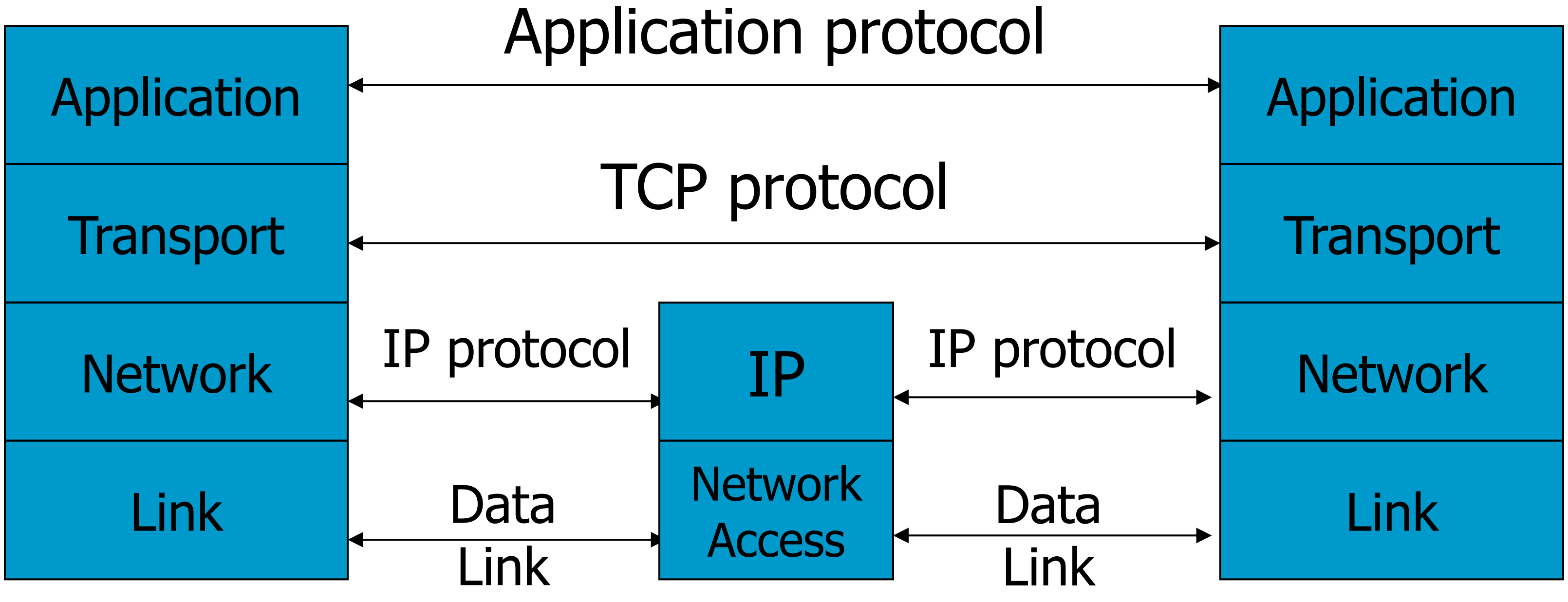
Information Security
CS 526

Network Security (1)

Network Protocols Stack



Types of Addresses in Internet

- Media Access Control (MAC) addresses in the network access layer
  - Associated w/ network interface card (NIC)
  - 48 bits or 64 bits
- IP addresses for the network layer
  - 32 bits for IPv4, and 128 bits for IPv6
  - E.g., 128.3.23.3
- IP addresses + ports for the transport layer
  - E.g., 128.3.23.3:80
- Domain names for the application/human layer
  - E.g., www.purdue.edu

Routing and Translation of Addresses

- Translation between IP addresses and MAC addresses
  - Address Resolution Protocol (ARP) for IPv4
  - Neighbor Discovery Protocol (NDP) for IPv6
- Routing with IP addresses
  - TCP, UDP, IP for routing packets, connections
  - Border Gateway Protocol for routing table updates
- Translation between IP addresses and domain names
  - Domain Name System (DNS)

Threats in Networking

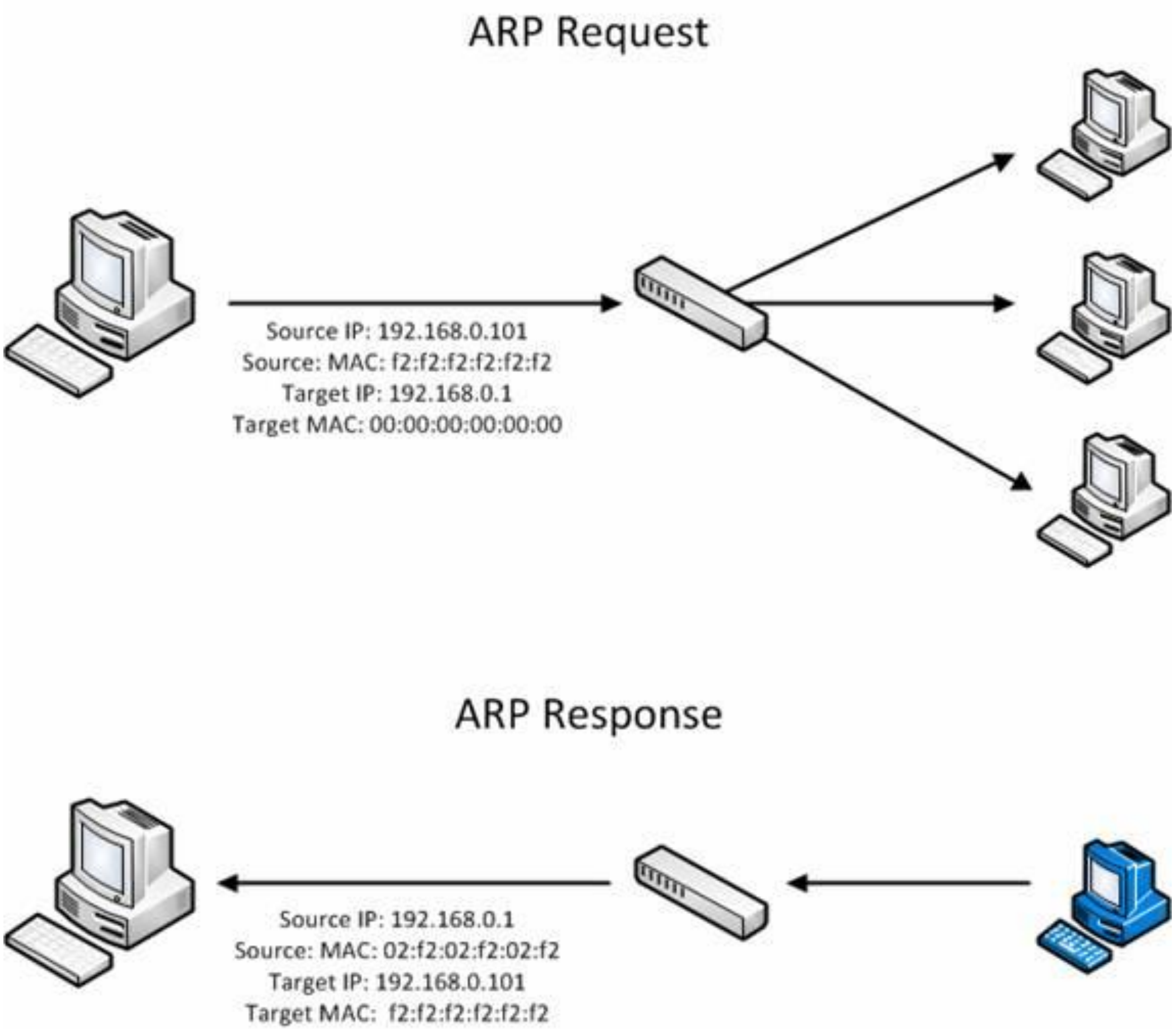
- Confidentiality
  - e.g. Packet sniffing
- Integrity
  - e.g. Session hijacking
- Availability
  - e.g. Denial of service attacks
- Common
  - e.g. Address translation poisoning attacks
  - e.g. Routing attacks

Concrete Security Problems

- ARP is not authenticated
  - APR spoofing (or ARP poisoning)
- Network packets pass by untrusted hosts
  - Packet sniffing
- TCP state can be easy to guess
  - TCP spoofing attack
- Open access
  - Vulnerable to DoS attacks
- DNS is not authenticated
  - DNS poisoning attacks

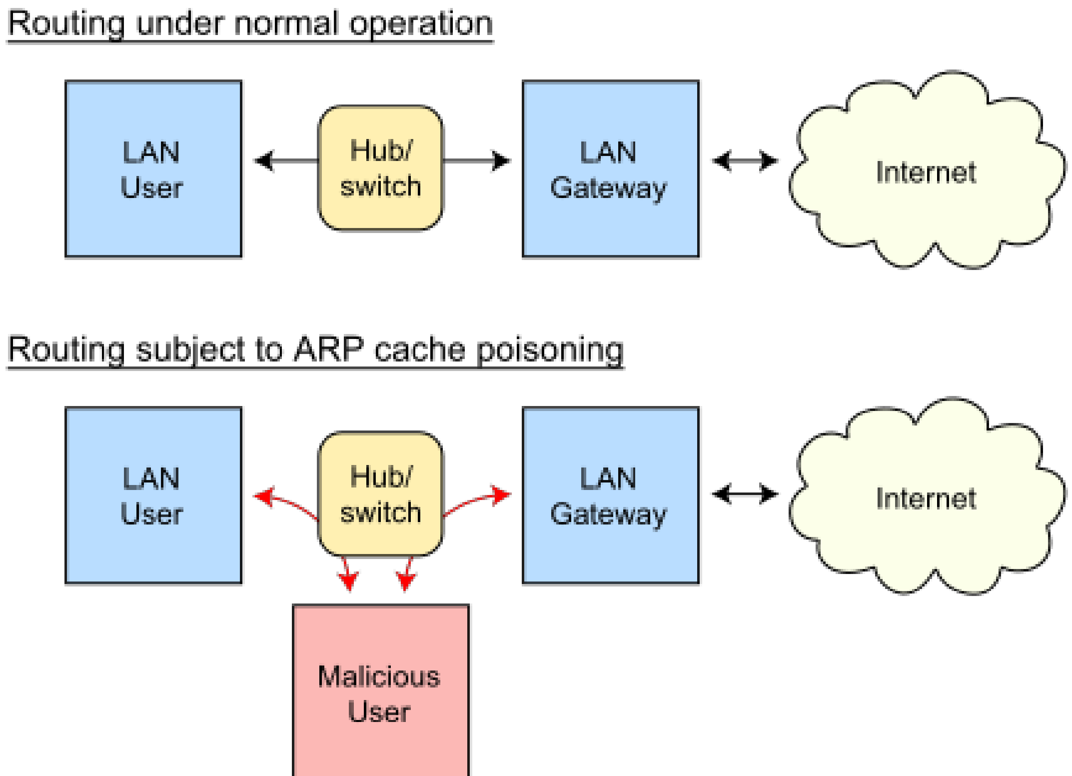
Address Resolution Protocol (ARP)

- Primarily used to translate IP addresses to Ethernet MAC addresses
  - The device drive for Ethernet NIC needs to do this to send a packet
- Also used for IP over other LAN technologies, e.g. IEEE 802.11
- Each host maintains a table of IP to MAC addresses
- Message types:
  - ARP request
  - ARP reply
  - ARP announcement



http://www.windowsecurity.com

ARP Spoofing (ARP Poisoning)

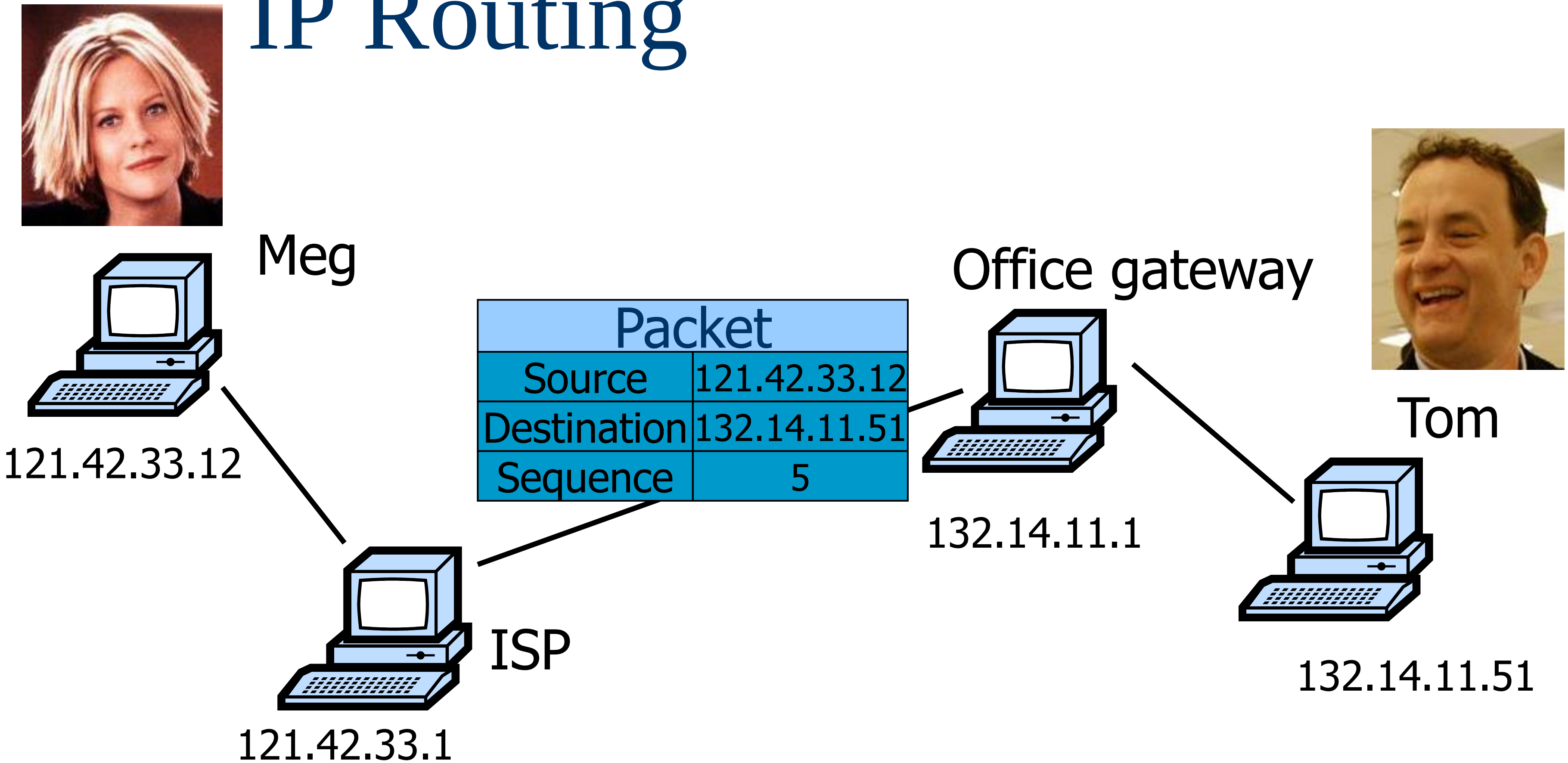


- Send fake or 'spoofed', ARP messages to an Ethernet LAN.
  - To have other machines associate IP addresses with the attacker's MAC
- Legitimate use
  - redirect a user to a registration page before allow usage of the network.
  - Implementing redundancy and fault tolerance

ARP Spoofing (ARP Poisoning) - 2

- Defenses
  - static ARP table
  - DHCP Certification (use access control to ensure that hosts only use the IP addresses assigned to them, and that only authorized DHCP servers are accessible).
  - detection: Arpwatch (sending email when updates occur),

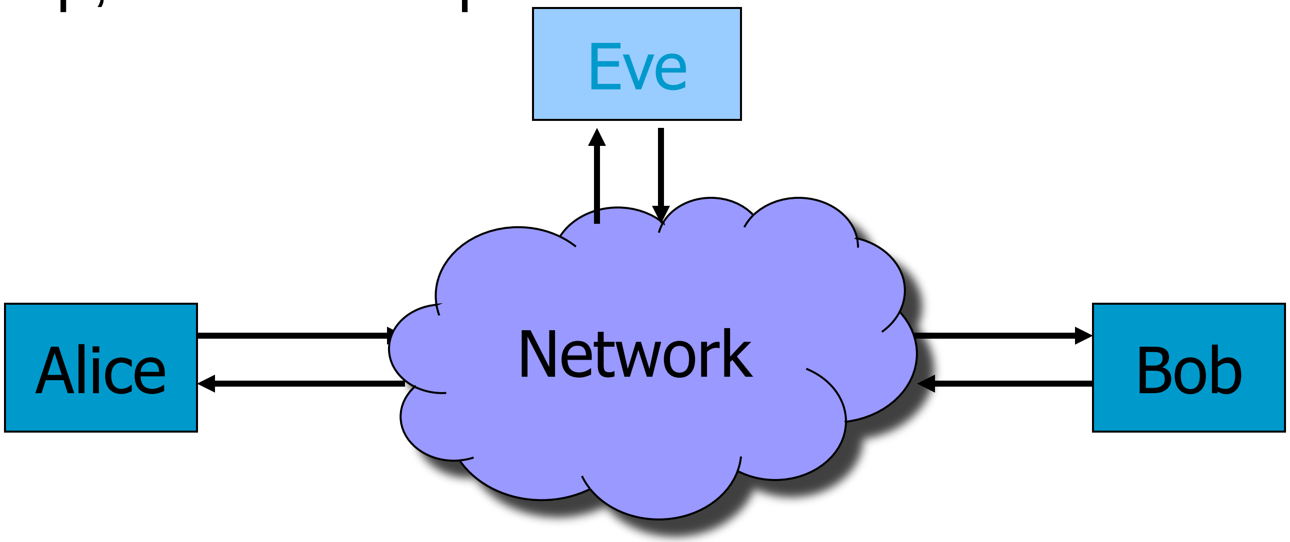
IP Routing



- Internet routing uses numeric IP address
- Typical route uses several hops

Packet Sniffing

- Promiscuous Network Interface Card reads all packets
  - Read all unencrypted data (e.g., “ngrep”)
  - ftp, telnet send passwords in clear!



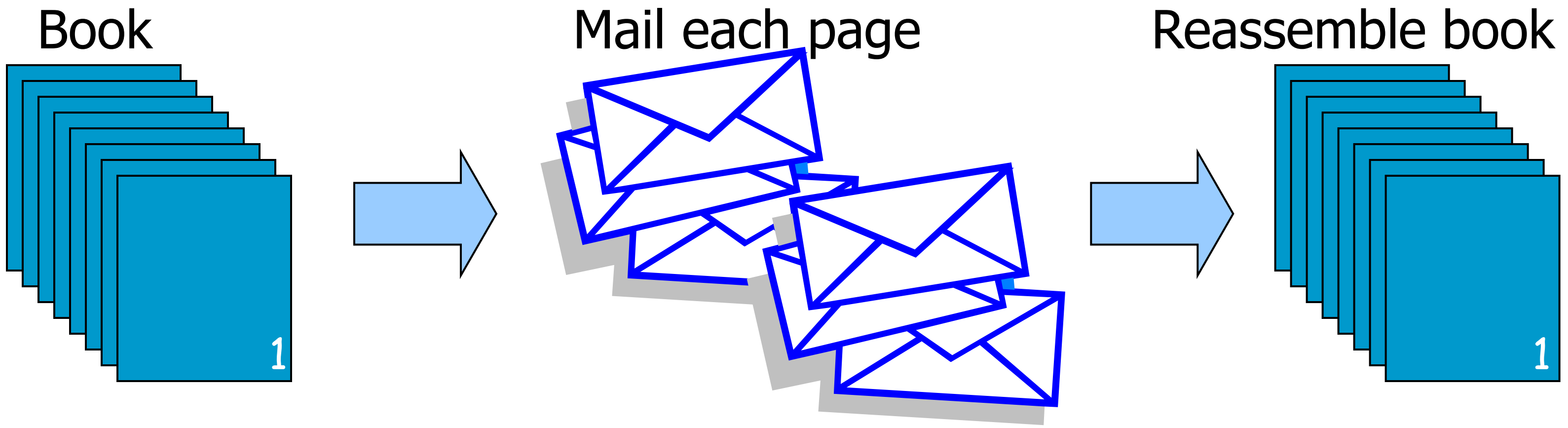
Prevention: Encryption (IPSEC, TLS)

User Datagram Protocol

- IP provides routing
  - IP address gets datagram to a specific machine
- UDP separates traffic by port (16-bit number)
  - Destination port number gets UDP datagram to particular application process, e.g., 128.3.23.3:53
  - Source port number provides return address
- Minimal guarantees
  - No acknowledgment
  - No flow control
  - No message continuation

Transmission Control Protocol

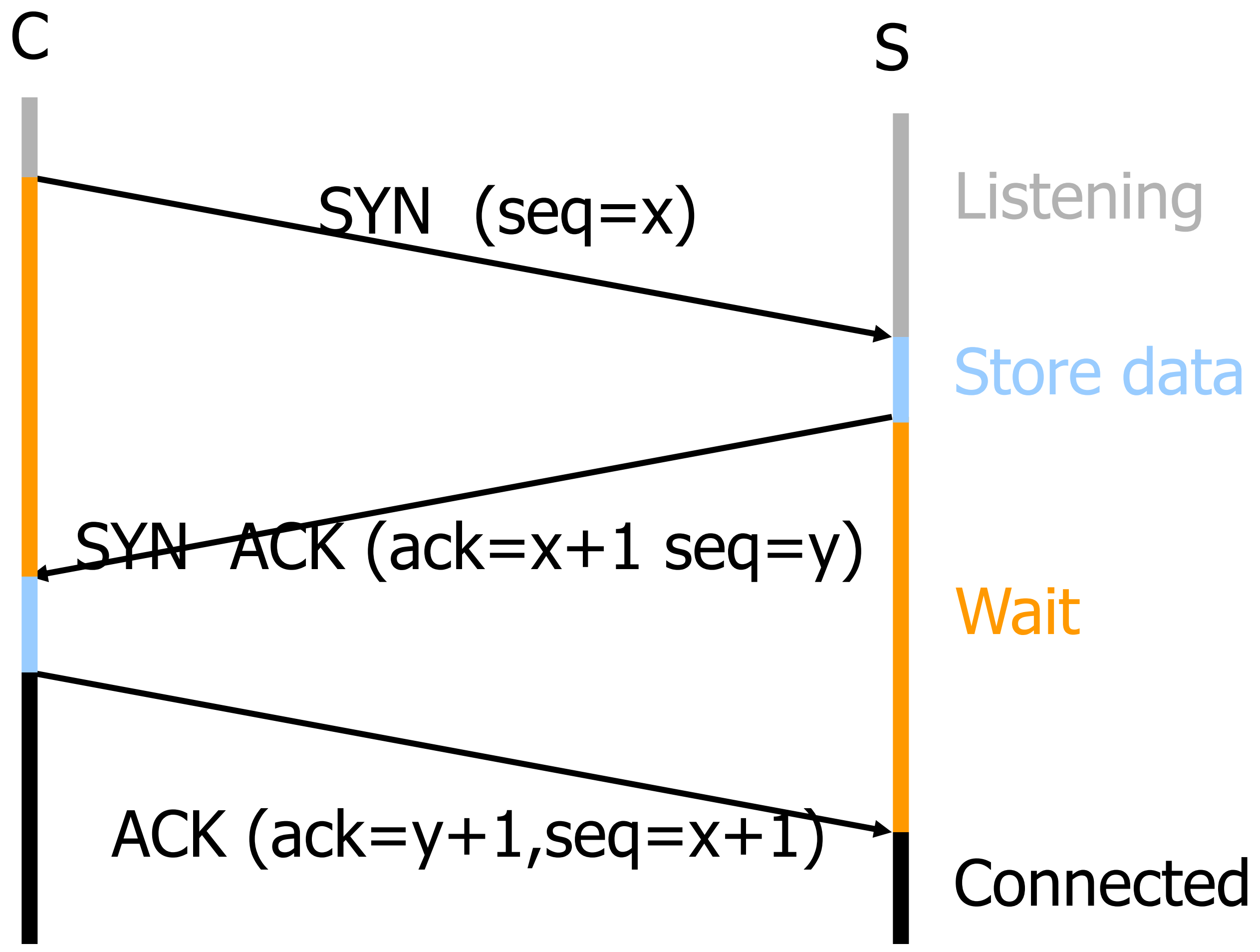
- Connection-oriented, preserves order
  - Sender
    - Break data into packets
    - Attach sequence numbers
  - Receiver
    - Acknowledge receipt; lost packets are resent
    - Reassemble packets in correct order



TCP Sequence Numbers

- Sequence number (32 bits) – has a dual role:
  - If the SYN flag is set, then this is the initial sequence number. The sequence number of the actual first data byte is this sequence number plus 1.
  - If the SYN flag is clear, then this is the accumulated sequence number of the first data byte of this packet for the current session.
- Acknowledgment number (32 bits) –
  - If the ACK flag is set then this the next sequence number that the receiver is expecting.
  - This acknowledges receipt of all prior bytes (if any).

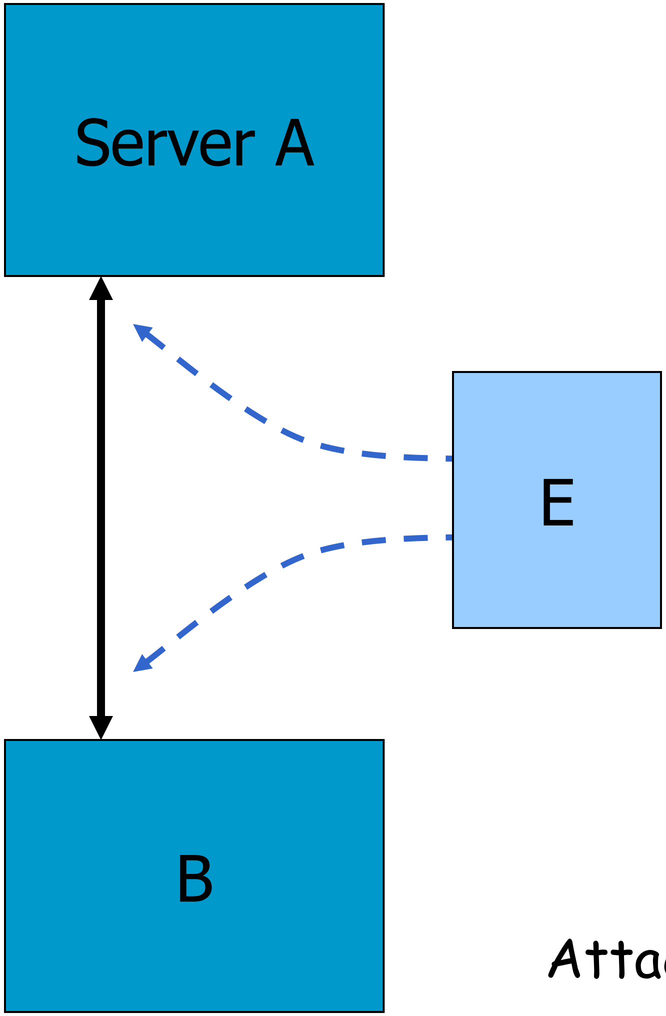
TCP Handshake



TCP sequence prediction attack

- Predict the sequence number used to identify the packets in a TCP connection, and then counterfeit packets.
- Adversary: do not have full control over the network, but can inject packets with fake source IP addresses
  - E.g., control a computer on the local network
- TCP sequence numbers are used for authenticating packets
- Initial seq# needs high degree of unpredictability
  - If attacker knows initial seq # and amount of traffic sent, can estimate likely current values
  - Some implementations are vulnerable

Blind TCP Session Hijacking



- A, B trusted connection
  - Send packets with predictable seq numbers
- E impersonates B to A
  - Opens connection to A to get initial seq number
  - DoS B's queue
  - Sends packets to A that resemble B's transmission
  - E cannot receive, but may execute commands on A

Attack can be blocked if E is outside firewall.

Risks from Session Hijacking

- Inject data into an unencrypted server-to-server traffic, such as an e-mail exchange, DNS zone transfers, etc.
- Inject data into an unencrypted client-to-server traffic, such as ftp file downloads, http responses.
- Spoof IP addresses, which are often used for preliminary checks on firewalls or at the service level.
- Carry out MITM attacks on weak cryptographic protocols.
  - often result in warnings to users that get ignored
- Denial of service attacks, such as resetting the connection.

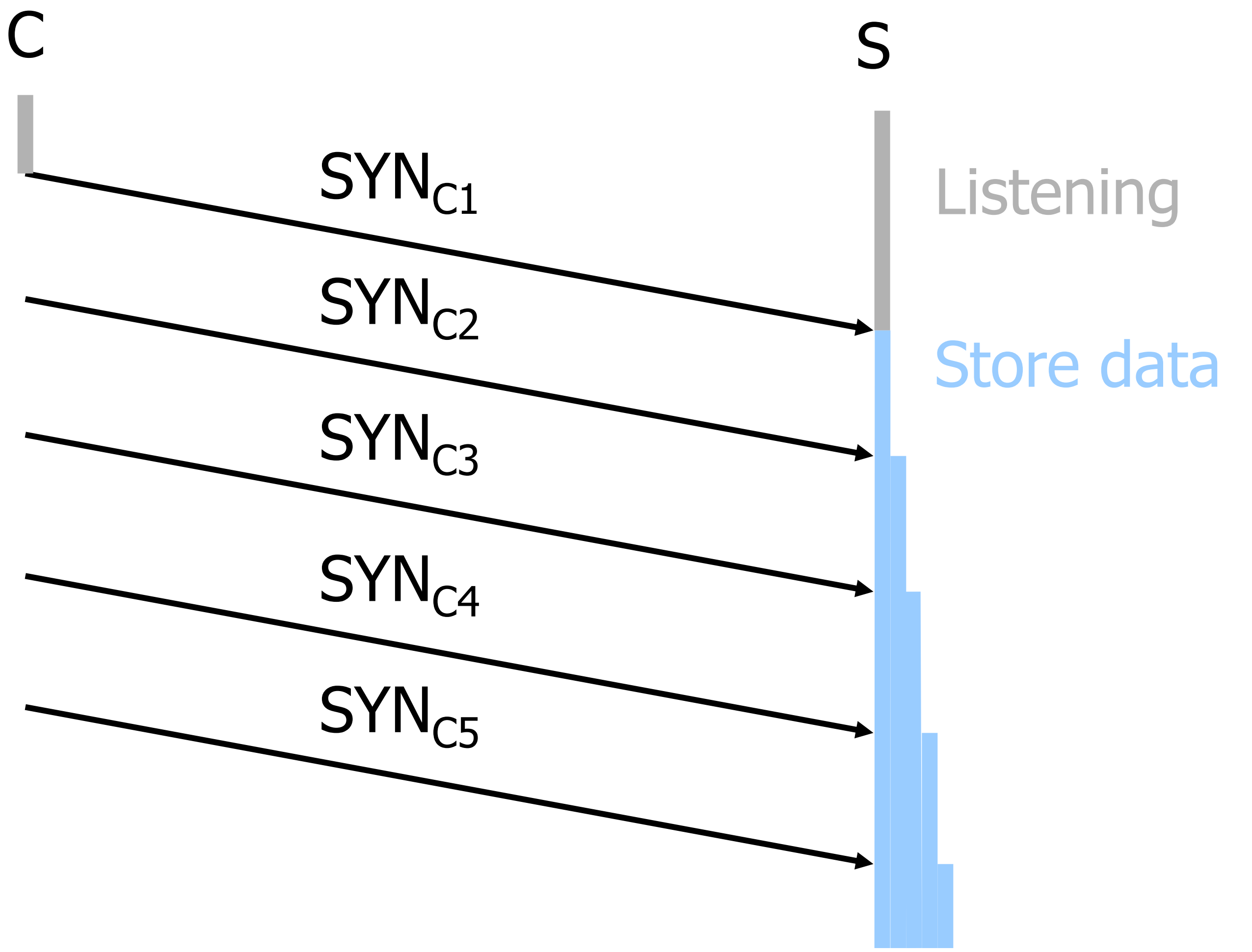
DoS vulnerability caused by session hijacking

- Suppose attacker can guess seq. number for an existing connection:
  - Attacker can send Reset packet to close connection. Results in DoS.
  - Naively, success prob. is $1/2^{32}$ (32-bit seq. #'s).
  - Most systems allow for a large window of acceptable seq. #'s
    - Much higher success probability.
- Attack is most effective against long lived connections, e.g. BGP.

Categories of Denial-of-service Attacks

	Stopping services	Exhausting resources
Locally	• Process killing • Process crashing • System reconfiguration	• Spawning processes to fill the process table • Filling up the whole file system • Saturate comm bandwidth
Remotely	• Malformed packets to crash buggy services	• Packet floods (Smurf, SYN flood, DDoS, etc)

SYN Flooding

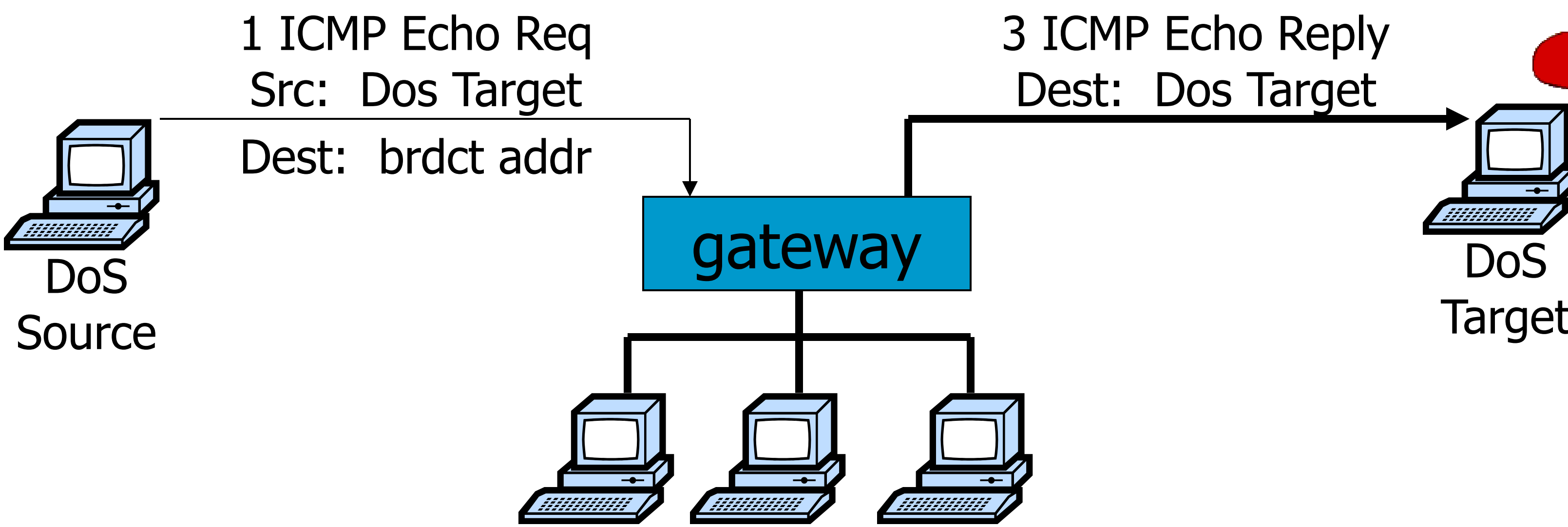


SYN Flooding

- Attacker sends many connection requests
  - Spoofed source addresses
- Victim allocates resources for each request
  - Connection requests exist until timeout
  - Old implementations have a small and fixed bound on half-open connections
- Resources exhausted $\Rightarrow$ requests rejected

- No more effective than other channel capacity-based attack today

Smurf DoS Attack



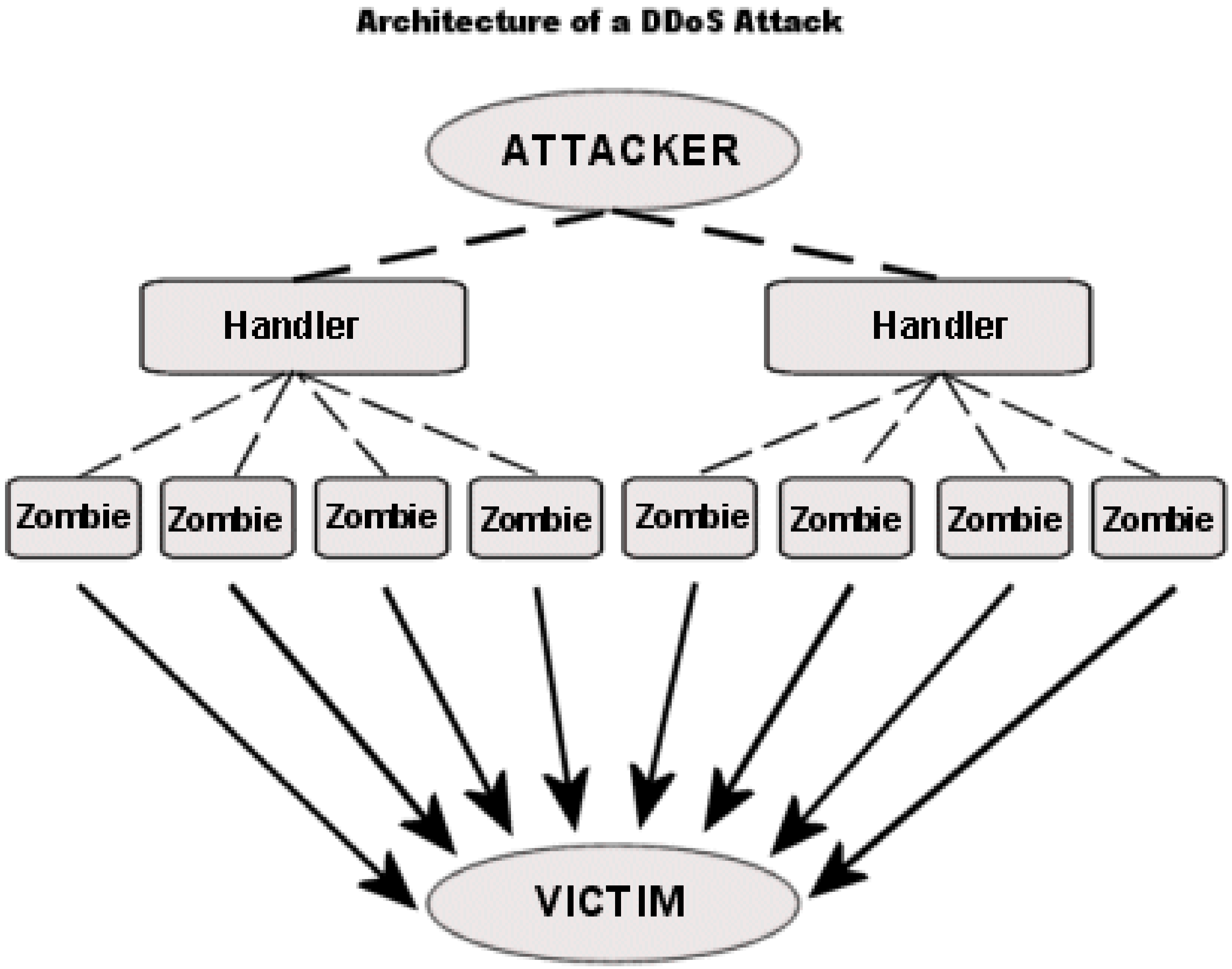
- Send ping request to broadcast addr (ICMP Echo Req)
- Lots of responses:
  - Every host on target network generates a ping reply (ICMP Echo Reply) to victim
  - Ping reply stream can overload victim

Prevention: reject external packets to broadcast address

Internet Control Message Protocol

- Provides feedback about network operation
  - Error reporting
  - Reachability testing
  - Congestion Control
- Example message types
  - Destination unreachable
  - Time-to-live exceeded
  - Parameter problem
  - Redirect to better gateway
  - Echo/echo reply - reachability test

Distributed DoS (DDoS)



Hiding DDoS Attacks

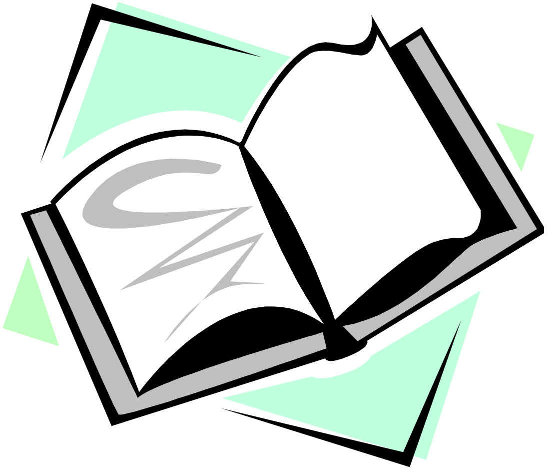
- Reflection
  - Find big sites with lots of resources, send packets with spoofed source address, response to victim
    - PING => PING response
    - SYN => SYN-ACK
- Pulsing zombie floods
  - each zombie active briefly, then goes dormant;
  - zombies taking turns attacking
  - making tracing difficult

Cryptographic network protection

- Solutions above the transport layer
  - Examples: SSL and SSH
  - Protect against session hijacking and injected data
  - Do not protect against denial-of-service attacks caused by spoofed packets
- Solutions at network layer
  - Use cryptographically random ISNs [RFC 1948]
  - More generally: IPsec
  - Can protect against
    - session hijacking and injection of data.
    - denial-of-service attacks using session resets.

Readings for This Lecture

- Optional Reading
  - Steve Bellovin: A Look Back at "Security Problems in the TCP/IP Protocol Suite"



Coming Attractions …

- DNS Security