Network Basics and Security

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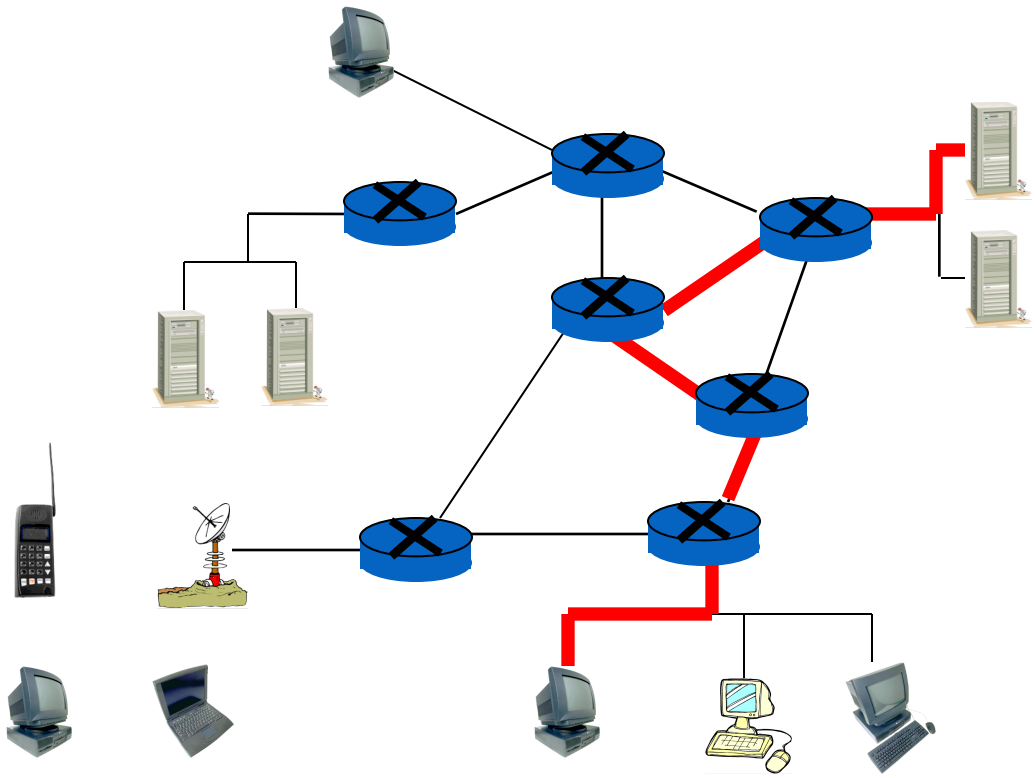
Some of the slides are from Mark Stamp.

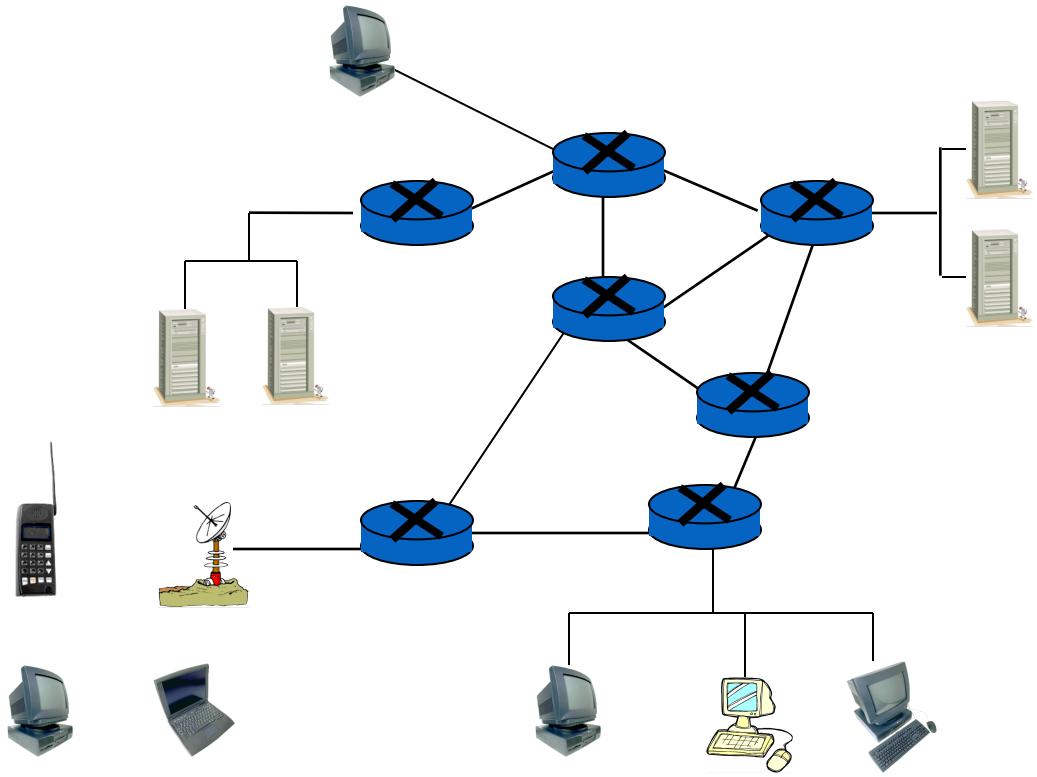
Networking Basics

- Includes
  - Computers
  - Servers
  - Routers
  - Wireless devices
  - Etc.
- Purpose is to transmit data



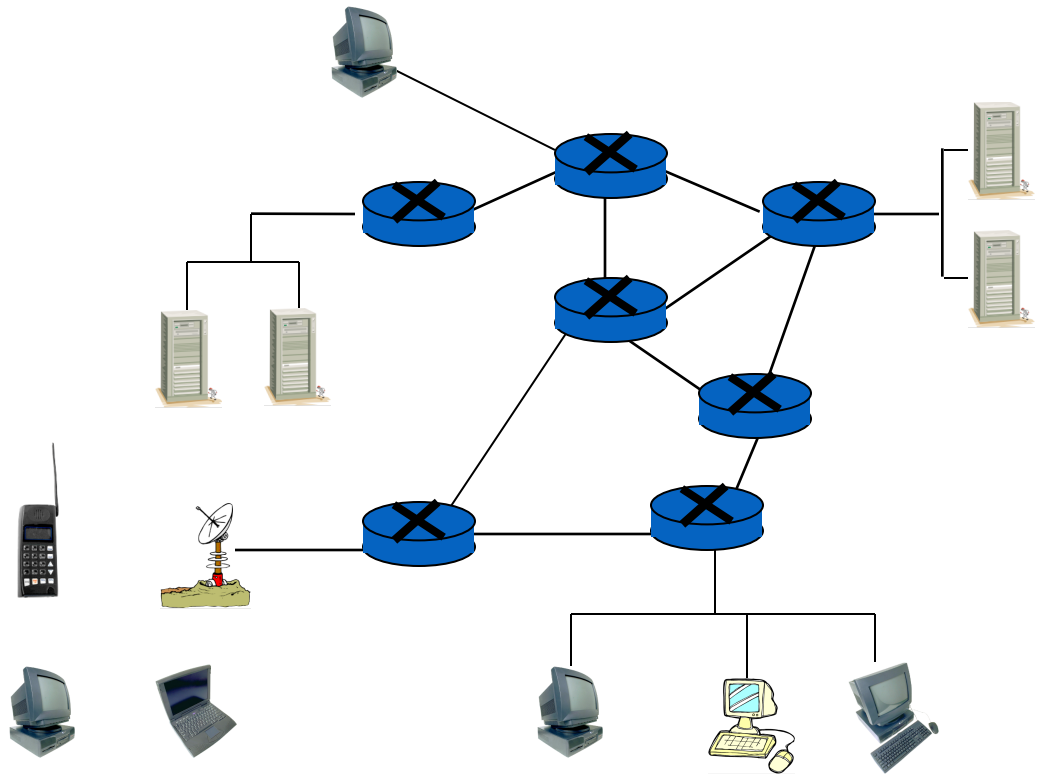
Network Hosts

- Network includes…
- …Hosts
  - Computers
  - Laptops
  - Servers
  - Cell phones
  - Etc., etc.



Network Routers

- Network **also** consists of
  - Interconnected mesh of routers
- Purpose is to move data from host to host



Packet Switched Network

- Telephone network is/was **circuit switched**
  - For each call, a dedicated circuit established
  - Dedicated bandwidth → lots of waste
- Modern data networks are **packet switched**
  - Data is chopped up into discrete packets
  - Packets are transmitted independently
  - No dedicated circuit is established

  \+ More efficient bandwidth usage

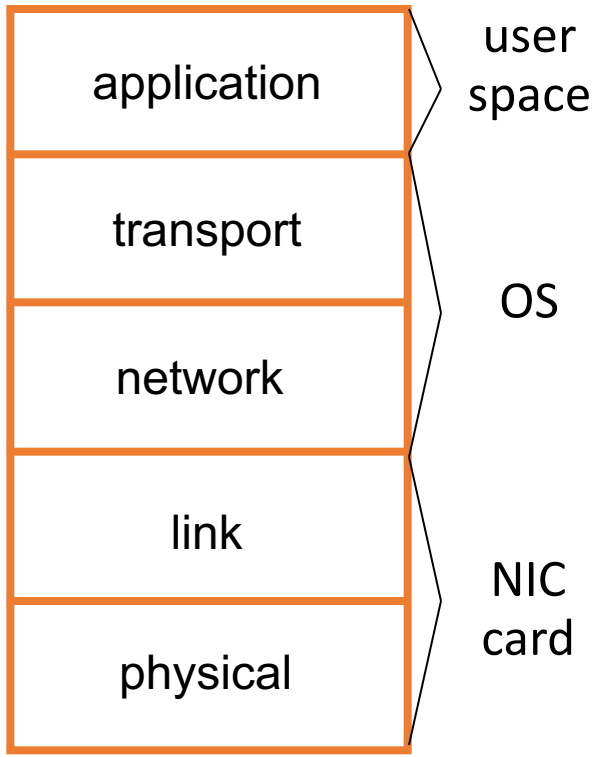
  – But more complex than circuit switched

Network Protocols

- Study of networking focused on **protocols**
- Networking protocols precisely specify "communication rules"
- Details are given in **RFC**s
  - RFC is essentially an Internet standard
- **Stateless** protocols do not "remember"
- **Stateful** protocols do "remember"
- Many security problems related to state
  - E.g., DoS is a problem with stateful protocols

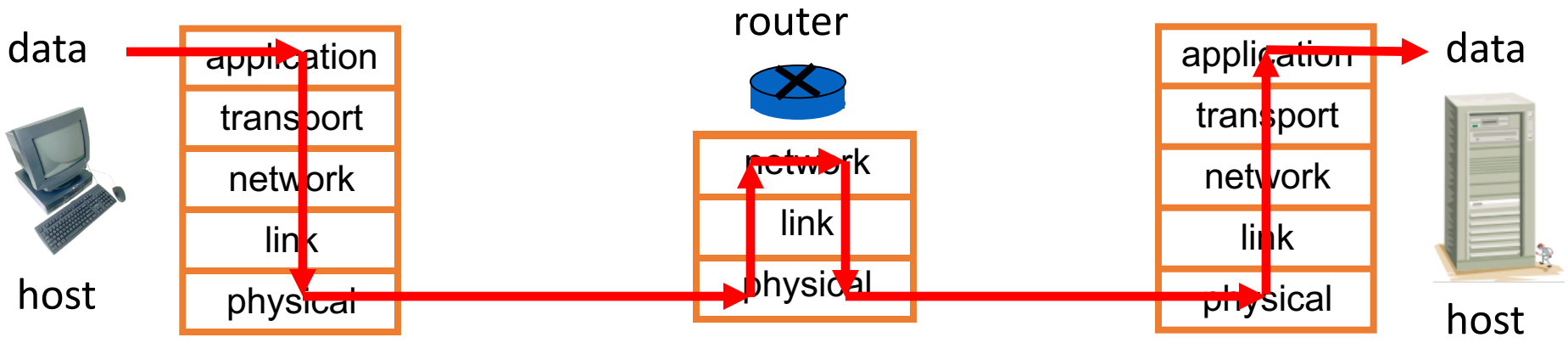
Protocol Stack (OSI Model)

- Application layer protocols
  - HTTP, FTP, SMTP, etc.
- Transport layer protocols
  - TCP, UDP
- Network layer protocols
  - IP, routing protocols
- Link layer protocols
  - Ethernet, PPP
- Physical layer



Five layers

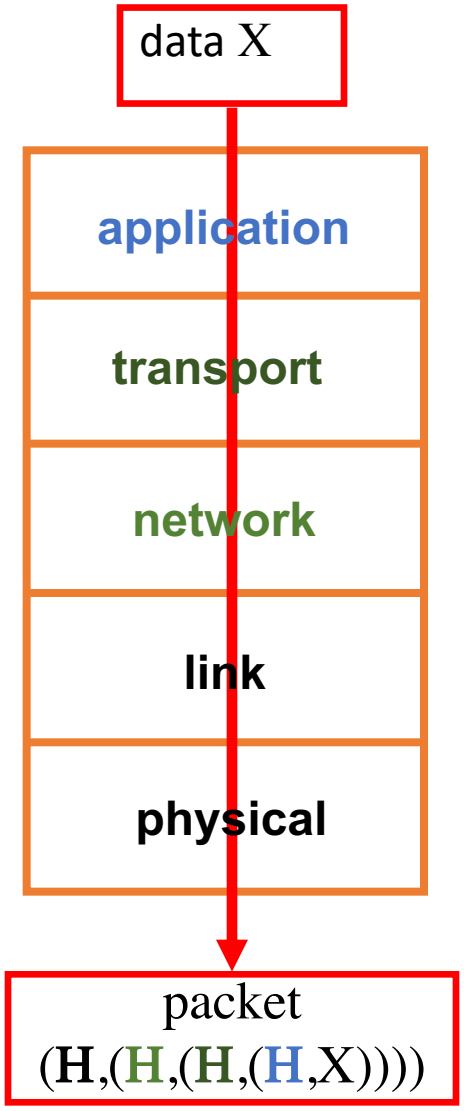
Layering in Action



- At source, data goes “down” the protocol stack
- Each router processes packet “up” to network layer
  - That’s where routing info lives
- Router then passes packet down the protocol stack
- Destination processes packet up to application layer
  - That’s where the application data lives

Encapsulation

- X = application data at source
- As X goes down protocol stack, each layer adds header information:
  - Application layer: (H, X)
  - Transport layer: (H, (H, X))
  - Network layer: (H, (H, (H, X)))
  - Link layer: (H, (H, (H, (H, X))))
- Header has info required by layer
- Note that app data is on the “inside”



Application Layer

- Applications
  - For example, Web browsing, email, P2P, etc.
  - Applications run on hosts
  - To hosts, network details should be transparent
- Application layer protocols
  - HTTP, SMTP, IMAP, Gnutella, etc., etc.
- Protocol is only one part of an application
  - For example, HTTP only a part of web browsing

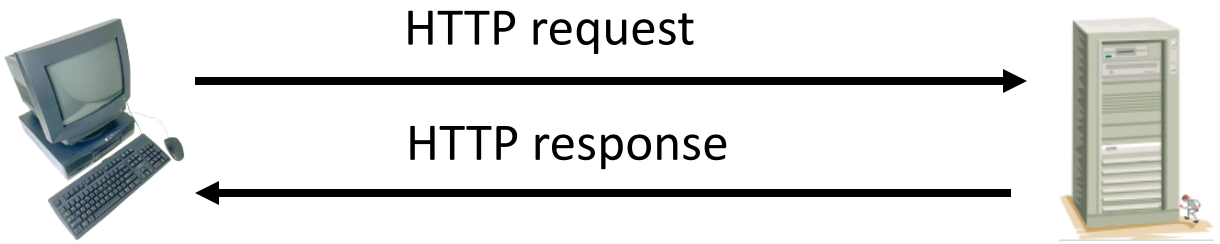
Client-Server Model

- **Client**
  - “speaks first”
- **Server**
  - responds to client’s request
- Hosts are clients or servers
- Example: Web browsing
  - You are the client (request web page)
  - Web server is the server

Peer-to-Peer Paradigm

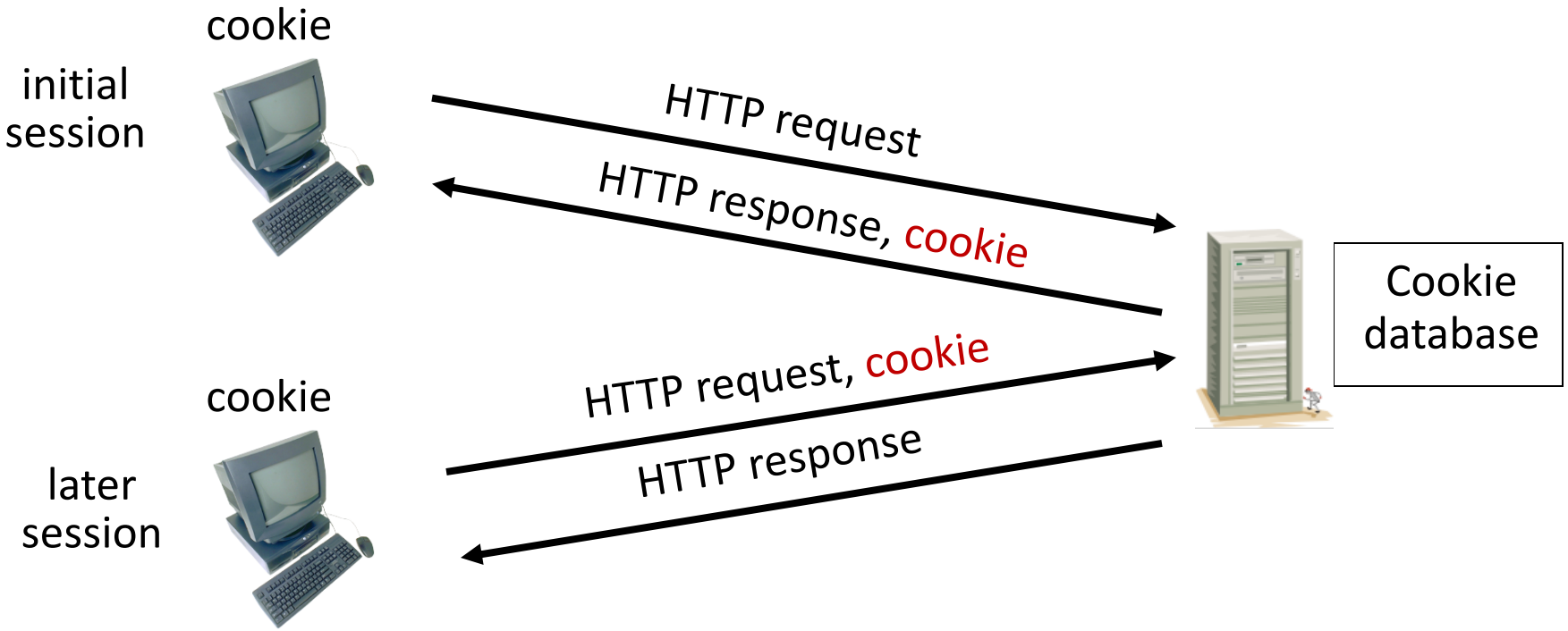
- Hosts act as clients and servers
- For example, when sharing music
  - You are client when requesting a file
  - You are a server when someone downloads a file from you
- In P2P, how does client find server?
  - Many different P2P models for this

HTTP Example



- HTTP — **H**yper**T**ext **T**ransfer **P**rotocol
- Client (you) requests a web page
- Server responds to your request

Web Cookies



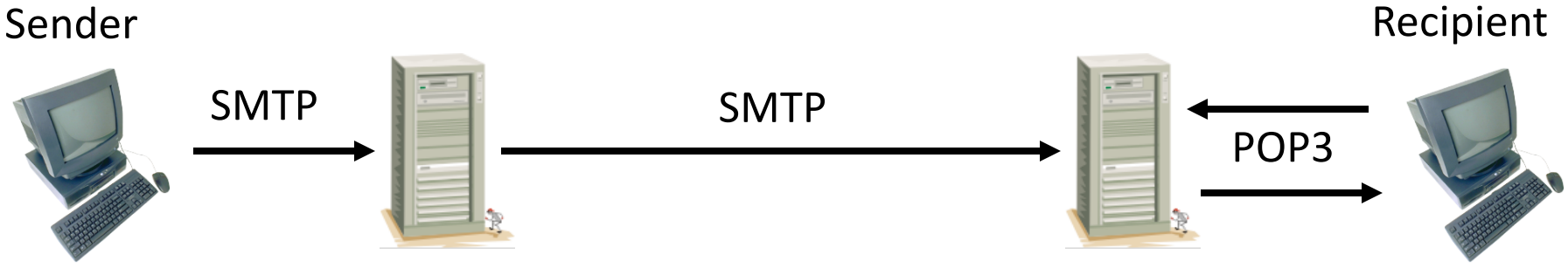
- HTTP is stateless — cookies used to add state
- Initially, cookie sent from server to browser
- Browser manages cookie, sends it to server
- Server uses cookie database to “remember” you

Web Cookies (Privacy Concerns)

- Web cookies used for…
  - Shopping carts, recommendations, etc.
  - A very (very) weak form of authentication
- Privacy concerns
  - Web site can learn a lot about you
  - Multiple web sites could learn even more

SMTP

- SMTP used to deliver email from sender to recipient's mail server
- Then POP3, IMAP or HTTP (Web mail) used to get messages from server
- As with many application protocols, SMTP commands are human readable



Spoofed email with SMTP

User types the red lines:

```
> telnet eniac.cs.sjsu.edu 25
220 eniac.sjsu.edu
HELO ca.gov
250  Hello ca.gov, pleased to meet you
MAIL FROM: <arnold@ca.gov>
250 arnold@ca.gov... Sender ok
RCPT TO: <stamp@cs.sjsu.edu>
250 stamp@cs.sjsu.edu ... Recipient ok
DATA
354 Enter mail, end with "." on a line by itself
It is my pleasure to inform you that you
are terminated
 .
250 Message accepted for delivery
QUIT
221 eniac.sjsu.edu closing connection
```

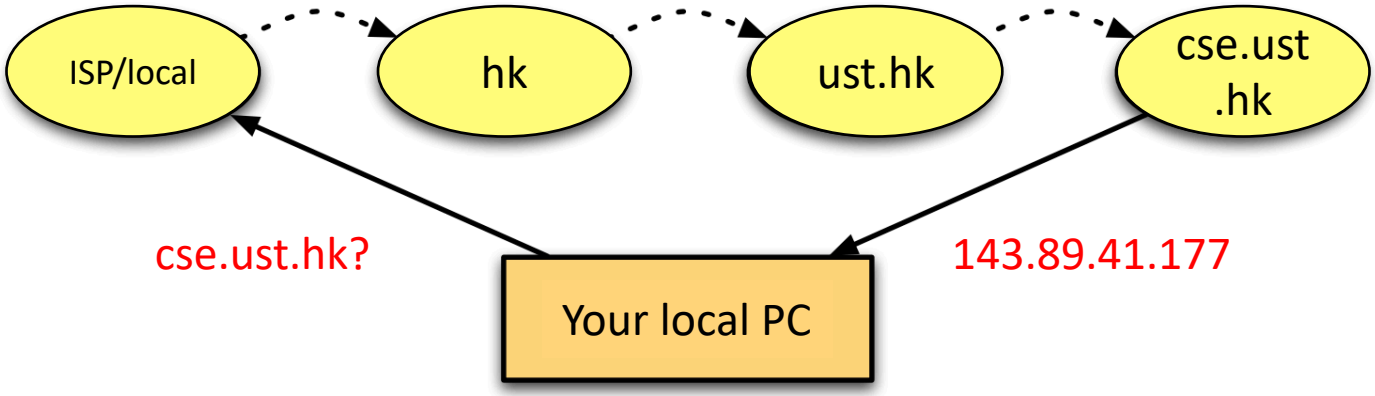
This is just a PoC, an ideal case. SMTP protocol requires more than that (depends on the implementation). Don't do this to the CSE mail server and it won't work.

Application Layer

- DNS — Domain Name Service
  - Convert human-friendly names such as www.google.com into 32-bit IP address
  - A distributed database
- Only 13 “root” DNS server clusters
  - Essentially, a single point of failure for Internet
  - Attacks on root servers have succeeded…
  - …but, attacks did not last long enough (yet)

DNS - The domain name system

- DNS maps between IP address (143.89.41.177) and domain and host names (cse.ust.hk)
  - How it works: the “root” servers redirect you to the top level domains (TLD) DNS servers, which redirect you to the appropriate sub-domain, and recursively ….
  - Note: there are 13 “root” servers that contain the info for .org, .edu, and locality specific registries



DNS Vulnerabilities (DNS Poison)

- Normally if the server does not know a requested translation it will ask another server, recursively.
  - To increase performance, a server will typically remember (cache) these translations for a certain amount of time.
- When a DNS server has received a false translation and caches it for performance optimization, it is considered poisoned, and it supplies the false data to clients.
  - If a DNS server is poisoned, it may return an incorrect IP address, diverting traffic to another computer → often the *attacker's computer*

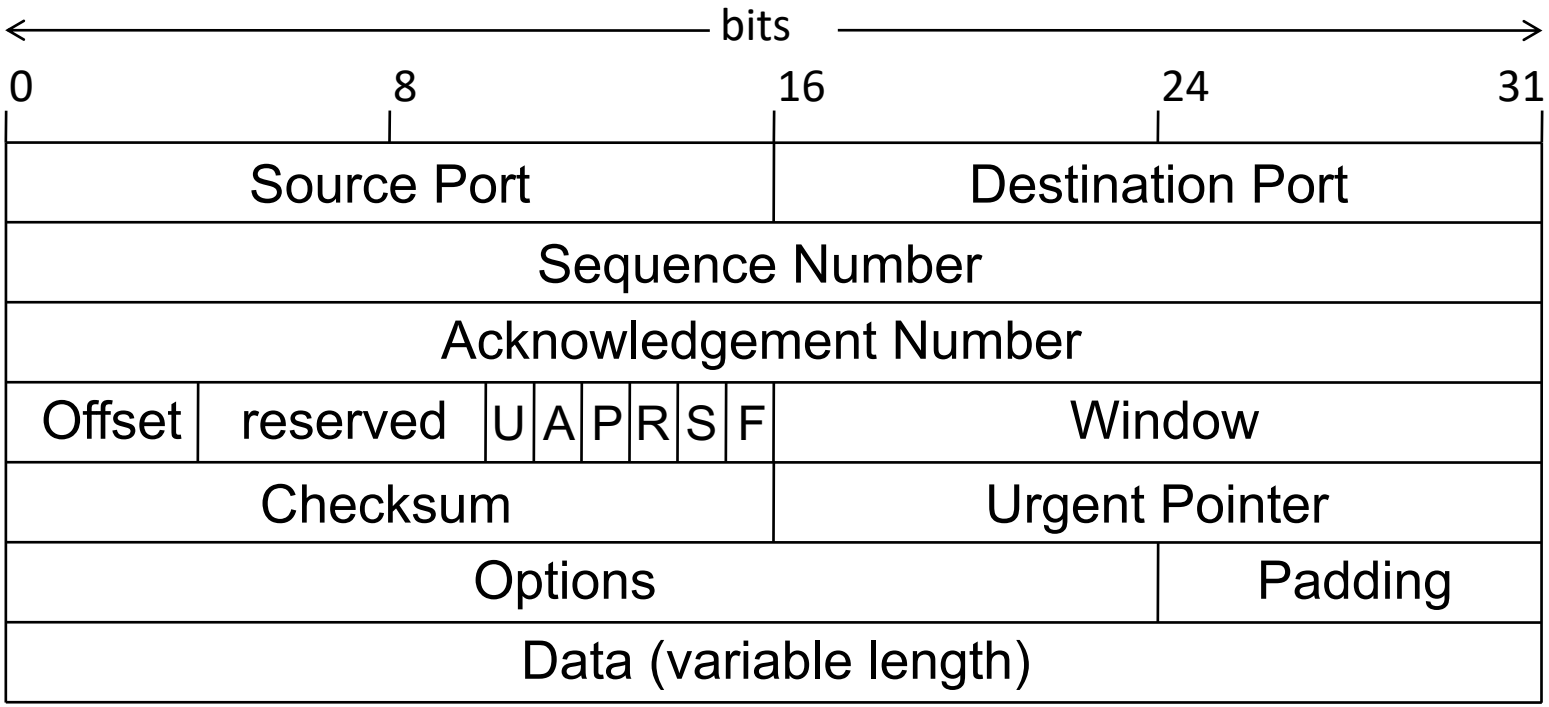
Transport Layer

- The network layer offers unreliable, "best effort" delivery of packets
- Any improved service must be provided by the hosts
- Transport layer: 2 protocols of interest
  - TCP — **more** service, **more** overhead
  - UDP — **less** service, **less** overhead

TCP

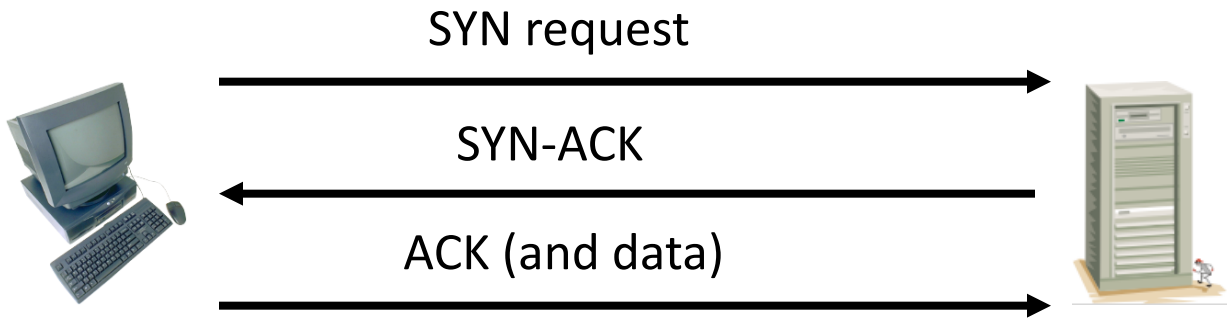
- TCP assures that packets…
  - Arrive at destination
  - Are processed in order
  - Are not sent too fast for receiver: **flow control**
- TCP is **connection-oriented**
  - TCP contacts server before sending data
  - Orderly setup and take down of “connection”
  - But no true connection, only logical “connection”

TCP Header



- Source and destination port
- Sequence number
- Flags (ACK, SYN, RST, etc.)
- Header usually 20 bytes (if no options)

TCP Three-Way Handshake



- **SYN** — synchronization requested
- **SYN-ACK** — acknowledge SYN request
- **ACK** — acknowledge SYN-ACK (send data)
- Then TCP “connection” established

Denial of Service Attack (SYN flooding)

- The TCP 3-way handshake makes denial of service (DoS) attacks possible
- Whenever SYN packet is received, server remembers this “half-open” connection
  - Remembering consumes resources
  - Too many half-open connections and server running out of memory and crashing
  - Therefore, server can’t respond to legitimate connections
- This occurs because TCP is ***stateful***

Network Layer (Internet Layer)

- Core of network/Internet
  - Interconnected mesh of routers
- Purpose of network layer
  - Route packets through this mesh
- Network layer protocol of interest is **IP**
  - Follows a **best effort** approach
- IP runs in every host and every router
- Routers also run routing protocols
  - Used to determine the path to send packets
  - Routing protocols: RIP, OSPF, BGP, …

IP Addresses

- **IP address** is 32 bits
- Every host has an IP address
- Big problem — Not enough IP addresses!
  - Lots of tricks used to extend address space
- IP addresses given in dotted decimal notation
  - For example: 195.72.180.27
  - Each number is between 0 and 255
- Usually, a host's IP address can change

Socket

- Each host has a 32 bit IP address
- But, many processes can run on one host
  - E.g., you can browse web, send email at same time
- How to distinguish processes on a host?
- Each process has a 16 bit **port number**
  - Numbers below 1024 are “well-known” ports (HTTP is port 80, POP3 is port 110, etc.)
  - Port numbers above 1024 are dynamic (as needed)
- IP address + port number = **socket**
  - Socket uniquely identifies ***process***, Internet-wide

Network Address Translation

- Network Address Translation (**NAT**)
  - Trick to extend IP address space
- Use one IP address (different port numbers) for multiple hosts
  - “Translates” outside IP address (based on port number) to inside IP address

NAT-less Example

Web server

IP: 12.0.0.1

Port: 80

source 11.0.0.1:1025
destination 12.0.0.1:80

source 12.0.0.1:80
destination 11.0.0.1:1025

Alice

IP: 11.0.0.1

Port: 1025

NAT Example

Web server

IP: 12.0.0.1

src 11.0.0.1:4000
dest 12.0.0.1:80

src 12.0.0.1:80
dest 11.0.0.1:4000

Firewall

IP: 11.0.0.1

NAT Table	
4000	192.168.0.12 :1025

src 192.168.0.12:1025
dest 12.0.0.1:80

src 12.0.0.1:80
dest 192.168.0.12:1025

Alice

IP: 192.168.0.12

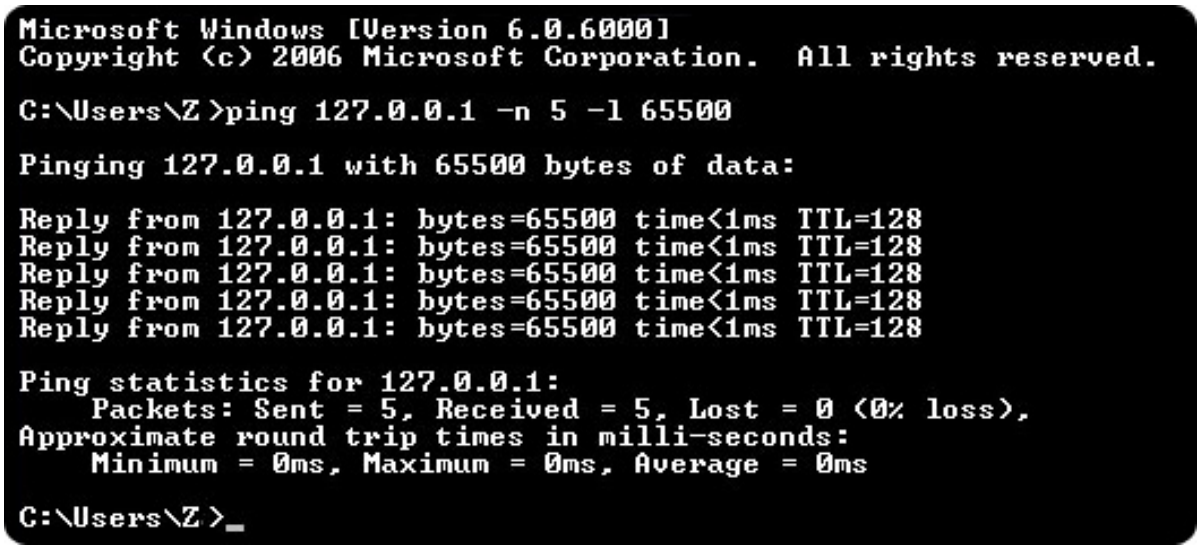
Private IP address

NAT Security

- Advantage(s)?
  - Extends IP address space
  - One (or a few) IP address(es) can be shared by many users
  - (implicitly) make the original source addresses hidden.
- Disadvantage(s)?
  - Denial-of-service attack is feasible.

Ping Attack (Ping of Death/Ping flood)

- Work by abusing the ping command
  - Ping operates by sending ICMP echo request packets to the target host and waiting for an ICMP echo reply
- A ping flood is a simple DoS attack where many attackers conspire to overwhelm victim with ICMP packets
  - But it's possible that before you PoD a host, you saturate your own bandwidth…



Link Layer

- On host, implemented in adapter: Network Interface Card (NIC)
  - Ethernet card, wireless 802.11 card, etc.
  - NIC is “semi-autonomous” device
- NIC is (mostly) out of host’s control
  - Implements both link and physical layers

Link Layer Addressing

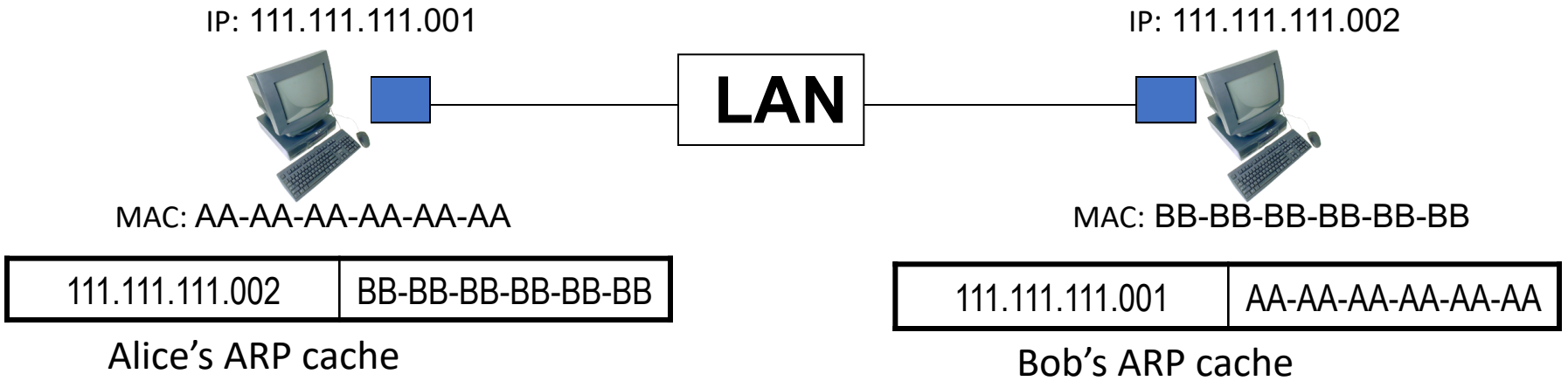
- IP addresses live at network layer
- Link layer also needs addresses
  - **MAC address** (LAN address, physical address)
- MAC address
  - 48 bits, globally unique
  - Used to forward packets over one link
- Analogy…
  - IP address is like your home address
  - MAC address is like a social security number

ARP

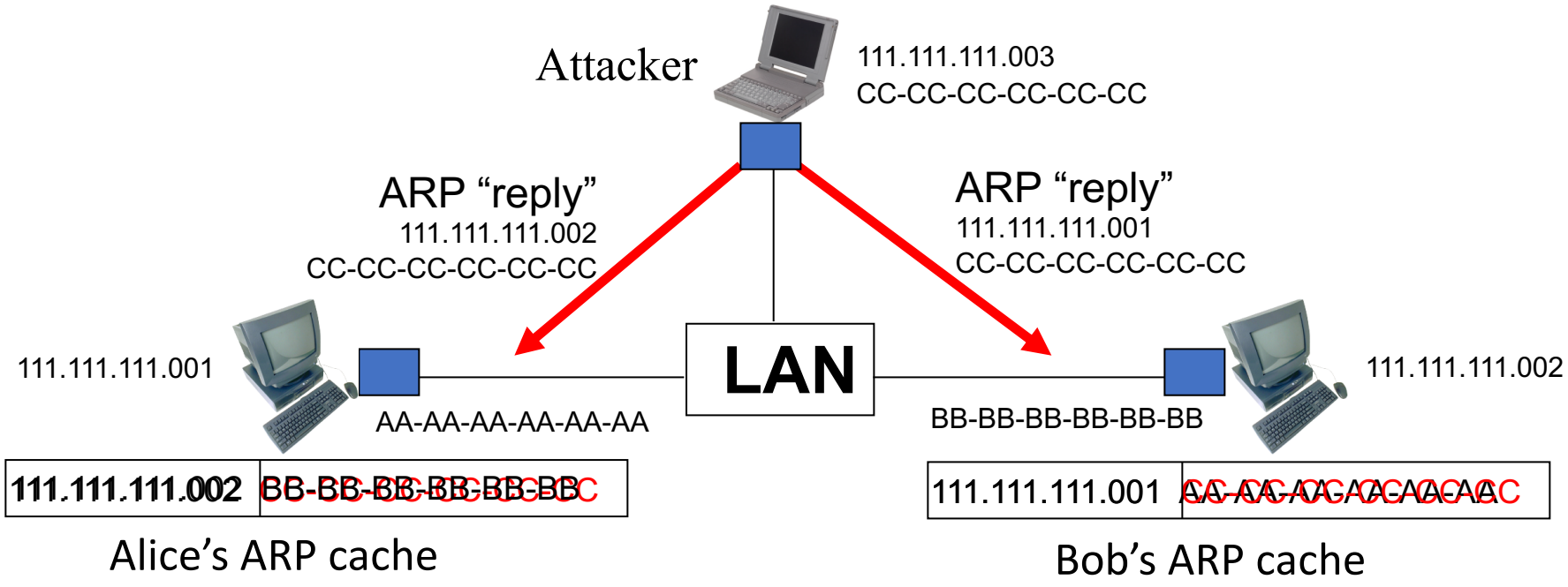
- Address Resolution Protocol (ARP)
- Used by link layer — given IP address, find corresponding MAC address
- Each host has ARP table, or **ARP cache**
  - Generated automatically
  - Entries expire after some time (about 20 min)
  - ARP used to find ARP table entries

ARP

- ARP is ***stateless***
- ARP can send **request** and receive **reply**
- Reply msgs used to fill/update ARP cache



ARP Cache Poisoning



- Host CC-CC-CC-CC-CC-CC is man-in-the-middle