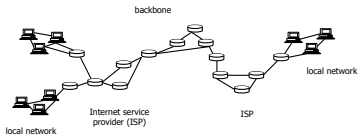
Goals for Today

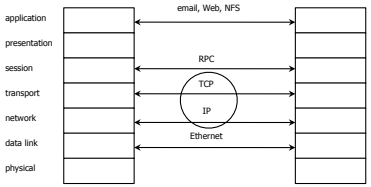
- Network Security Attacks
  - Routing
  - IP
  - TCP
  - DNS
- Key points:
  - Failures at interaction between layers
  - Asymmetry between attacker and defender
  - Some attacks designers never considered
  - All motivations for existing security decisions (SSL/TLS, filter certain types of packets, check inputs, etc).

Internet Infrastructure

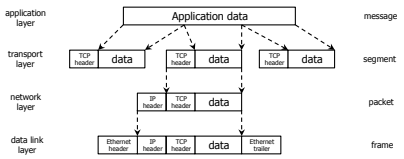


- TCP/IP for packet routing and connections
- Border Gateway Protocol (BGP) for route discovery
- Domain Name System (DNS) for IP address discovery

OSI Protocol Stack

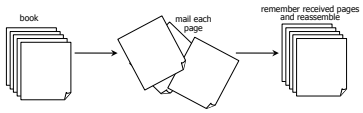


Data Formats



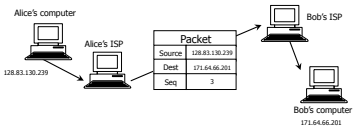
TCP (Transmission Control Protocol)

- Sender: break data into packets
  - Sequence number is attached to every packet
- Receiver: reassemble packets in correct order
  - Acknowledge receipt; lost packets are re-sent
- Connection state maintained on both sides



IP (Internet Protocol)

- Connectionless
  - Unreliable, "best-effort" protocol
- Uses numeric addresses for routing
  - Typically several hops in the route



IP Routing

- Routing of IP packets is based on IP addresses
- Routers use a forwarding table
  - Entry = destination, next hop, network interface, metric
  - For each packet, a table look-up is performed to determine how to route it
- Routing information exchange allows update of old routes and creation of new ones
  - RIP (Routing Information Protocol)
  - OSPF (Open Shortest Path First Protocol)
  - BGP (Border Gateway Protocol)

Routing Attacks

- Source routing
  - Source of the packet specifies a particular route
    - For example, because the automatic route is dead
  - Attacker can spoof source IP address and use source routing to direct response through a compromised host
  - Solution: reject packets with source routing!
    - More heavy-duty: allow source route only via trusted gateways
- Routing Information Protocol (RIP)
  - Use bogus routing updates to intercept traffic
    - RIP implicitly assumes that routers are trusted
  - "Black hole" attacks and many others

BGP Misconfiguration

- Domain advertises good routes to addresses it does not known how to reach
  - Result: packets go into a network "black hole"
- April 25, 1997: "The day the Internet died"
  - AS7007 (Florida Internet Exchange) de-aggregated the BGP route table and re-advertised all prefixes as if it originated paths to them
  - In effect, AS7007 was advertising that it has the best route to every host on the Internet
  - Huge network instability as incorrect routing data propagated and routers crashed under traffic

ICMP (Control Message Protocol)

- Provides feedback about network operation
  - "Out-of-band" messages carried in IP packets
  - Error reporting, congestion control, reachability, etc.
- Example messages:
  - Destination unreachable
  - Time exceeded
  - Parameter problem
  - Redirect to better gateway
  - Reachability test (echo / echo reply)
  - Message transit delay (timestamp request / reply)

Security Issues in TCP/IP

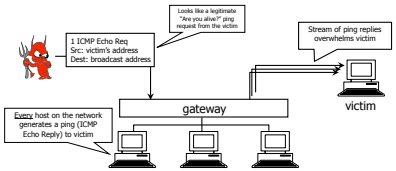
- Network packets pass by untrusted hosts
  - Eavesdropping (packet sniffing)
- IP addresses are public
  - Smurf attacks
- TCP connection requires state
  - SYN flooding
- TCP state is easy to guess
  - TCP spoofing and connection hijacking

Packet Sniffing

- Many applications send data unencrypted
  - ftp, telnet send passwords in the clear
- Network interface card (NIC) in "promiscuous mode" reads all passing data

Solution: encryption (e.g., IPSec), improved routing

Smurf Attack



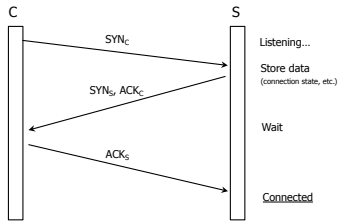
Solution: reject external packets to broadcast addresses

"Ping of Death"

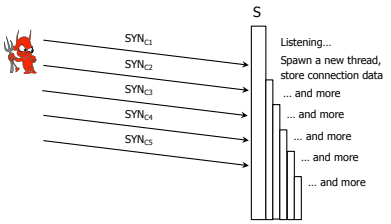
- If an old Windows machine received an ICMP packet with a payload longer than 64K, machine would crash or reboot
  - Programming error in older versions of Windows
  - Packets of this length are illegal, so programmers of Windows code did not account for them
- Recall "security theme" of this course - every line of code might be the target of an adversary

Solution: patch OS, filter out ICMP packets

TCP Handshake



SYN Flooding Attack



SYN Flooding Explained

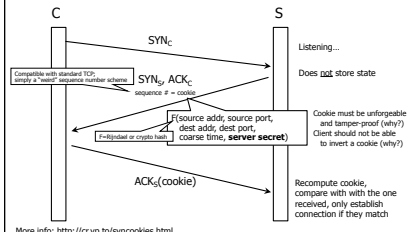
- Attacker sends many connection requests with spoofed source addresses
- Victim allocates resources for each request
  - Connection state maintained until timeout
  - Fixed bound on half-open connections
- Once resources exhausted, requests from legitimate clients are denied
- This is a classic denial of service (DoS) attack
  - Common pattern: it costs nothing to TCP initiator to send a connection request, but TCP responder must allocate state for each request (asymmetry!)

Preventing Denial of Service

- DoS is caused by asymmetric state allocation
  - If responder opens a state for each connection attempt, attacker can initiate thousands of connections from bogus or forged IP addresses
- Cookies ensure that the responder is stateless until initiator produced at least 2 messages
  - Responder's state (IP addresses and ports of the connection) is stored in a cookie and sent to initiator
  - After initiator responds, cookie is regenerated and compared with the cookie returned by the initiator

SYN Cookies

[Bernstein and Schenk]

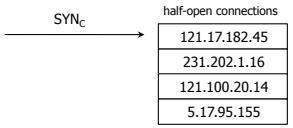


More info: http://cr.yp.to/syncookies.html

Anti-Spoofing Cookies: Basic Pattern

- Client sends request (message #1) to server
- Typical protocol:
  - Server sets up connection, responds with message #2
  - Client may complete session or not (potential DoS)
- Cookie version:
  - Server responds with hashed connection data instead of message #2
  - Client confirms by returning hashed data
    - If source IP address is bogus, attacker can't confirm
  - Need an extra step to send postponed message #2, except in TCP (SYN-ACK already there)

Another Defense: Random Deletion

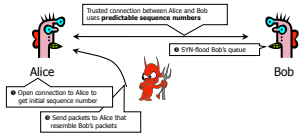


- If SYN queue is full, delete random entry
  - Legitimate connections have a chance to complete
  - Fake addresses will be eventually deleted
- Easy to implement

TCP Connection Spoofing

- Each TCP connection has an associated state
  - Sequence number, port number
- TCP state is easy to guess
  - Port numbers are standard, sequence numbers are often predictable
  - Can inject packets into existing connections
- If attacker knows initial sequence number and amount of traffic, can guess likely current number
  - Send a flood of packets with likely sequence numbers

"Blind" IP Spoofing Attack



- Can't receive packets sent to Bob, but maybe can penetrate Alice's computer if Alice uses IP address-based authentication
  - For example, rlogin and many other remote access programs uses address-based authentication

DoS by Connection Reset

- If attacker can guess current sequence number for an existing connection, can send Reset packet to close it
  - With 32-bit sequence numbers, probability of guessing correctly is $1/2^{32}$ (not practical)
  - Most systems accept large windows of sequence numbers ⇒ much higher probability of success
    - Need large windows to handle massive packet losses