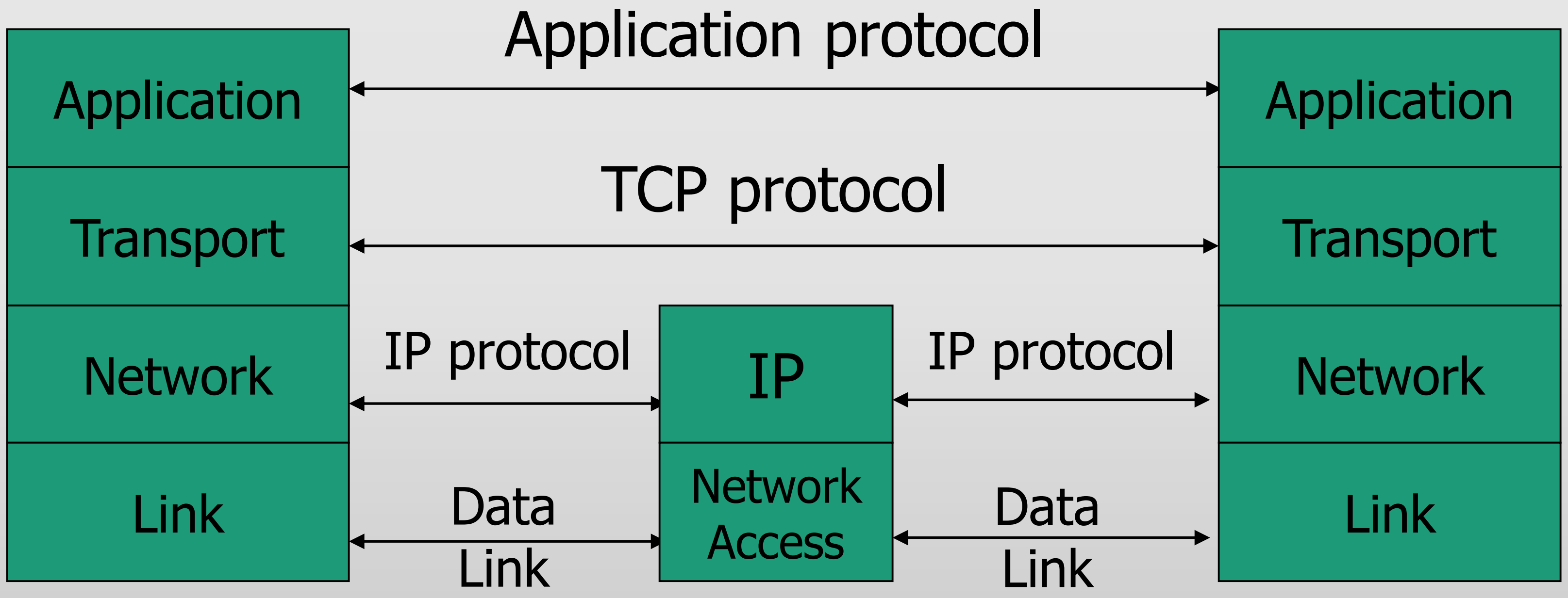
Network Security

CS 419 Computer Security

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.rutgers.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

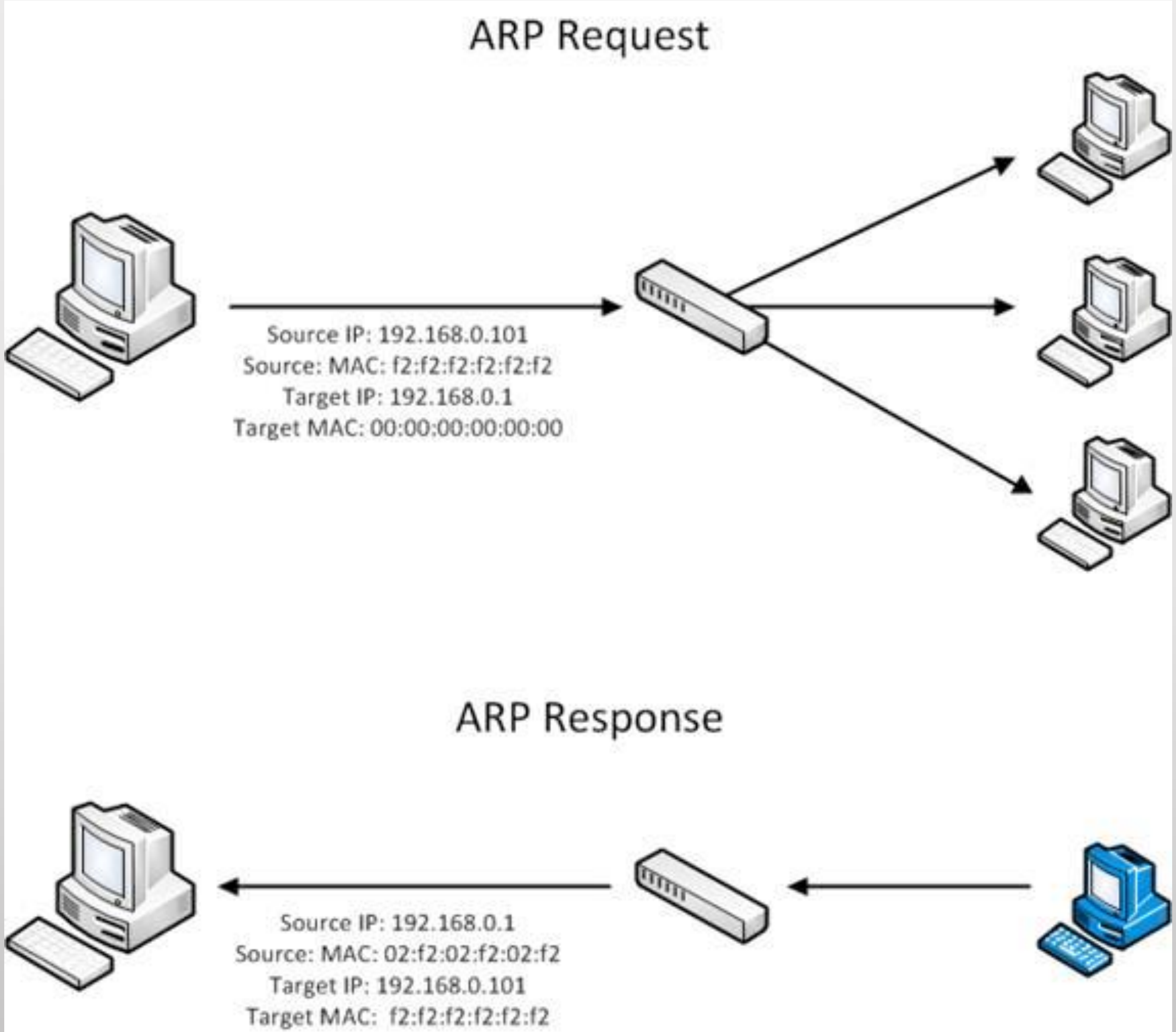
- Confidentiality
  - e.g. Packet sniffing
- Integrity
  - e.g. Session hijacking
- Availability
  - e.g. Denial of service attacks
- Common
  - e.g. Address translation poisoning attacks
  - e.g. Routing attacks

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)

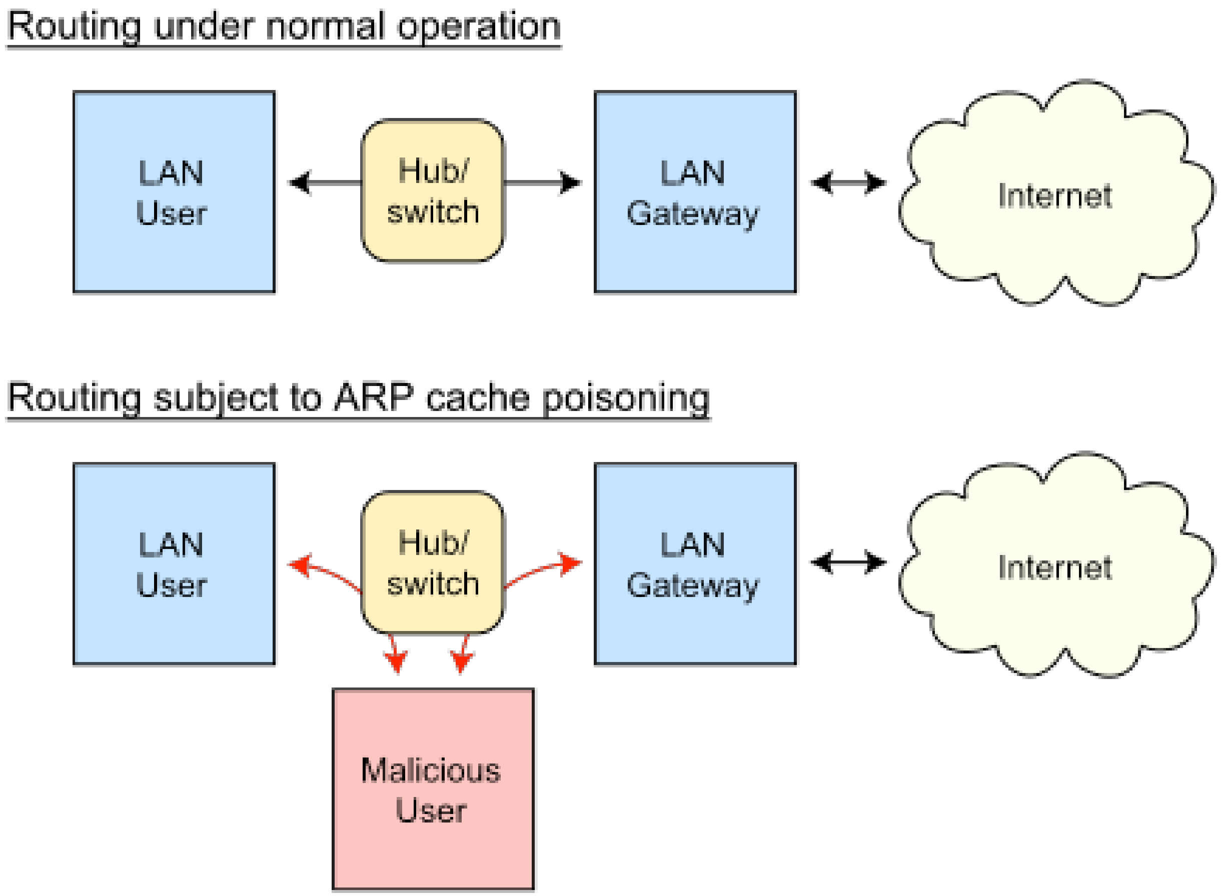
- Primarily used to translate IP addresses to Ethernet MAC addresses
  - The device drive for Ethernet NIC needs to do this to send a packet
- Also used for IP over other LAN technologies, e.g. IEEE 802.11
- Each host maintains a table of IP to MAC addresses
- Message types:
  - ARP request
  - ARP reply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



http://www.windowsecurity.com

ARP Spoofing (ARP Poisoning)

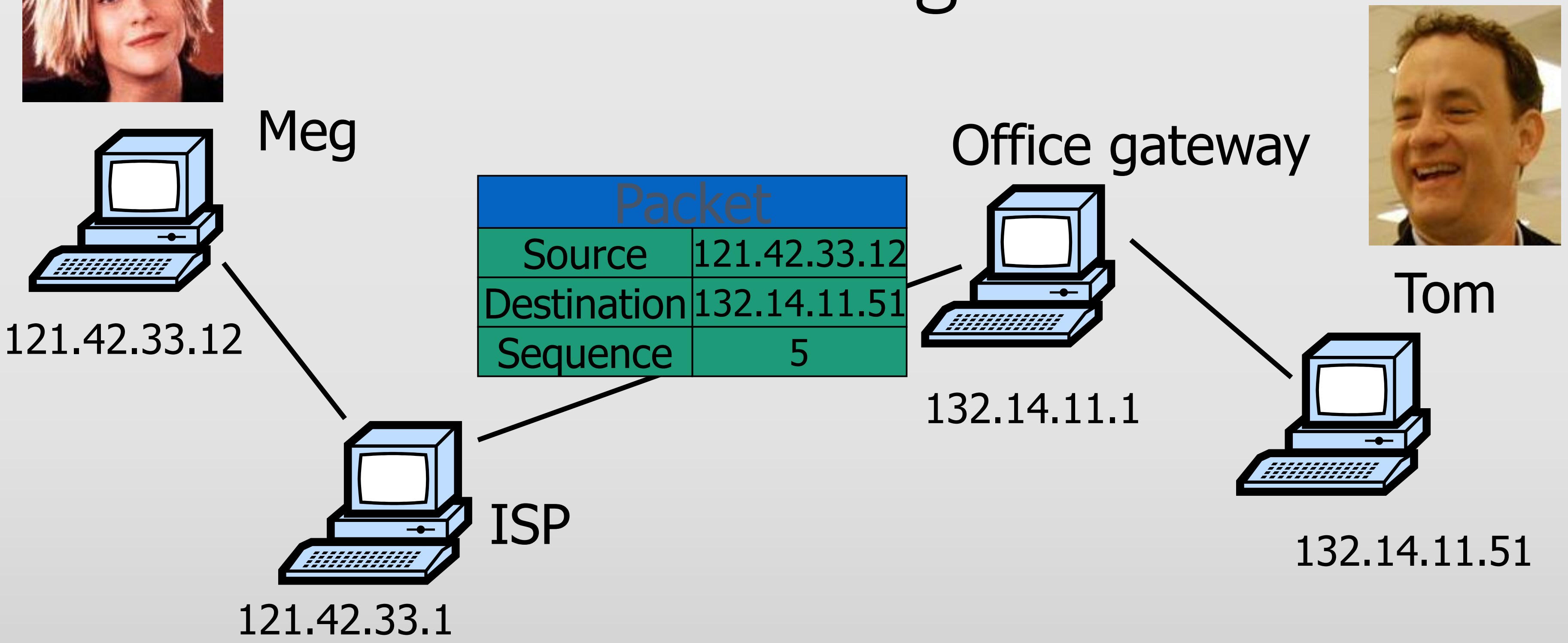
- Send fake or 'spoofed', ARP messages to an Ethernet LAN.
  - To have other machines associate IP addresses with the attacker's MAC
- Legitimate use
  - redirect a user to a registration page before allow usage of the network.
  - Implementing redundancy and fault tolerance



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),

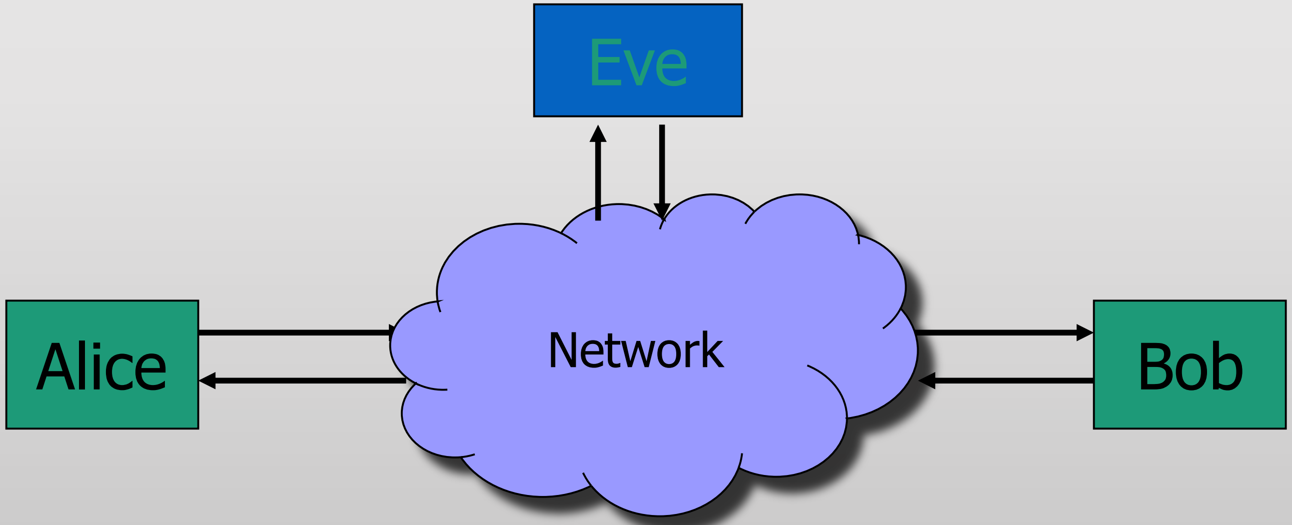
IP Routing



- 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!



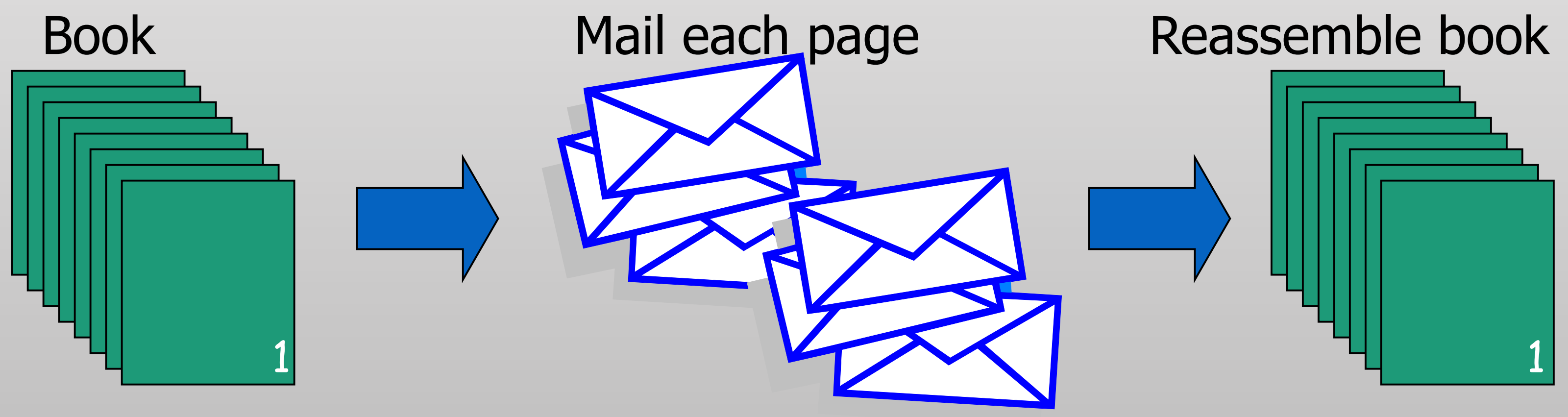
Prevention: Encryption (IPSEC, TLS)

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

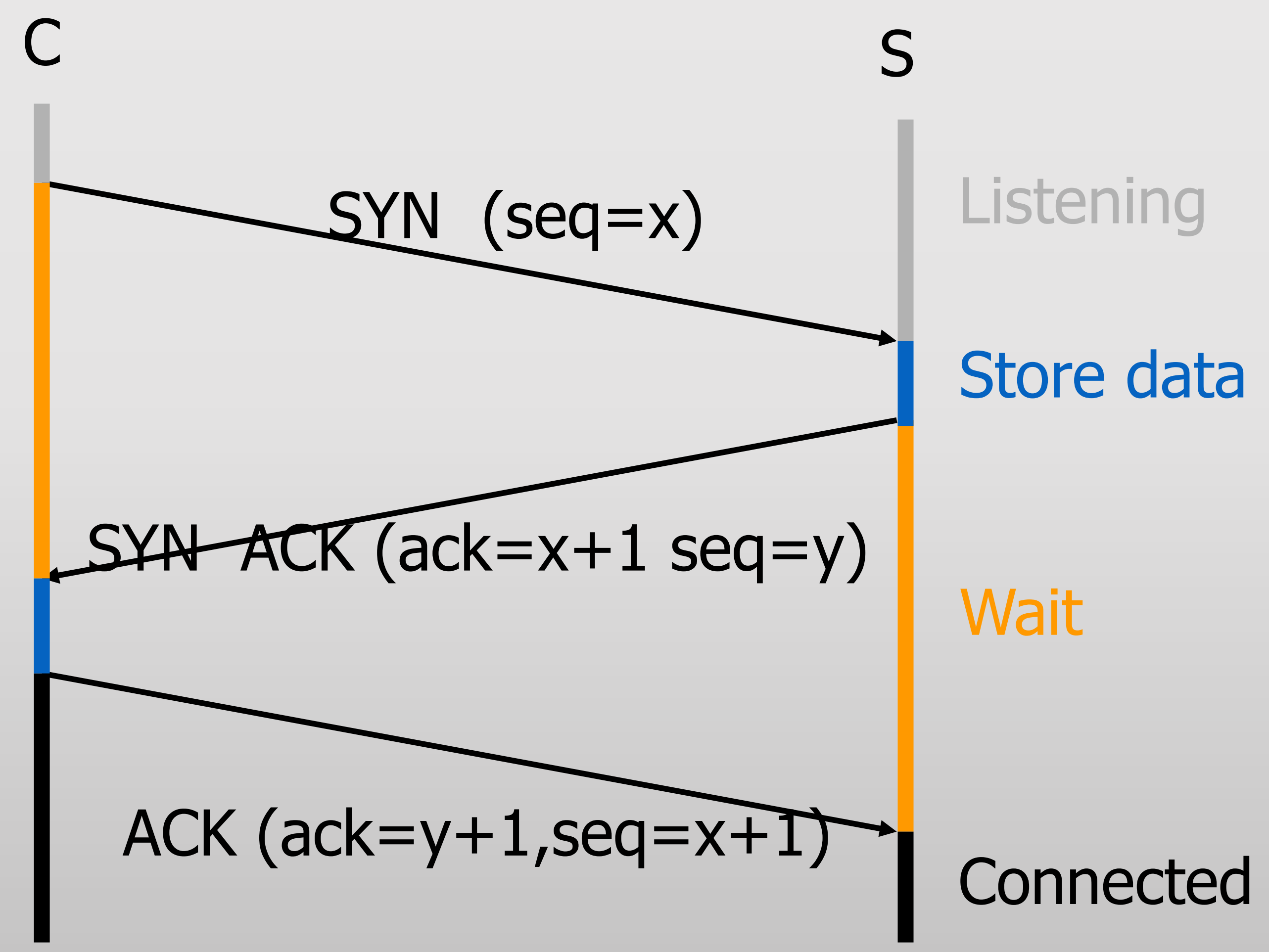
- Connection-oriented, preserves order
  - Sender
    - Break data into packets
    - Attach sequence numbers
  - Receiver
    - Acknowledge receipt; lost packets are resent
    - Reassemble packets in correct order



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).

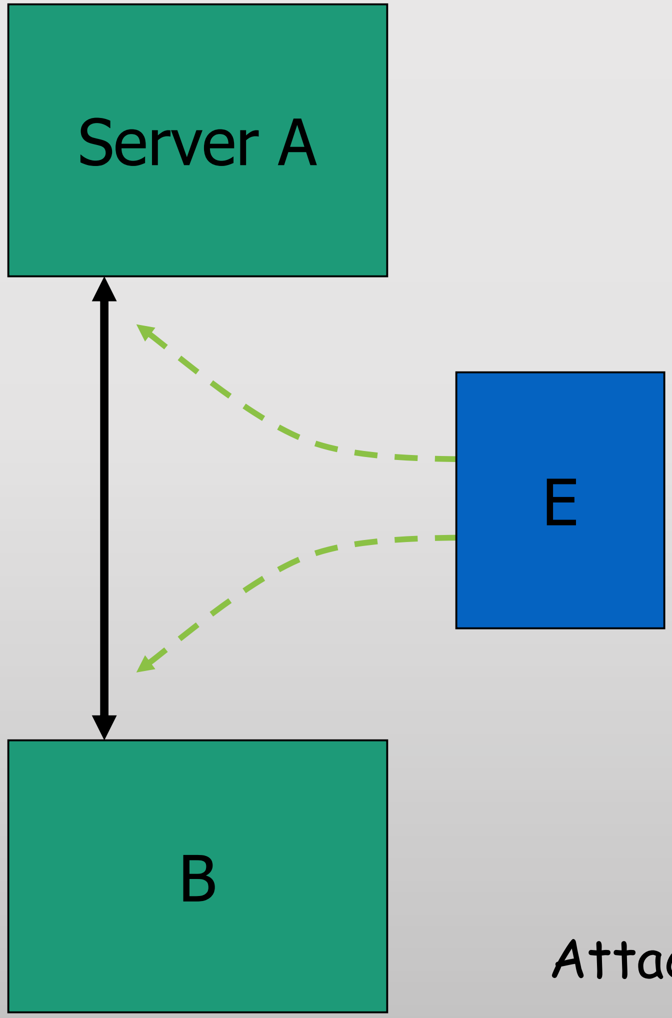
TCP Handshake



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.

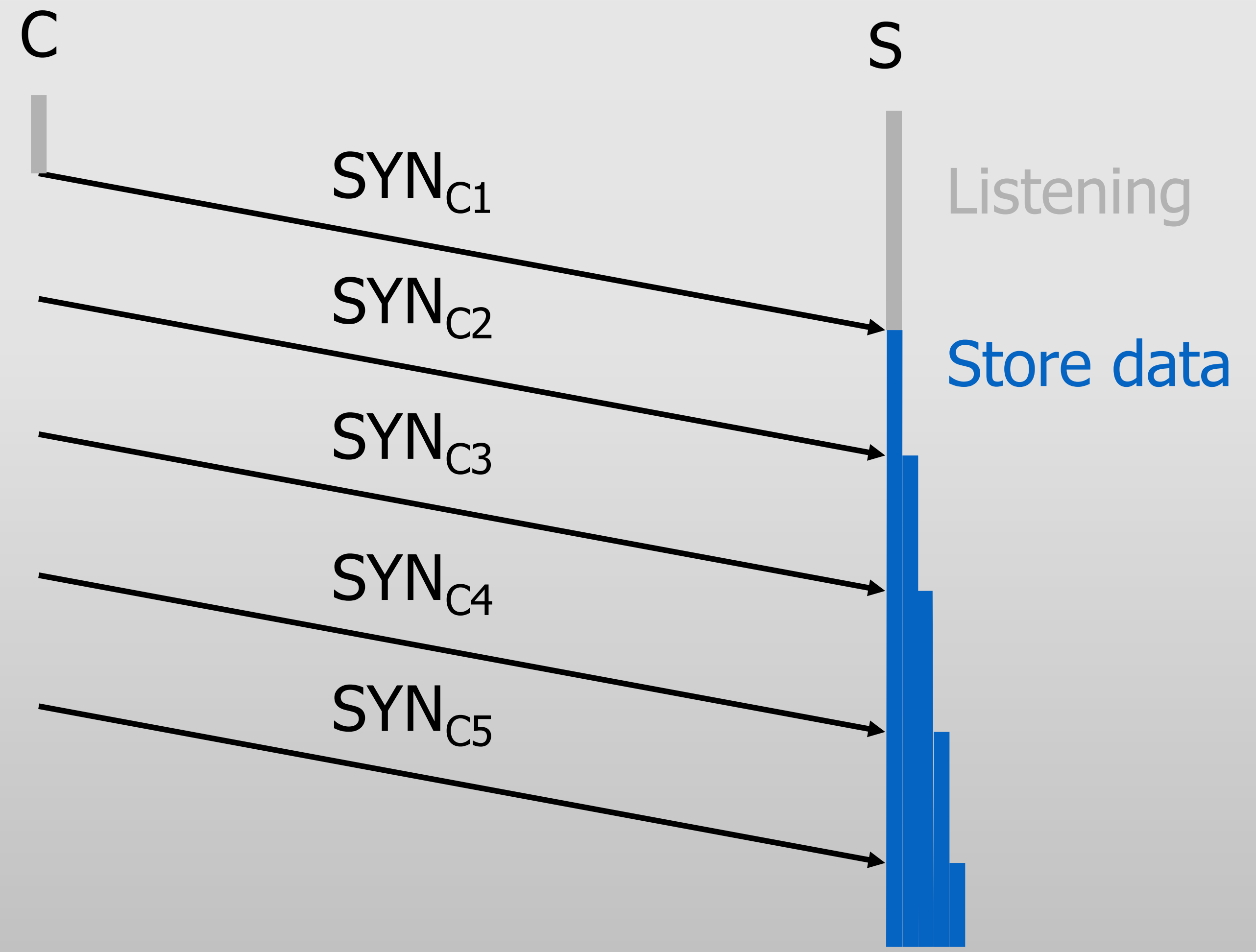
DoS vulnerability caused by session hijacking

- 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

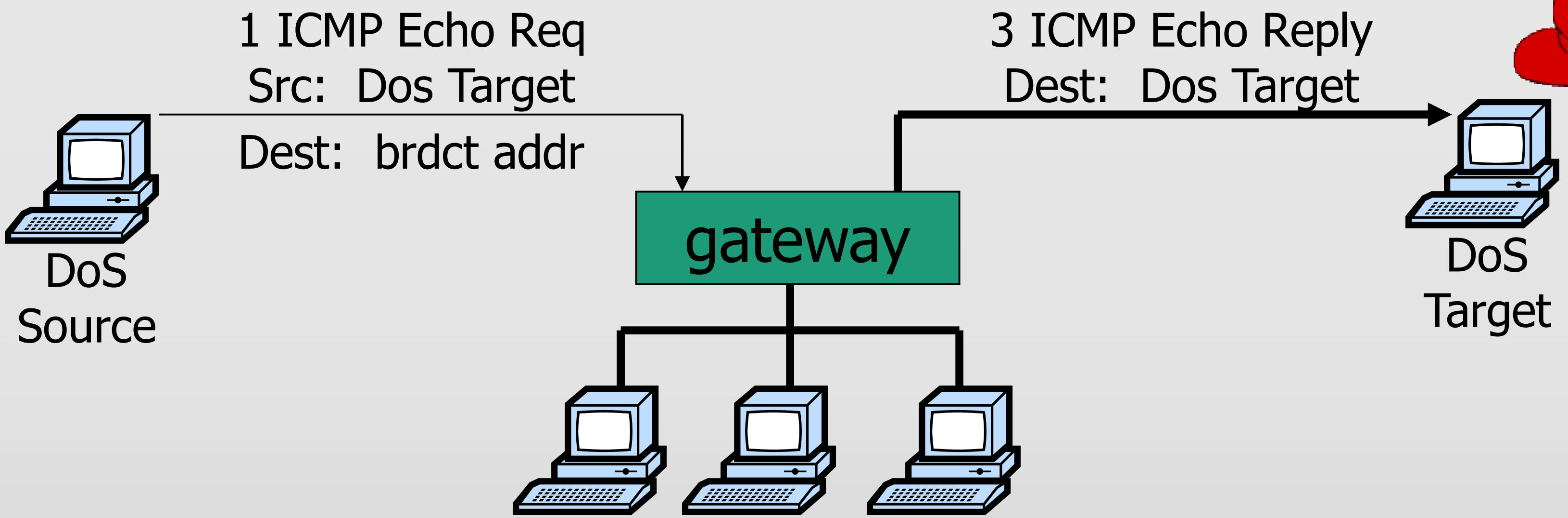


SYN Flooding

- 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



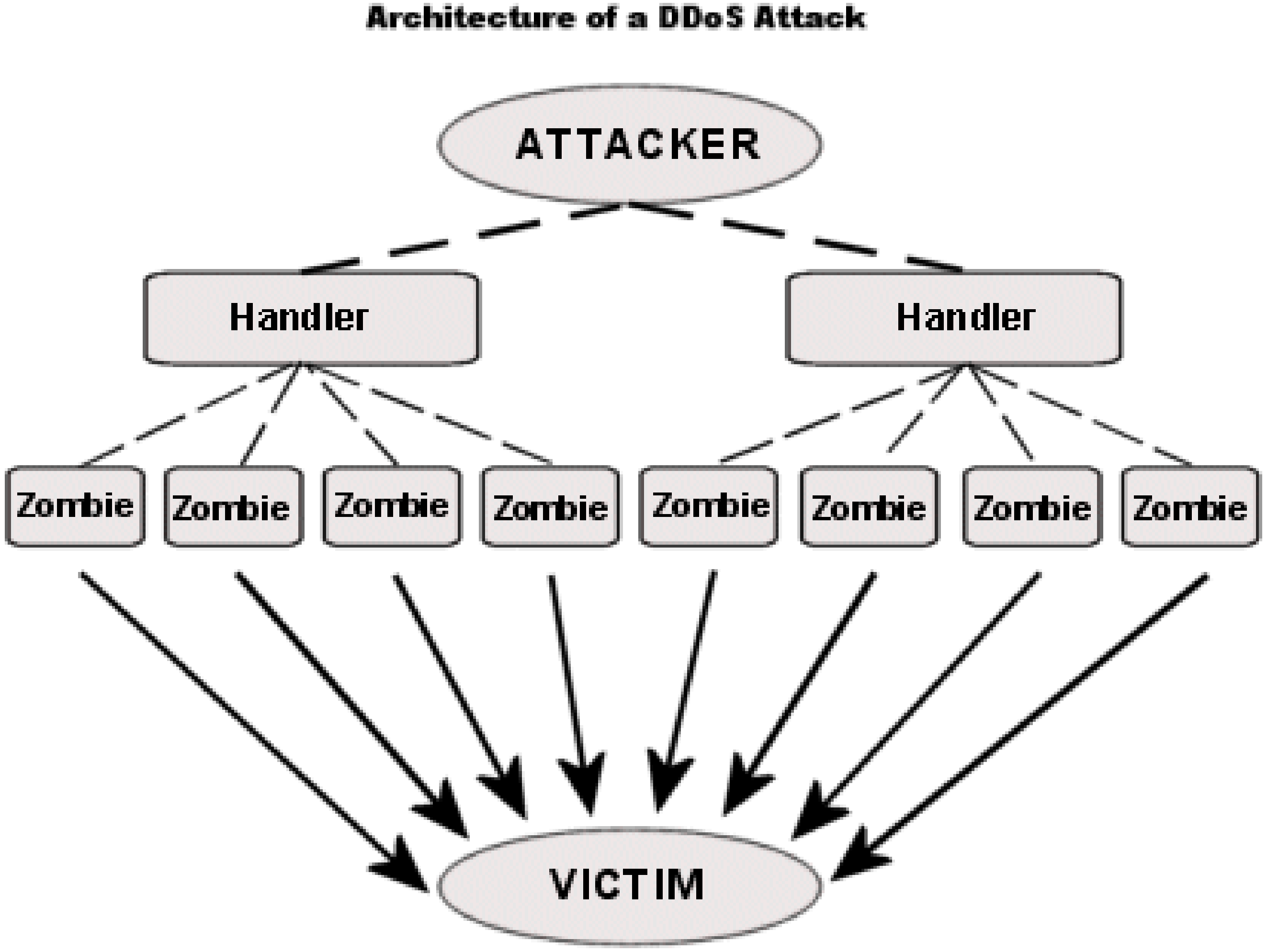
- Send ping request to broadcast addr (ICMP Echo Req)
- Lots of responses:
  - Every host on target network generates a ping reply (ICMP Echo Reply) to victim
  - Ping reply stream can overload victim

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

Domain Name System

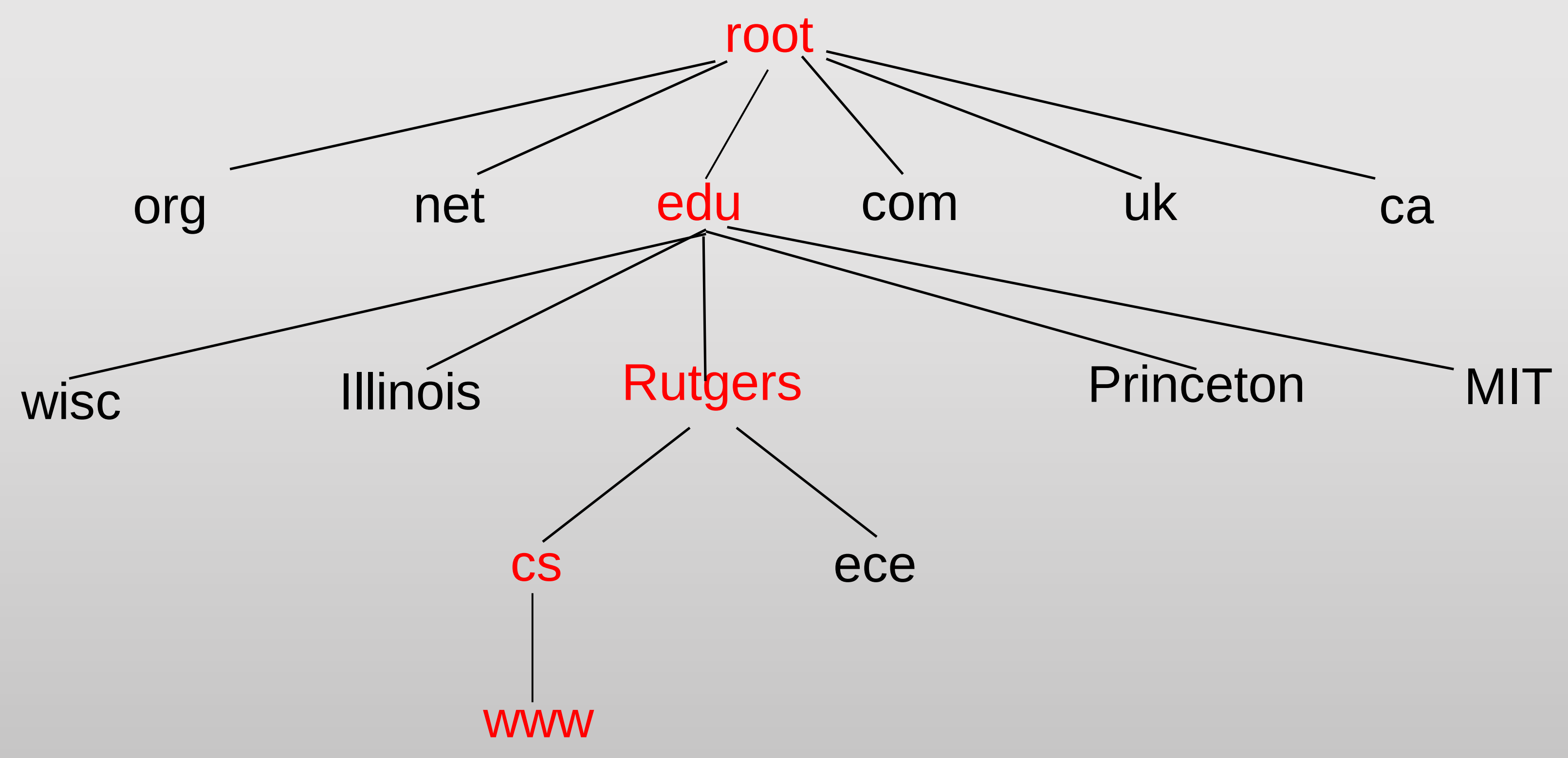
- Translate host names to IP addresses
  - E.g., www.xyz.com ➔ 74.125.91.103
- And back
  - From IP addresses to DNS name

DNS is a Distributed Database

- Information is stored in a distributed way
- Highly dynamic
- Decentralized authority

Domain Name System

- Hierarchical Name Space



Domain Name System

Domain Name Servers

- Top-level domain (TLD) servers:
  - responsible for com, org, net, edu, etc, and all top-level country domains, e.g. uk, fr, ca, jp.
  - Network Solutions maintains servers for “.com”
- Authoritative DNS servers:
  - organization’s DNS servers, providing authoritative hostname to IP mappings for organization’s servers.
  - can be maintained by organization or service provider.

Domain Name Servers - 2

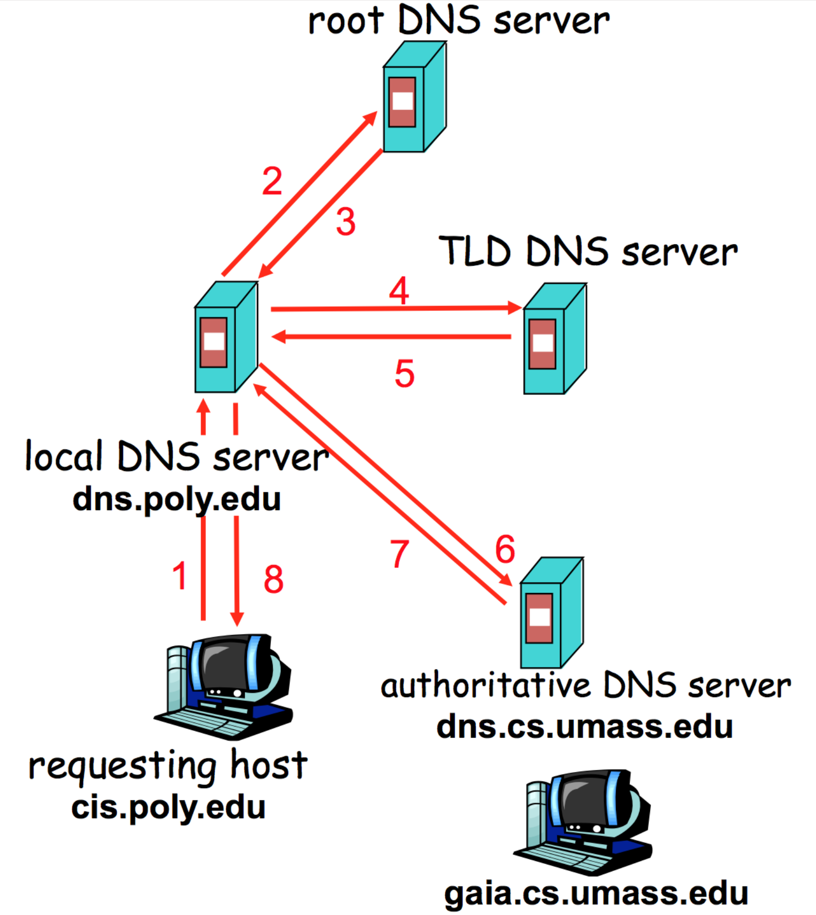
- Local Name Server
  - does not strictly belong to hierarchy
  - each ISP (residential ISP, company, university) has one.

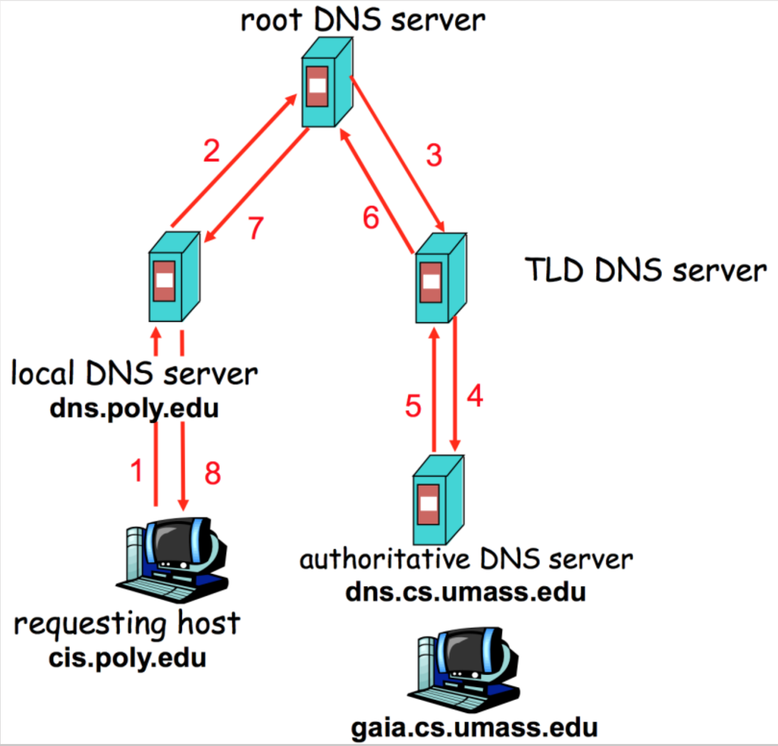
DNS Resolving

- When host makes DNS query, query is sent to its local DNS server.
  - acts as proxy, forwards query into hierarchy.

- Two resolving schemes:
  - Iterative, and
  - Recursive.

DNS Resolving - 2





Caching

DNS responses are cached

- Quick response for repeated translations

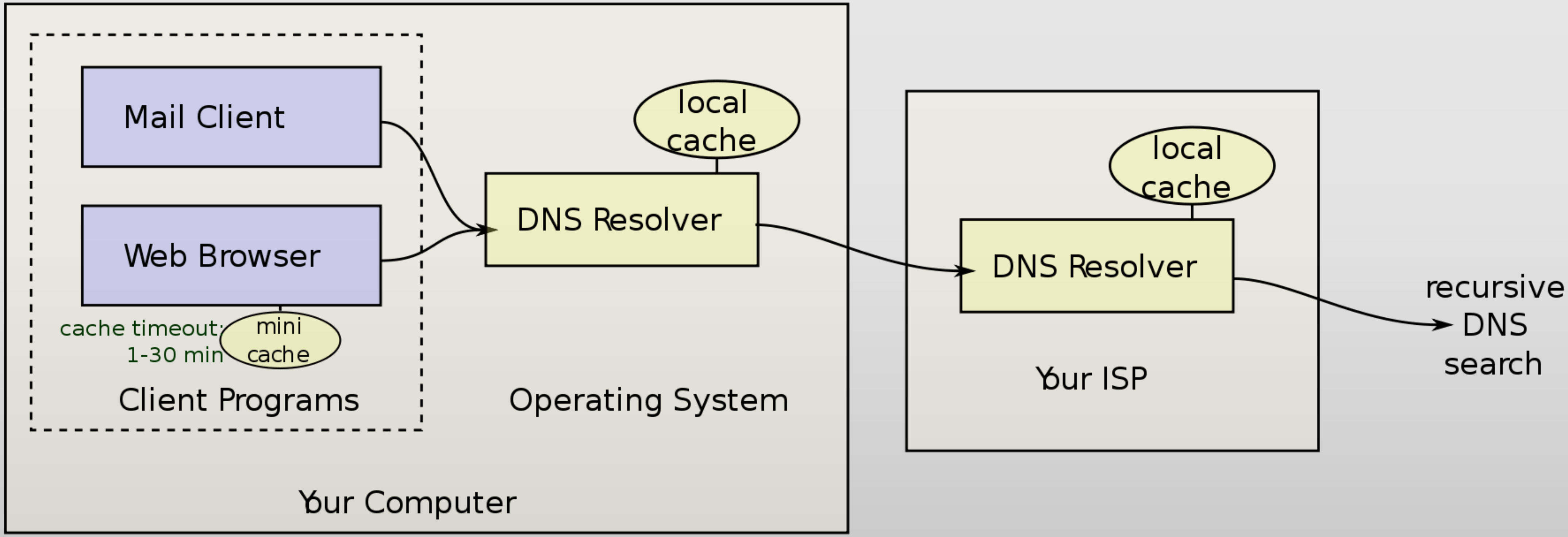
Negative results are also cached

- Save time for nonexistent sites, e.g. misspelling

Cached data periodically times out

- Each record has a TTL field

Caching - 2



Mail Client
Web Browser
cache timeout: 1-30 min
mini cache
Client Programs
local cache
DNS Resolver
Operating System
Your Computer
local cache
DNS Resolver
Your ISP
recursive DNS search

Inherent DNS Vulnerabilities

- Users/hosts typically trust the host-address mapping provided by DNS
  - What bad things can happen with wrong DNS info?
- DNS resolvers trust responses received after sending out queries.
  - How to attack?
- Obvious problem
  - No authentication for DNS responses

User Side Attack - Pharming

- Exploit DNS poisoning attack
  - Change IP addresses to redirect URLs to fraudulent sites
  - Potentially more dangerous than phishing attacks
    - Why?

- DNS poisoning attacks have occurred:
  - January 2005, the domain name for a large New York ISP, Panix, was hijacked to a site in Australia.
  - In November 2004, Google and Amazon users were sent to Med Network Inc., an online pharmacy

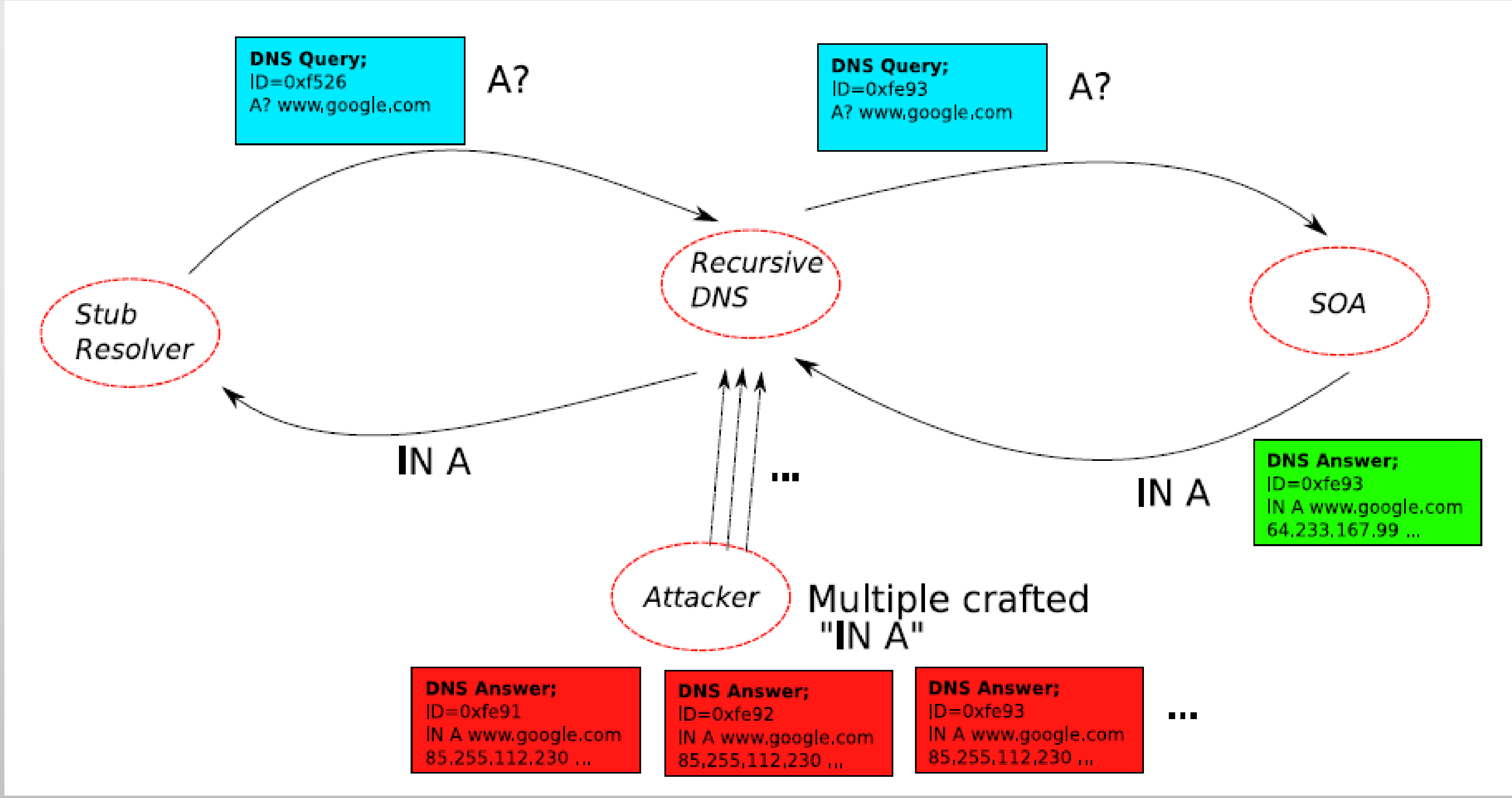
DNS Cache Poisoning

- Attacker wants his IP address returned for a DNS query
- When the resolver asks ns1.google.com for www.google.com, the attacker could reply first, with his own IP
- What is supposed to prevent this?
- Transaction ID
  - 16-bit random number
  - The real server knows the number, because it was contained in the query
  - The attacker has to guess

DNS cache poisoning - 2

- Responding before the real nameserver
  - An attacker can guess when a DNS cache entry times out and a query has been sent, and provide a fake response.
  - The fake response will be accepted only when its 16-bit transaction ID matches the query
  - CERT reported in 1997 that BIND uses sequential transaction ID and is easily predicted
    - fixed by using random transaction IDs

DNS cache poisoning: Racing to Respond First



DNS cache poisoning (Schuba and Spafford in 1993)

- DNS resource records (see RFC 1034)
  - An “A” record supplies a host IP address
  - A “NS” record supplies name server for domain
- First, guess query ID:
  - Ask (dns.target.com) for www.evil.org
  - Request is sent to dns.evil.org (get quid).
- Second, attack:
  - Ask (dns.target.com) for www.yahoo.com
  - Give responses from “dns.yahoo.com” to our chosen IP.

DNS cache poisoning – Birthday attack

- Improve the chance of responding before the real nameserver (discovered by Vagner Sacramento in 2002)
  - Have many (say hundreds of) clients send the same DNS request to the name server
    - Each generates a query
  - Send hundreds of reply with random transaction IDs at the same time
  - Due to the Birthday Paradox, the success probability can be close to 1
    - 300 will give you 50%.

DNS poisoning – So far

- Early versions of DNS servers deterministically incremented the ID field
- Vulnerabilities were discovered in the random ID generation
  - Weak random number generator
  - The attacker is able to predict the ID if knowing several IDs in previous transactions
- Birthday attack
  - 16- bit (only 65,536 options).
  - Force the resolver to send many identical queries, with different IDs, at the same time
  - Increase the probability of making a correct guess

DNS cache poisoning - Kaminsky

- Kaminsky Attack
  - Big security news in summer of 2008
  - DNS servers worldwide were quickly patched to defend against the attack

- In previous attacks, when the attacker loses the race, the record is cached, with a TTL.
  - Before TTL expires, no attack can be carried out
  - Posining address for google.com in a DNS server is not easy.

What is New in the Kaminsky Attack?

- The bad guy does not need to wait to try again
- The bad guy asks the resolver to look up www.google.com
  - If the bad guy lost the race, the other race for www.google.com will be suppressed by the TTL
- If the bad guy asks the resolver to look up 1.google.com, 2.google.com, 3.google.com, and so on
  - Each new query starts a new race
- Eventually, the bad guy will win
  - he is able to spoof 183.google.com
  - So what? No one wants to visit 183.google.com

Kaminsky-Style Poisoning

- A bad guy who wins the race for “183.google.com” can end up stealing “www.google.com” as well

- Original malicious response:
  - google.com NS www.google.com
  - www.google.com A 6.6.6.6
- Killer response:
  - google.com NS ns.badguy.com

Kaminsky-Style Poisoning (cont')

- Why it succeeded:
  - Can start anytime; no waiting for old good cached entries to expire
  - No "wait penalty" for racing failure
  - The attack is only bandwidth limited

- Defense (alleviate, but not solve the problem)
  - Also randomize the UDP used to send the DNS query, the attacker has to guess that port correctly as well (increase the space of possible IDs).

DNS Poisoning Defenses

- Difficulty to change the protocol
  - Protocol stability (embedded devices)
  - Backward compatibility.
- Long-term
  - Cryptographic protections
    - E.g., DNSSEC, DNSCurve
  - Require changes to both recursive and authority servers
  - A multi-year process
- Short-term
  - Only change the recursive server (local DNS).
  - Easy to adopt

Short-Term Defenses

- Source port randomization
  - Add up to 16 bits of entropy
  - NAT could de-randomize the port
- DNS 0x20 encoding
  - From Georgia tech, CCS 2008
- Tighter logic for accepting responses

Long Term Solution

- DNSSEC:
  - Authenticate responses.
  - Google DNS now is enabled by default.

- Challenges in deployment:
  - Response is large, might no linger fit in single UDP message.
  - Legacy software and machines.

NEXT CLASS

- OS Basics