Network Security in Practice

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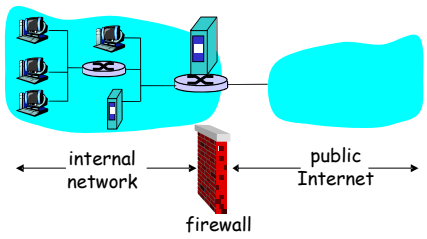
Practices of Network Security

- Access control: firewalls
- Attacks and counter measures
- Security protocol case studies

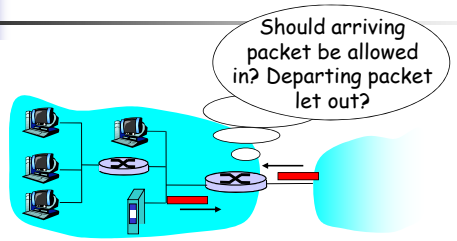
Access Control: Firewalls

firewall

isolates organization's internal network from the public Internet through filtering, allowing some data to pass, blocking others.



Network-layer Packet Filtering



- Firewall is built into the edge router connected to the Internet
- Router filters packet-by-packet, decision to forward/drop packet based on:
  - source IP address, destination IP address
  - TCP/UDP source and destination port numbers
  - TCP SYN and ACK bits

Policies in Network-layer Packet Filtering

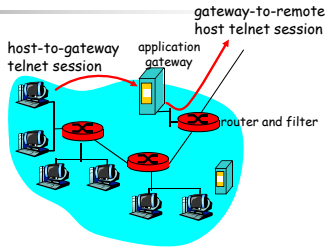
- Example 1: blocking all incoming TCP datagrams with dest port = 80
  - No external clients can access internal Web servers.
- Example 2: blocking all TCP datagrams with source or dest port = 23, except for those with source or dest IP = 128.151.67.155 (a particular internal machine)
  - All incoming and outgoing telnet connections have to go through a telnet gateway.
- Example 3: blocking all incoming TCP datagrams with ACK bit set to 0
  - Prevents external clients from initiating TCP connections with internal clients, but allows internal clients to connect to outside.

More on Network-layer Packet Filtering

- Advantage:
  - transparent to network applications
  - incurring little extra overhead/latency
- Limitation:
  - relying only on IP/TCP/UDP header info
    ⇒ not flexible enough, e.g., firewall can know the IP of the source, but not the "user"

Application-layer Gateways

- Access control according to application-layer information.
- Example: allow selected internal users to telnet outside.



1. Router filter blocks all telnet connections not originating from gateway ⇒ require all telnet users to telnet through gateway.
2. For authorized users, gateway sets up telnet connection to dest host.

Practices of Network Security

- Access control: firewalls
  - network-layer firewall
  - application-layer firewall
- Attacks and countermeasures
- Security protocol case studies

Network Security Threat: Mapping

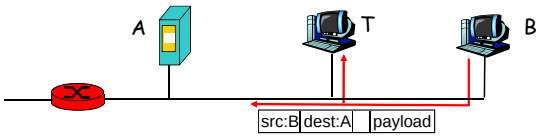
- Before attacking: "scout the area" – find out what services are implemented on network
- Try to determine what host addresses are valid on the network
- Port-scanning: try to establish TCP connection to each port in sequence (see what happens)

Countermeasures:

- Record traffic entering network
- Look for suspicious activity (e.g., IP addresses, ports being scanned sequentially)

Network Security Threat: Packet Sniffing

- promiscuous NIC reads all packets passing by a broadcast media (e.g. shared-link Ethernet)
- can read all unencrypted data (e.g. passwords)

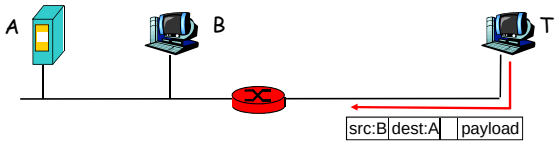


Countermeasures:

- checks periodically if host interface in promiscuous mode.
- one host per segment of broadcast media (switched Ethernet)
- encrypt all packets.

Network Security Threat: IP Spoofing

- with root privilege, one can generate "raw" IP packets with any value into IP source address field
- receiver can't tell if source is spoofed
- e.g.: T pretends to be B



Countermeasures:

- authentication
- ingress filtering – routers should not forward outgoing packets with invalid source addresses

Network Security Threat: Cross-Site Scripting

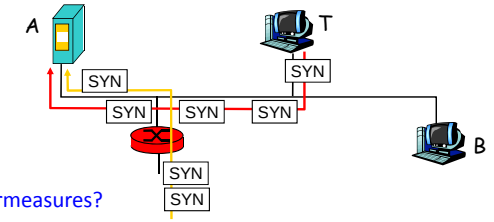
- Cross-site scripting:
  - duped to run script unintended by the original site
  - most significant vulnerability for web applications today
- Examples:
  - search engine FOOBAR displays the input search keywords in the return page; attacker prepares a search URL that includes HTML tag and JavaScript code; a user who trusts FOOBAR clicks the search URL
  - attacker supplies attack string as msg to a msg board
  - attacker embeds attack strings in machine names

Countermeasures?

- Careful input checking

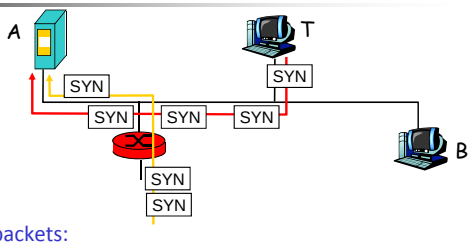
Network Security Threat: Denial-of-service Attack

- SYN flooding: attacker establishes many bogus TCP connections, flood of maliciously generated packets "swamp" receiver
- Distributed DOS (DDOS): multiple coordinated sources swamp receiver
- e.g., T and remote host SYN-attack A



Countermeasures?

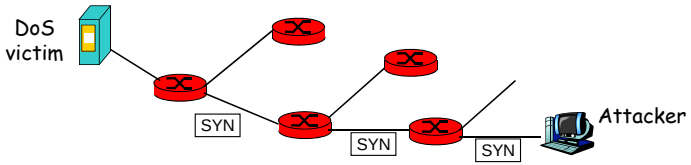
Countermeasure 1: Packet Filtering



Filtering out attack packets:

- attack packets carry spoofed IP addresses – hard to filter based on IP address
- if filtering out all SYN packets, then no good connections
- if filtering out some SYN packets, throw out good and bad connections

Countermeasure 2: Trace Back



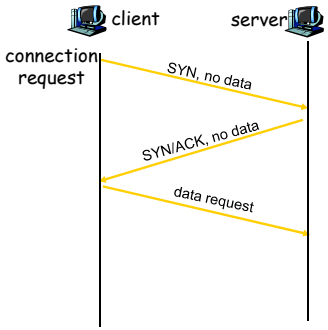
Trace back to flood source:

- attack packets with spoofed IPs
- trace back through network statistics
- sources are most likely innocent, compromised machines

Countermeasure 3: Delayed Processing

Delayed processing or resource allocation:

- Data structure allocation and initialization at receipt of real data request, not at receipt of first SYN
- What if attacker sends SYN, waits for SYNACK, and then sends some dummy data?



Stateless TCP

Stateless TCP [Shieh et al. NSDI 2005]:

- server side maintains no state about TCP connections
- advantage: TCP connections only require temporary space during packet processing
- state for a TCP connection:
  - receive buffer
  - send buffer
  - various control parameters and network statistics
- how to avoid maintaining such state at server side?
- also useful for transparent server fail-over/migration

Practices of Network Security

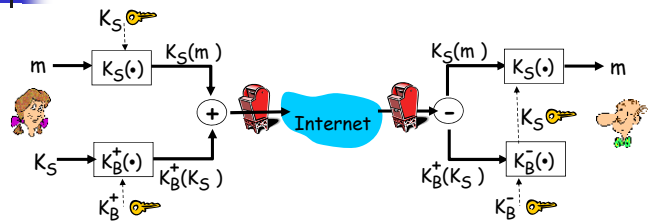
- Access control: firewalls
- Attacks and counter measures
  - mapping, sniffing, spoofing, cross-site scripting, DOS attack
- Security protocol case studies
  - Application-layer PGP: secure email
  - Transport-layer SSL: secure sockets
  - Network-layer IPsec: secure networking

Secure Email: Confidentiality

Alice wants to send confidential e-mail, m, to Bob.

- encrypts message with Bob's public key

Secure Email: Confidentiality



Alice:

- generates *symmetric* key, K_S
- encrypts message with K_S
- encrypts K_S with Bob's public key
- sends both $K_S(m)$ and $K_B^+(K_S)$ to Bob

Bob:

- uses his private key to decrypt and recover K_S
- uses K_S to decrypt $K_S(m)$ to recover m

Secure Email: Sender Authentication and Message Integrity

- Sender authentication and message integrity:
  - generates a digital signature of the message digest using its private key
- Put everything together
  - uses one-time session key and the receiver's public key to encrypt a digitally signed message
  - supports confidentiality, sender authentication, and message integrity
  - PGP (pretty good privacy) for Internet email

Secure Sockets Layer (SSL)/ Transport Layer Security (TLS)

- SSL/TLS: transport layer security service to any TCP-based applications
  - used for remote terminal access (SSH).
  - used between Web browsers, servers for e-commerce (https).
  - used between IMAP clients and servers.
- Security services:
  - CA-certified public keys.
  - data confidentiality by encryption using a symmetric session key, key encrypted with server's public key.
  - source authentication & data integrity by signed message digests.

Network Layer Security Protocol IPsec

- Like before:
  - data confidentiality by encryption using a symmetric session key
  - source authentication & data integrity by signed message digests

- Done in a way that is compatible with basic IP routing functions
  - easy deployment – require no router changes

More on IPsec

- Transport mode:

- Tunnel mode:

- Transport mode is more natural for a host-to-host secure conn; tunnel mode is better fit for intermediate segment of secure conn between two routers.
- (Virtual Private Network) VPN:

Network Security (summary)

Basic techniques……

- cryptography (symmetric and public)
- authentication
- message integrity
- key distribution

…. network security in practice

- firewall
- attacks and countermeasures
- secure application (PGP for email)
- secure transport (SSL/TLS)
- secure network (IPsec)

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