CSC358 Week 11

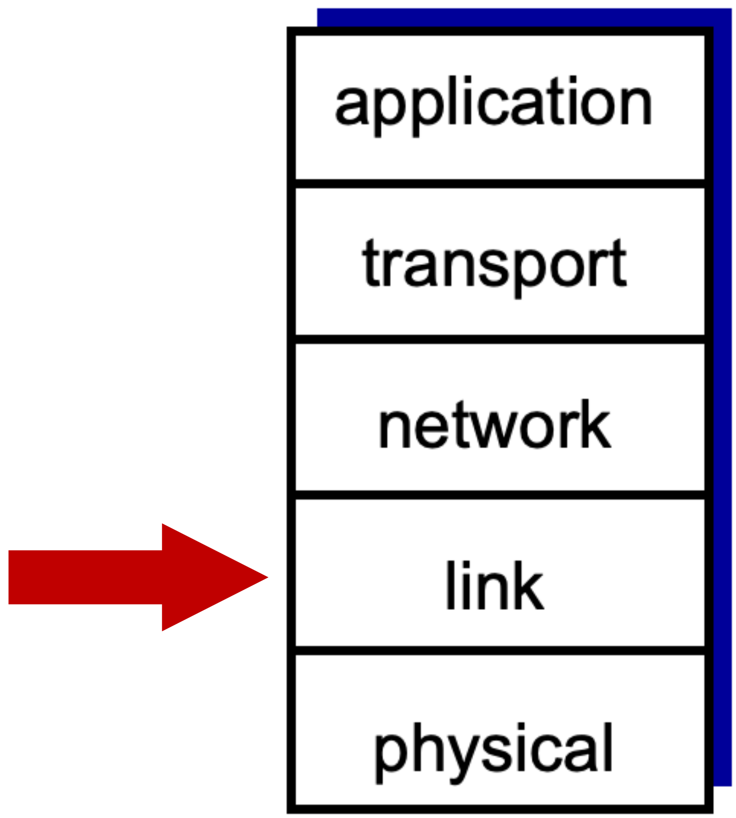
Logistics

- Exam
  - online exam (Quercus Quiz) at the originally scheduled exam time (Apr 13th, 9 am – 12 pm EST)
  - We will provide detailed exam instructions beforehand as well as a mock practice exam
  - more information next week
- Next week's lecture:
  - finishing up topics
  - exam review
- There are still tutorials this week and next.

Communication Protocol

- All students’ audio is muted by default.
- You may ask questions using Chat. Chat messages will be anonymized in the recording.
- If you’d like to ask a question by speaking, click on “raise your hand”, the instruction may assign you at a presenter, then your audio will be heard by the class.
- The instructor may miss your raised hand from time to time when they stare at their presentation. Apologies ahead.

We are here



Link layer, LANs: outline

6.1 introduction, services

6.2 error detection, correction

6.3 multiple access protocols

6.4 LANs

- addressing, ARP
- Ethernet
- **switches**
- **VLANS**

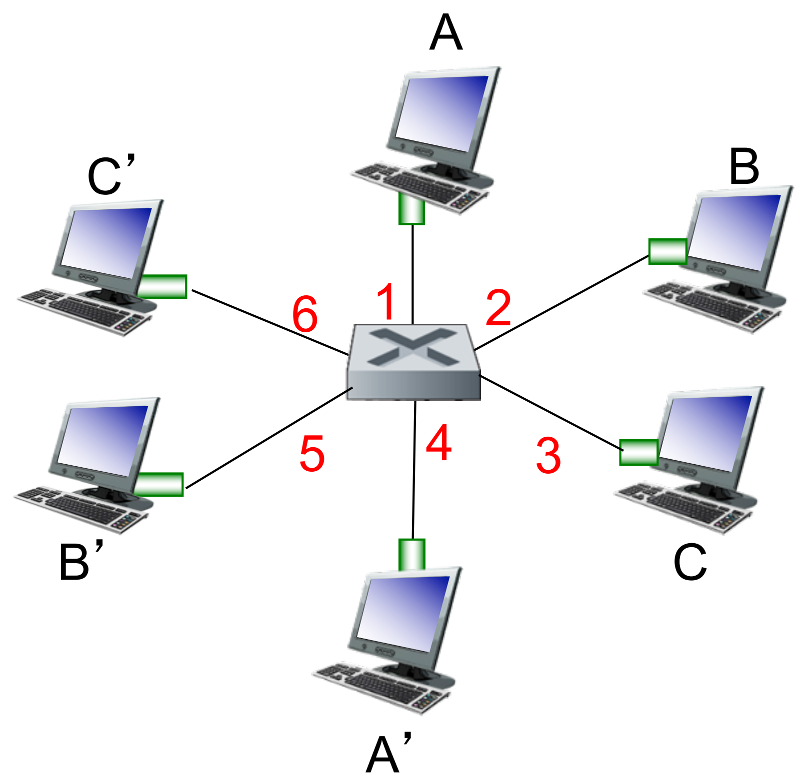
Ethernet switch

- link-layer device: takes an *active* role
  - store, forward Ethernet frames
  - examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses CSMA/CD to access segment
  - compared to traditional ***hubs*** that simply transmit the bits at the physical layer.
- *transparent*
  - hosts are unaware of presence of switches
- *plug-and-play, self-learning*
  - switches do not need to be configured

switch
splitter
hub
NETGEAR
ProSafe 5 Port Gigabit Switch
NETGEAR
Gigabit
Ethernet
Power
1
2
3
4
5
Ethernet Hub
EN 104

Switch: *multiple* simultaneous transmissions

- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex
  - each link is its own collision domain
- *switching:* A-to-A' and B-to-B' can transmit simultaneously, without collisions

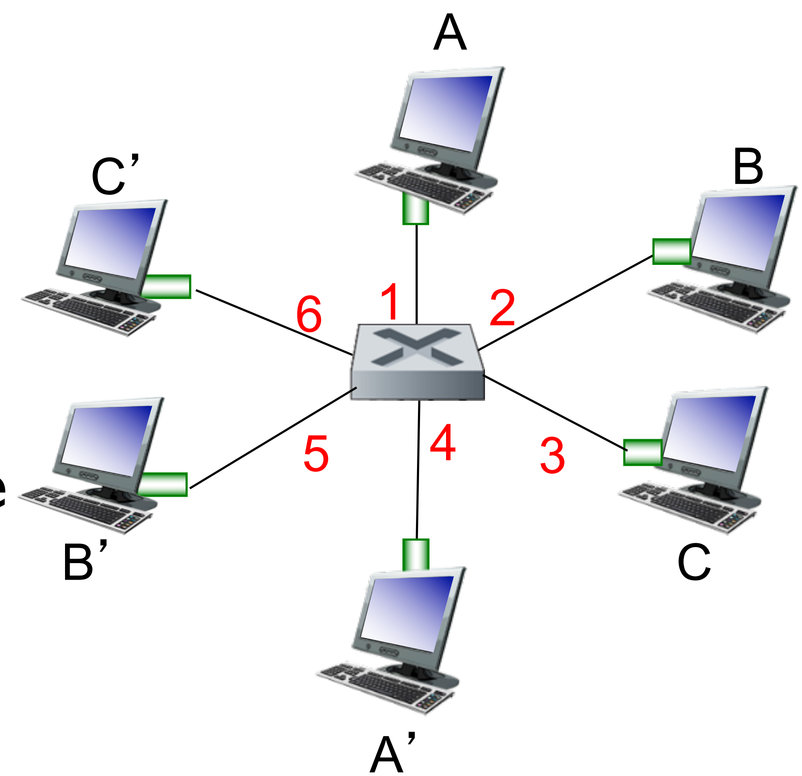


switch with six interfaces (1,2,3,4,5,6)

Switch forwarding table

Q: how does switch know A' reachable via interface 4, B' reachable via interface 5?

- *A:* each switch has a switch table, each entry:
  - (MAC address of host, interface to reach host, time stamp)
  - looks like a routing table!



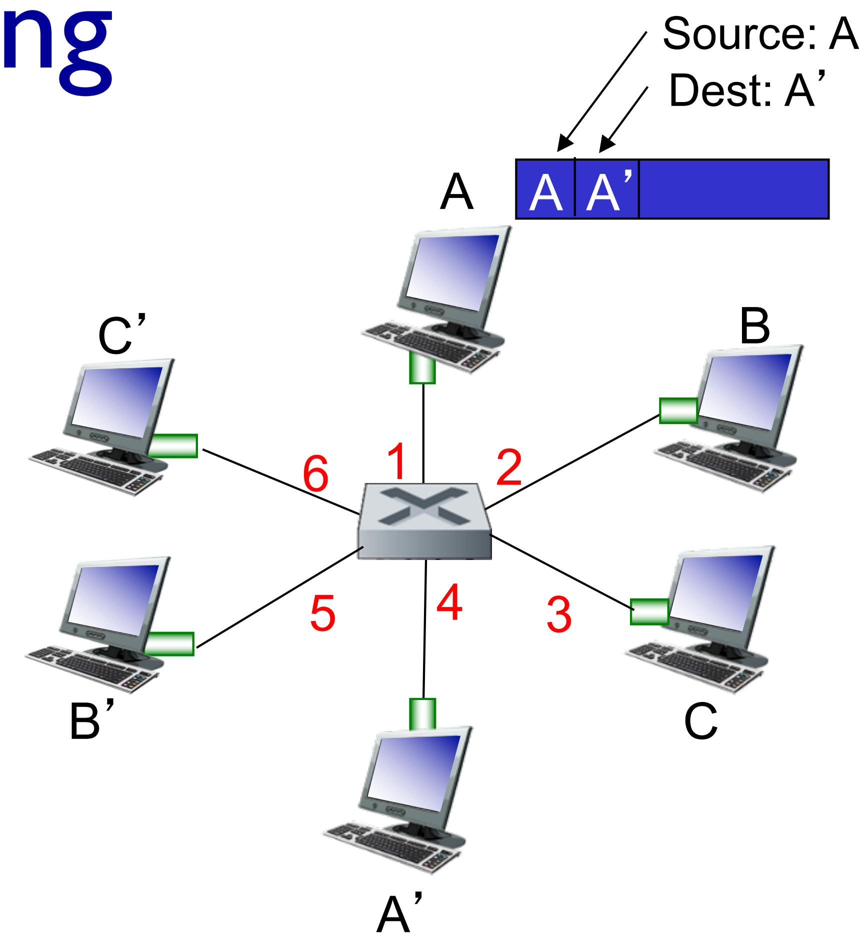
switch with six interfaces (1,2,3,4,5,6)

Q: how are entries created, maintained in switch table?

- something like a routing protocol?

Switch: self-learning

- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table



MAC addr	interface	TTL
A	*1*	*60*

Switch table (initially empty)

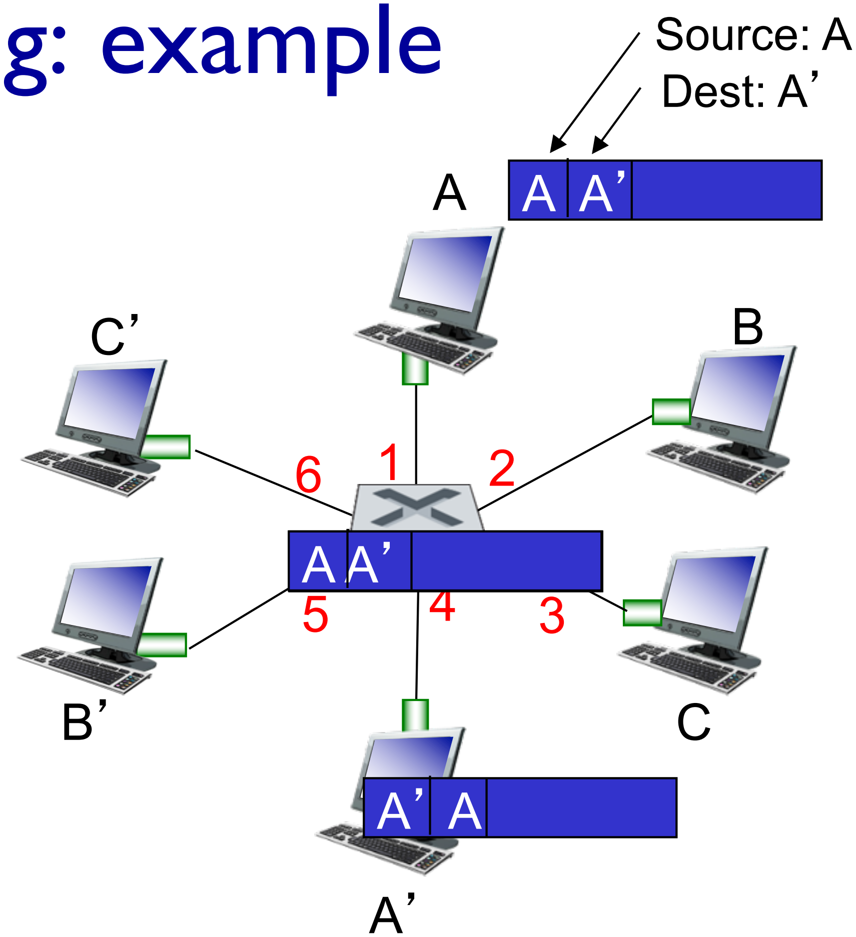
Switch: frame filtering/forwarding

when frame received at switch:

1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination
   then {
     if destination on segment from which frame arrived
     then drop frame
     else forward frame on interface indicated by entry
   }
   else
     flood /* forward on all interfaces except arriving
                  interface */

Self-learning, forwarding: example

- frame destination, A', location unknown: *flood*
- destination A location known: selectively send on just one link

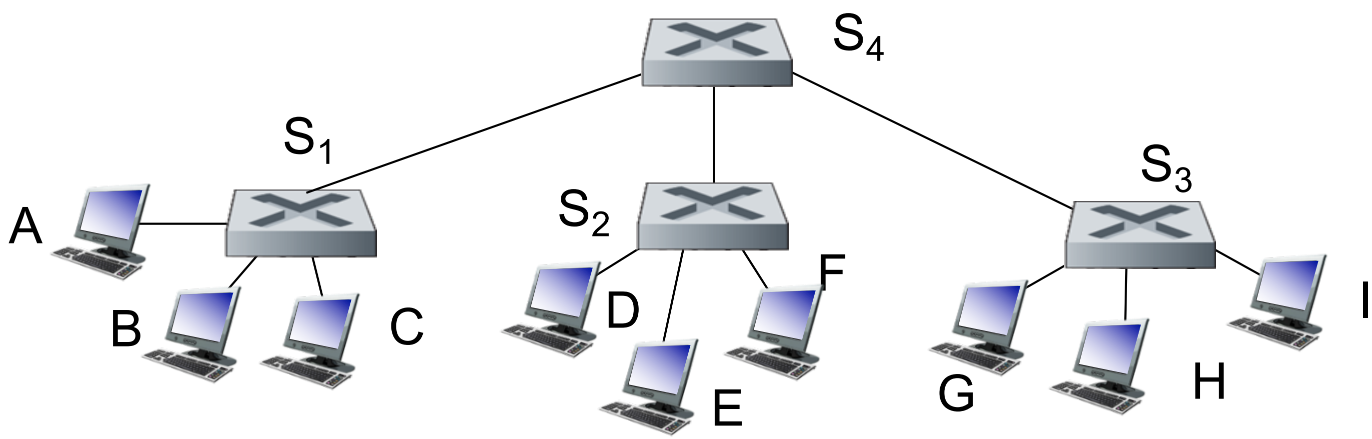


MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

Interconnecting switches

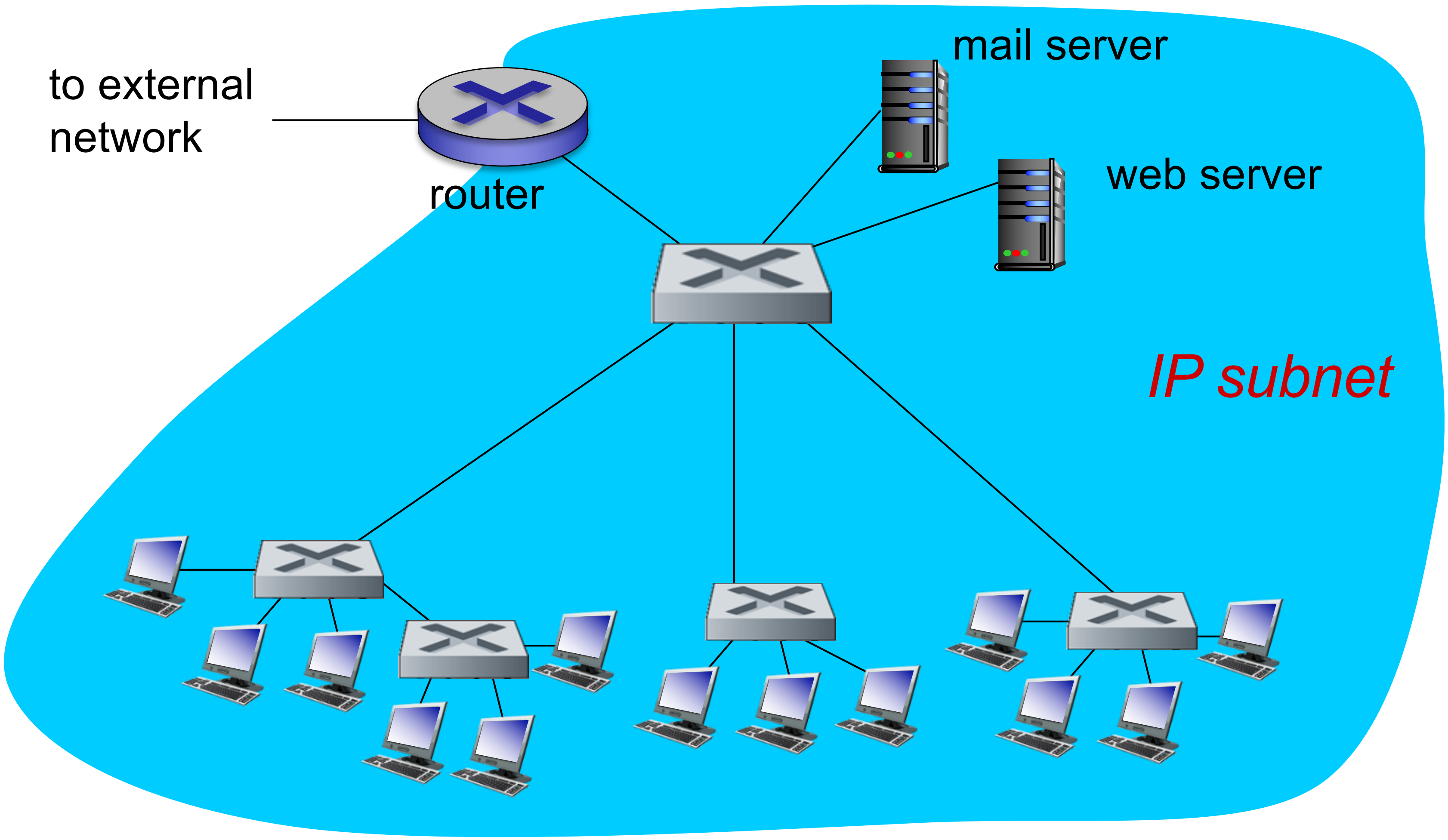
self-learning switches can be connected together:



Q: sending from A to G - how does S_1 know to forward frame destined to G via S_4 and S_3?

- *A:* self learning! (works exactly the same as in single-switch case!)

Institutional network



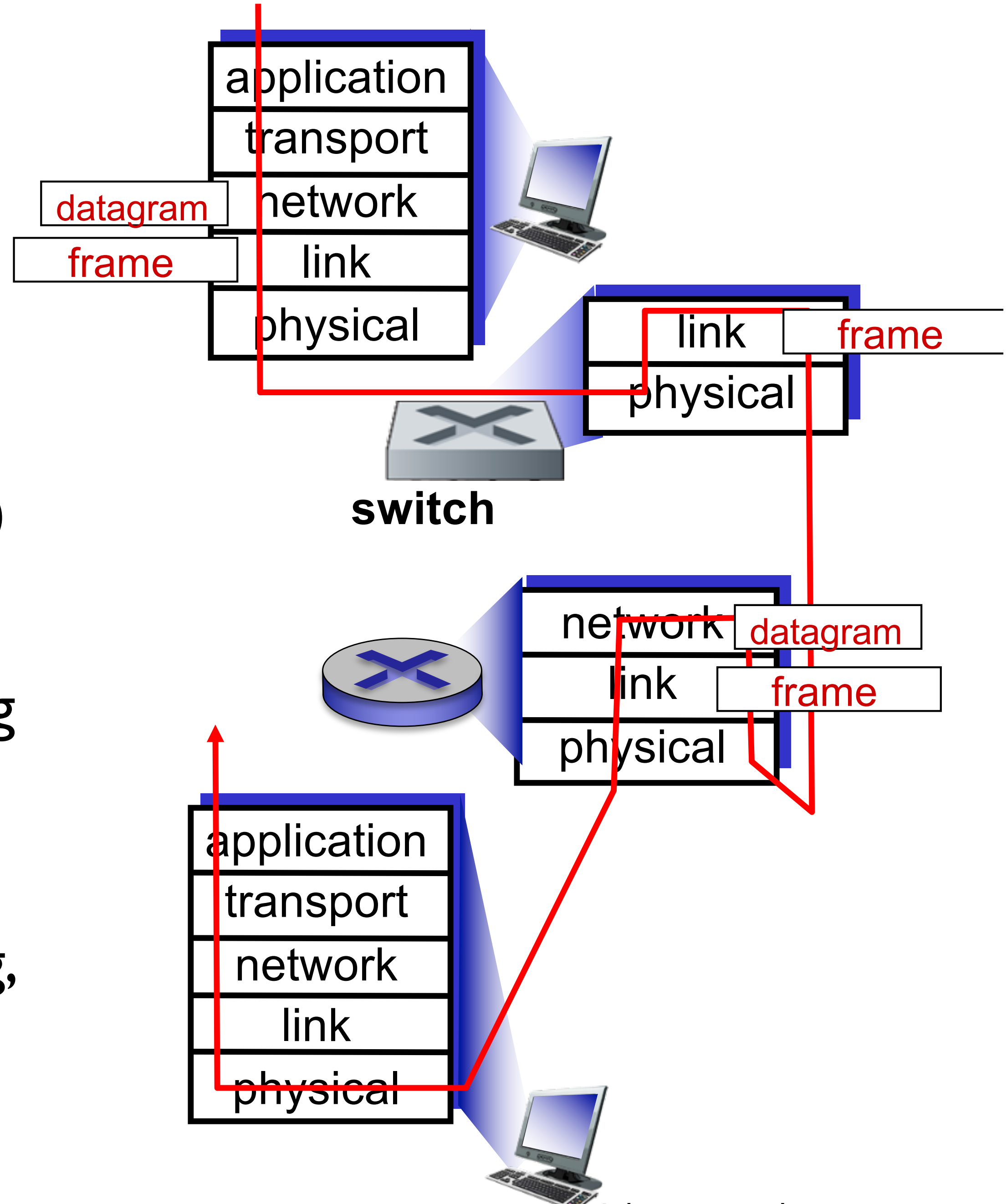
Switches vs. routers

both are store-and-forward:

- *routers:* network-layer devices (examine network-layer headers)
- *switches*: link-layer devices (examine link-layer headers)

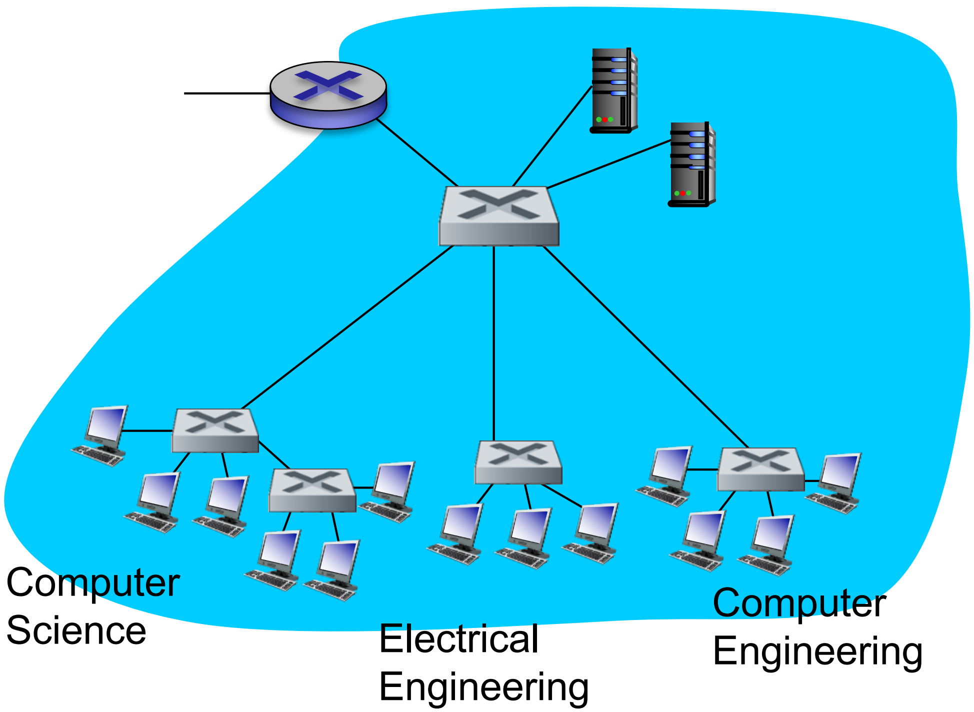
both have forwarding tables:

- *routers:* compute tables using routing algorithms, IP addresses
- *switches:* learn forwarding table using flooding, learning, MAC addresses



VLAN

VLANs: motivation



consider:

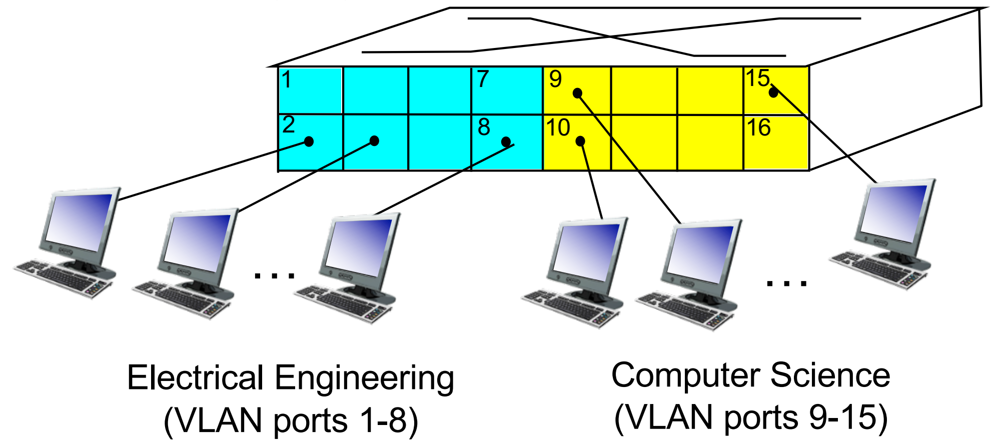
- CS user moves office to EE, but wants connect to CS switch?
- single broadcast domain:
  - all layer-2 broadcast traffic (ARP, DHCP, unknown location of destination MAC address) must cross entire LAN
  - security/privacy, efficiency issues

VLANs

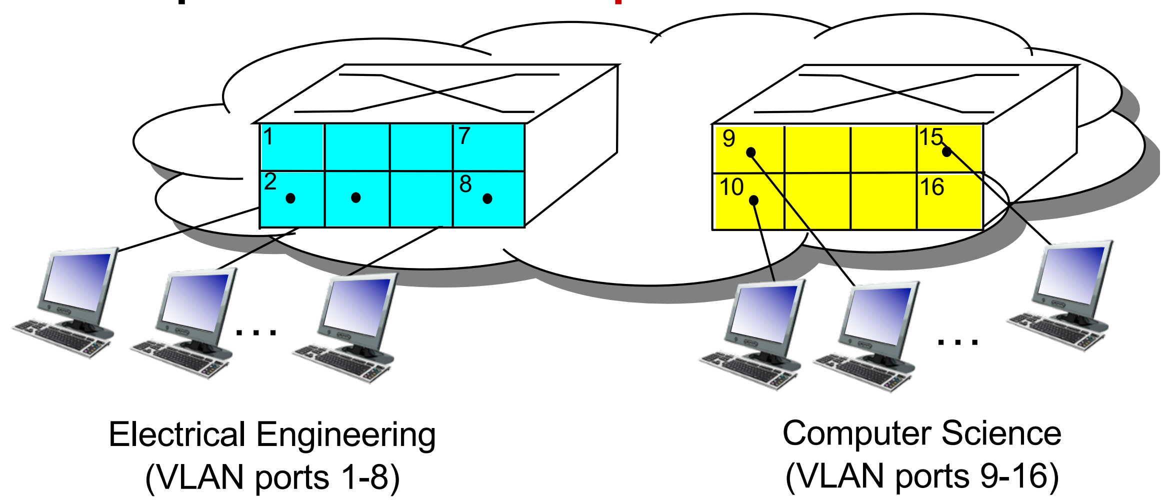
Virtual Local Area Network

switch(es) supporting VLAN capabilities can be configured to define multiple ***virtual*** LANS over single physical LAN infrastructure.

port-based VLAN: switch ports grouped (by switch management software) so that *single* physical switch ……

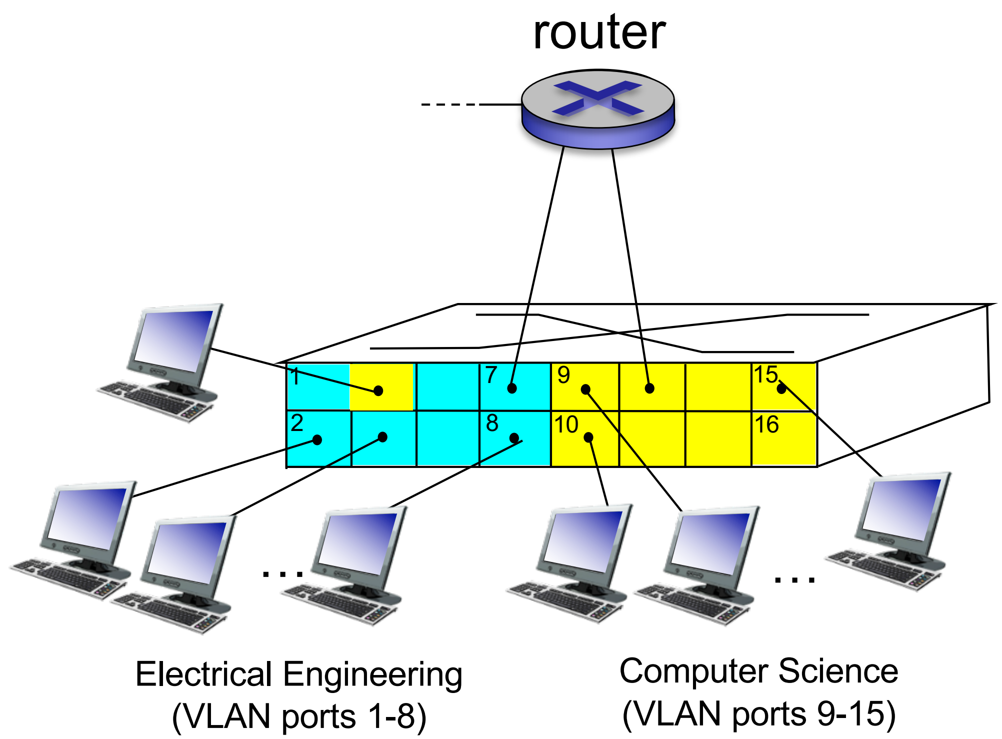


… operates as multiple virtual switches



Port-based VLAN

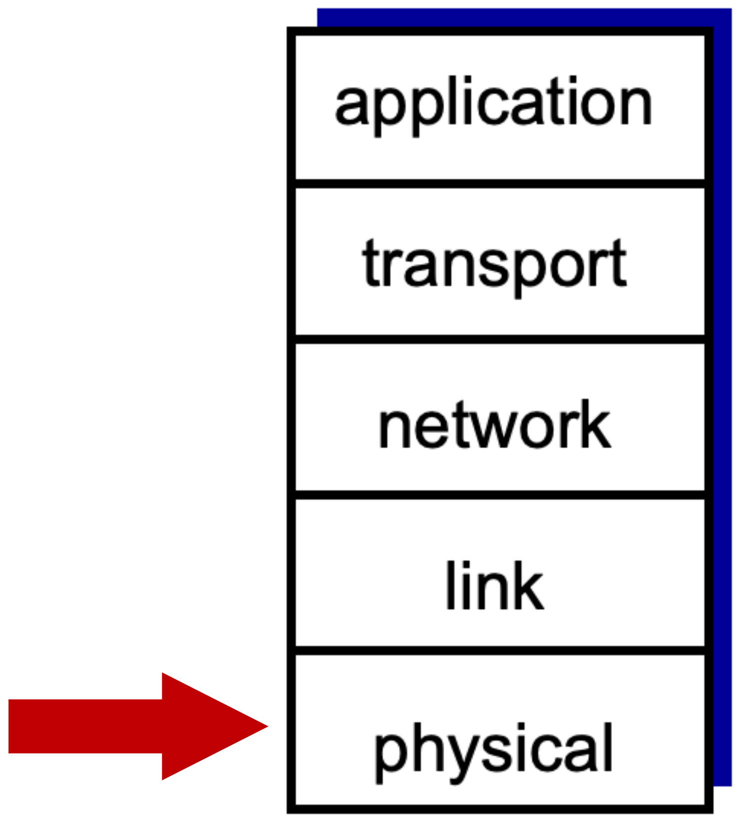
- *traffic isolation:* frames to/from ports 1-8 can *only* reach ports 1-8
  - can also define VLAN based on MAC addresses of endpoints, rather than switch port
- dynamic membership: ports can be dynamically assigned among VLANs
- forwarding between VLANS: done via routing (just as with separate switches)
  - in practice vendors sell combined switches plus routers



Link Layer Summary

- principles behind data link layer services:
  - error detection, correction
  - sharing a broadcast channel: multiple access
  - link layer addressing
- instantiation and implementation of various link layer technologies
  - Ethernet
  - switched LANS, VLANs

Going deeper: Physical Layer!!



Physical Layer Outline

1. Network Interface Card
   - Circuit Theory
2. Twisted pair
   - Electromagnetism
     - The Maxwell equations
   - Signal processing
   - Fourier transform; Laplace tra
3. Optic
   - O
   - O
   - Material science: fluoride glass, phosphate glass, chalcogenide glass
4. USB
   - connectors
   - cabling
   - power

Too many things going on at the physical layer, so we'll skip most of these.

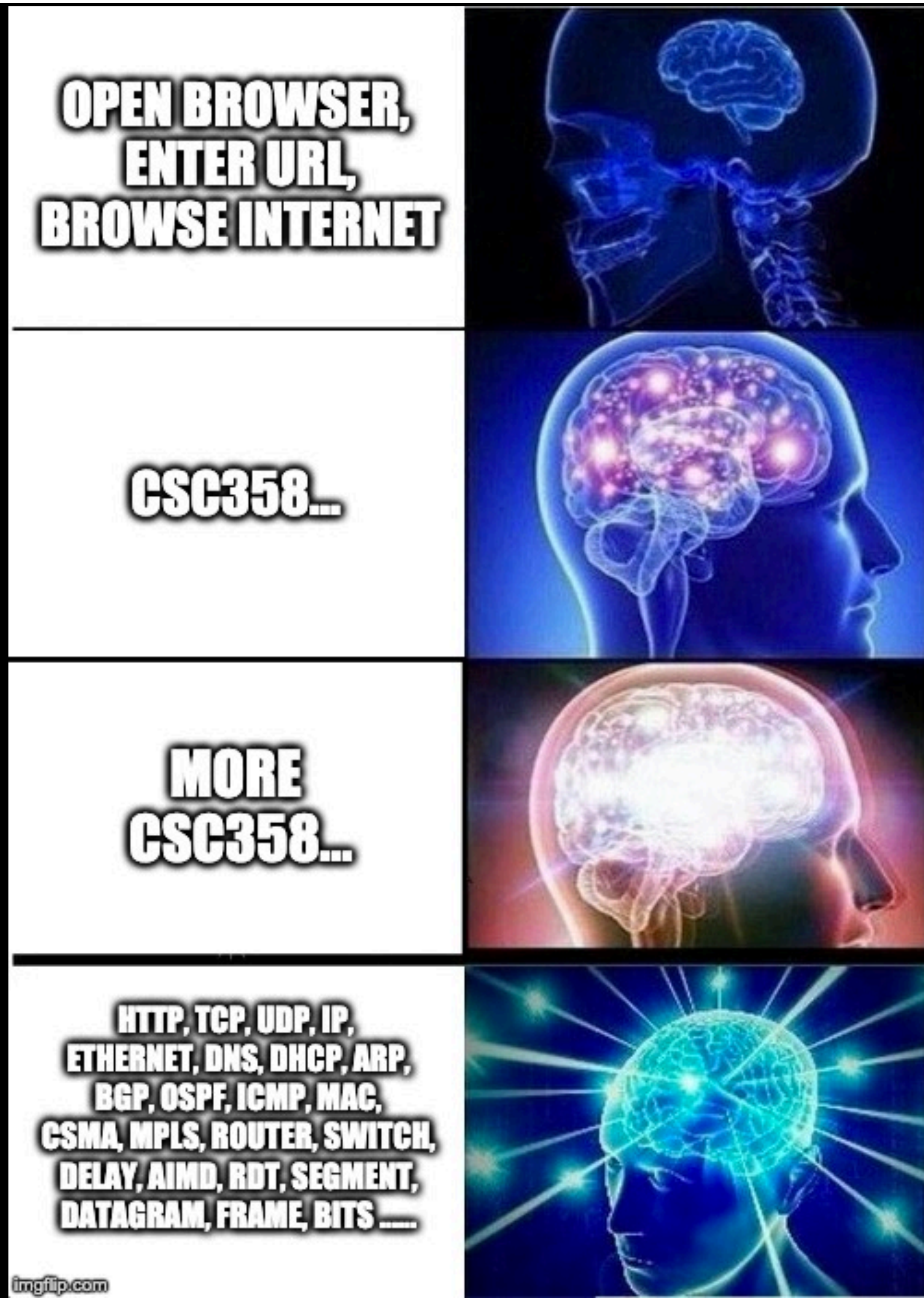
4. Wireless
   - Radio theory
   - Antenna
   - Modulation
   - Resonance
5. Bluetooth
   - Link manager

   n

   l antennas,

   - GSM, GPRS, 3G, LTE, 5G
7. Information Theory
   - Shannon's theorem
   - Entropy
8. Quantum communication
   - Quantum mechanics
   - Quantum information theory
   - Quantum teleportation

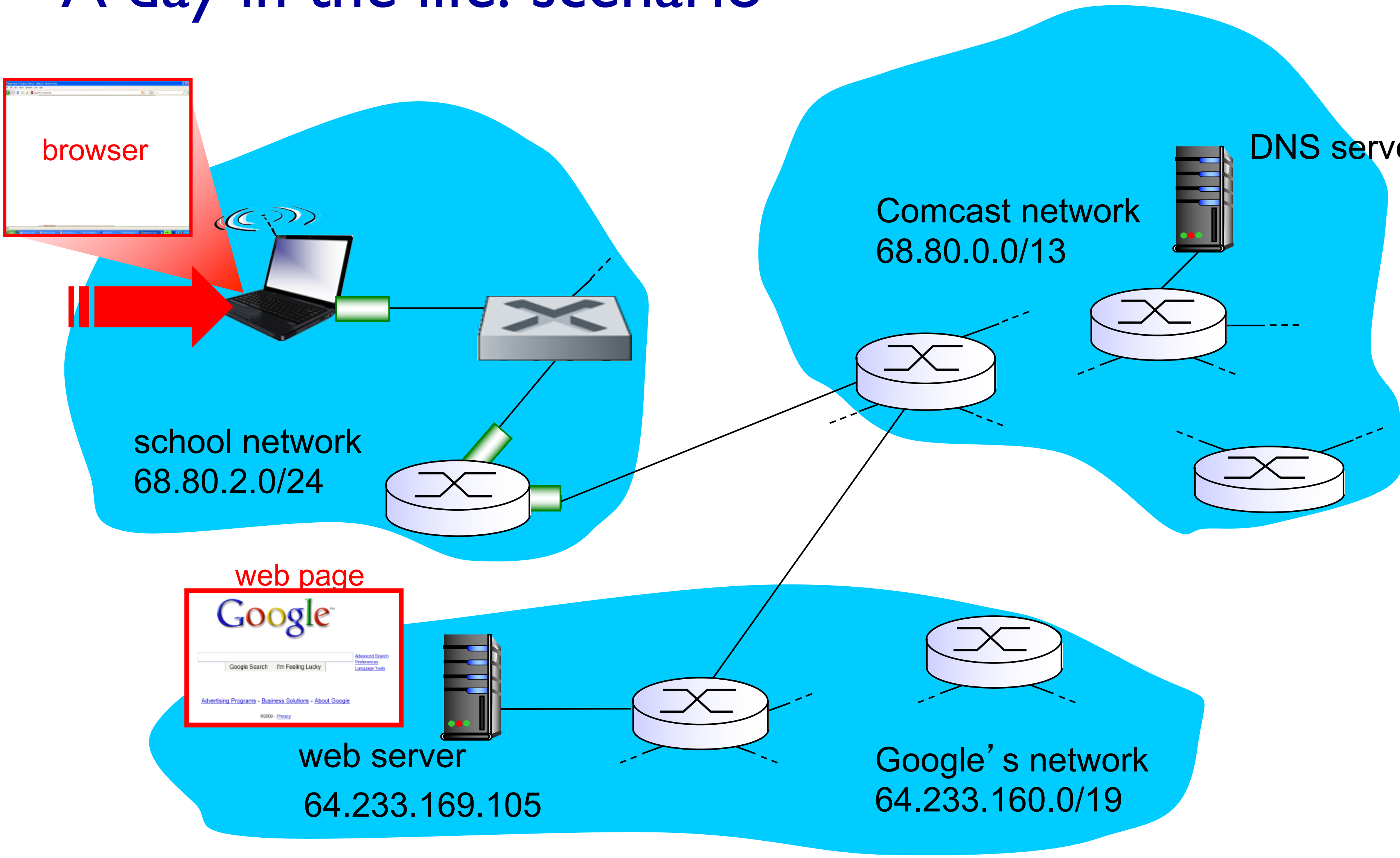
Synthesis:
A Day in the Life of a Web Request


OPEN BROWSER, ENTER URL, BROWSE INTERNET
CSC358...
MORE CSC358...
HTTP, TCP, UDP, IP, ETHERNET, DNS, DHCP, ARP, BGP, OSPF, ICMP, MAC, CSMA, MPLS, ROUTER, SWITCH, DELAY, AIMD, RDT, SEGMENT, DATAGRAM, FRAME, BITS ......
imgflip.com

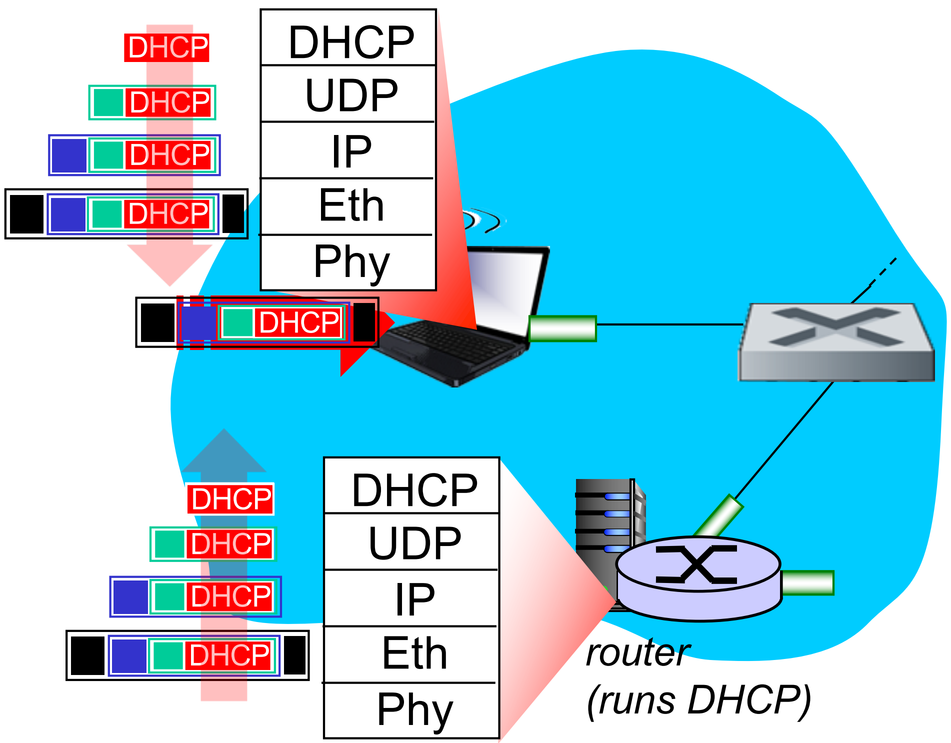
Synthesis: a day in the life of a web request

- journey down protocol stack complete!
  - application, transport, network, link
- putting-it-all-together: synthesis!
  - *goal:* identify, review, understand protocols (at all layers) involved in seemingly simple scenario: requesting www page
  - *scenario:* student attaches laptop to campus network, requests/receives www.google.com

A day in the life: scenario

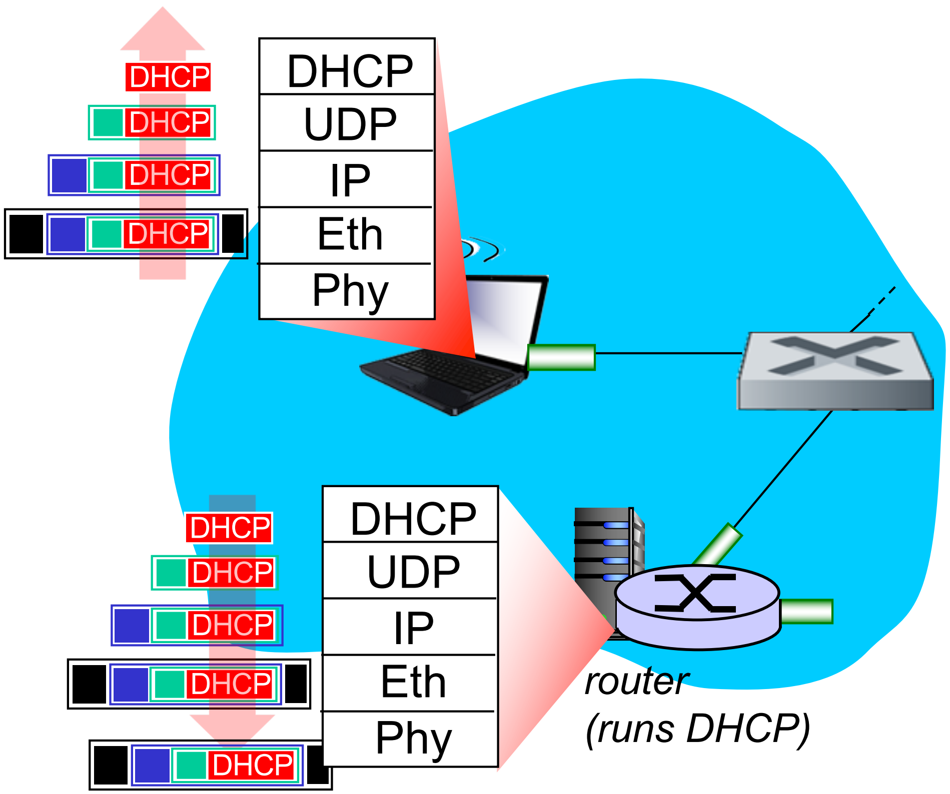


A day in the life… connecting to the Internet



- connecting laptop needs to get its own IP address, addr of first-hop router, addr of DNS server: use *DHCP*
- DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in 802.3 Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
- Ethernet demuxed to IP demuxed, UDP demuxed to DHCP

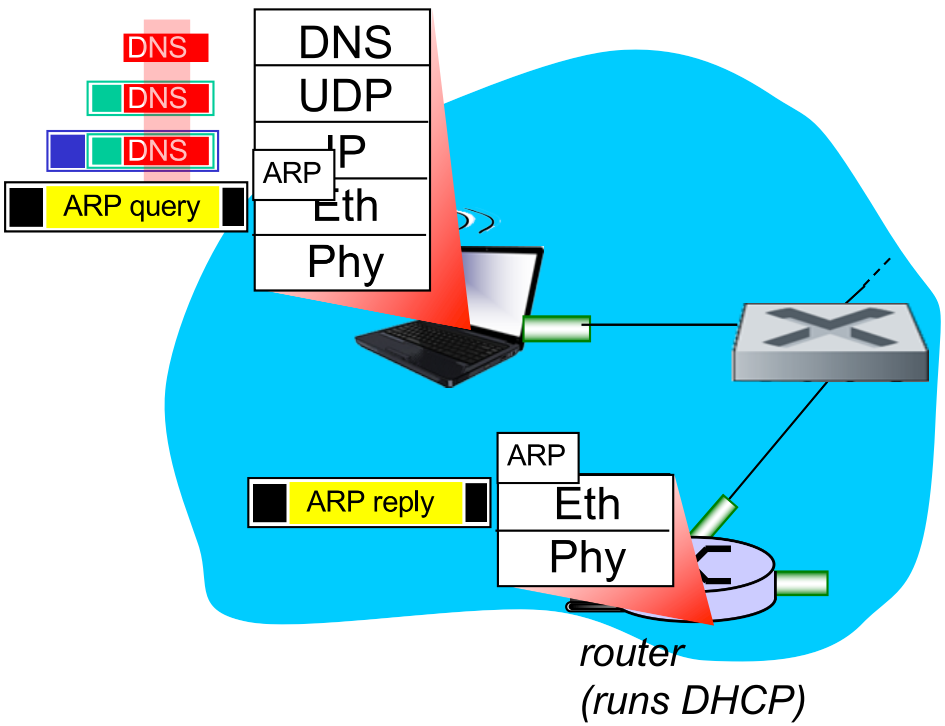
A day in the life… connecting to the Internet



- DHCP server formulates *DHCP ACK* containing client' s IP address, IP address of first-hop router for client, name & IP address of DNS server
- encapsulation at DHCP server, frame forwarded (switch learning) through LAN, demultiplexing at client
- DHCP client receives DHCP ACK reply

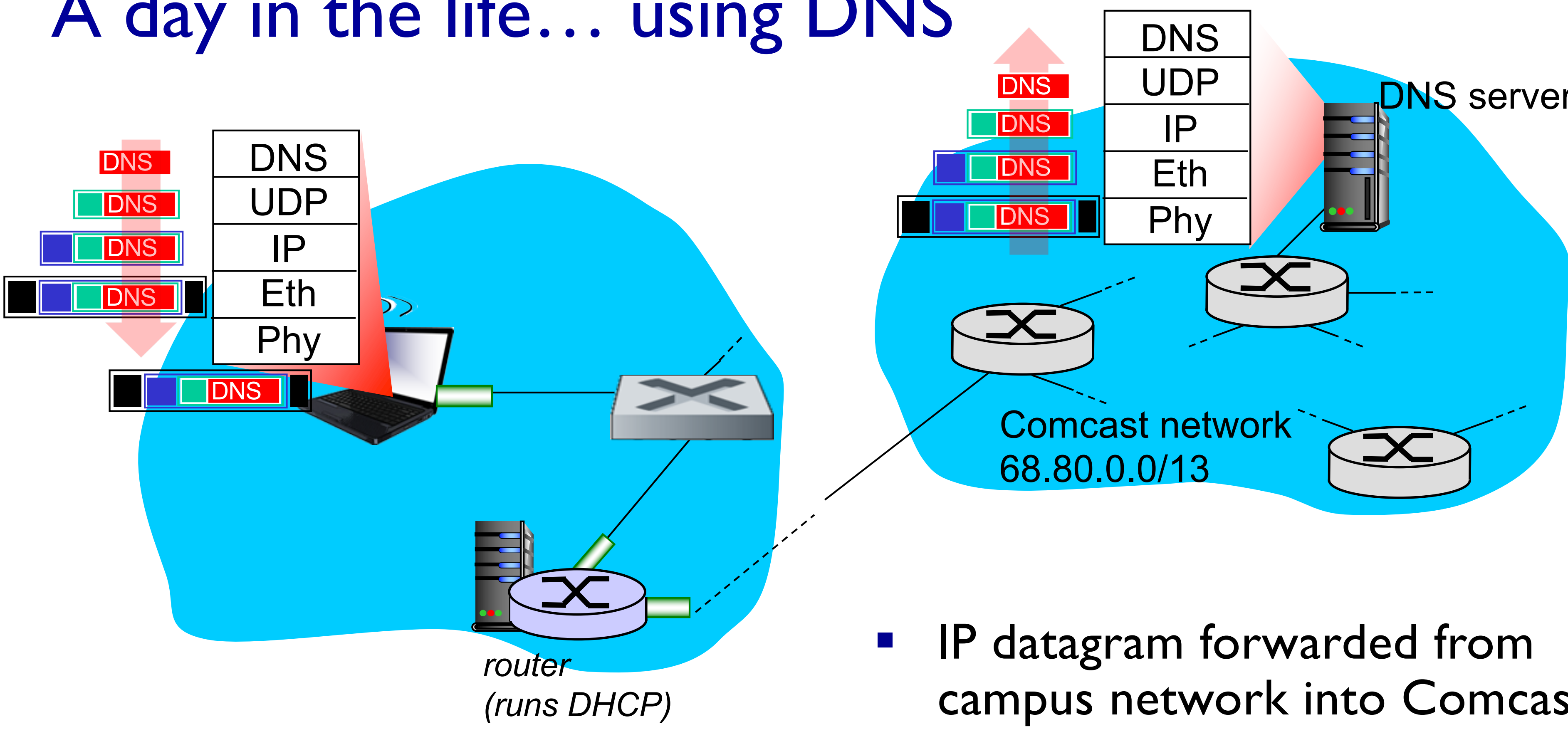
Client now has IP address, knows name & addr of DNS server, IP address of its first-hop router

A day in the life… ARP (before DNS, before HTTP)



- before sending *HTTP* request, need IP address of www.google.com: *DNS*
- DNS query created, encapsulated in UDP, encapsulated in IP, encapsulated in Eth. To send frame to router, need MAC address of router interface: ARP
- ARP query broadcast, received by router, which replies with ARP reply giving MAC address of router interface
- client now knows MAC address of first hop router, so can now send frame containing DNS query

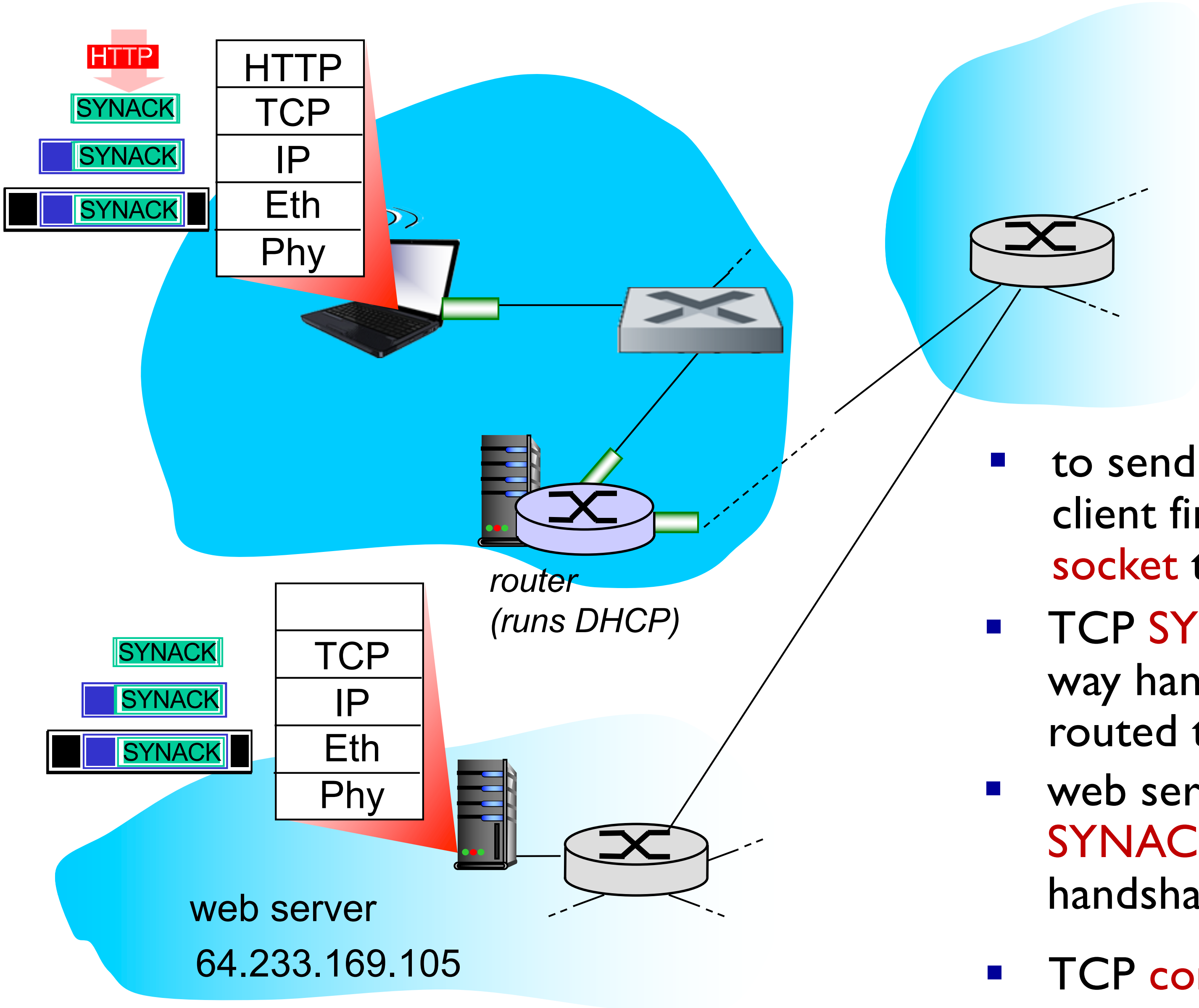
A day in the life… using DNS



- IP datagram containing DNS query forwarded via LAN switch from client to 1st hop router

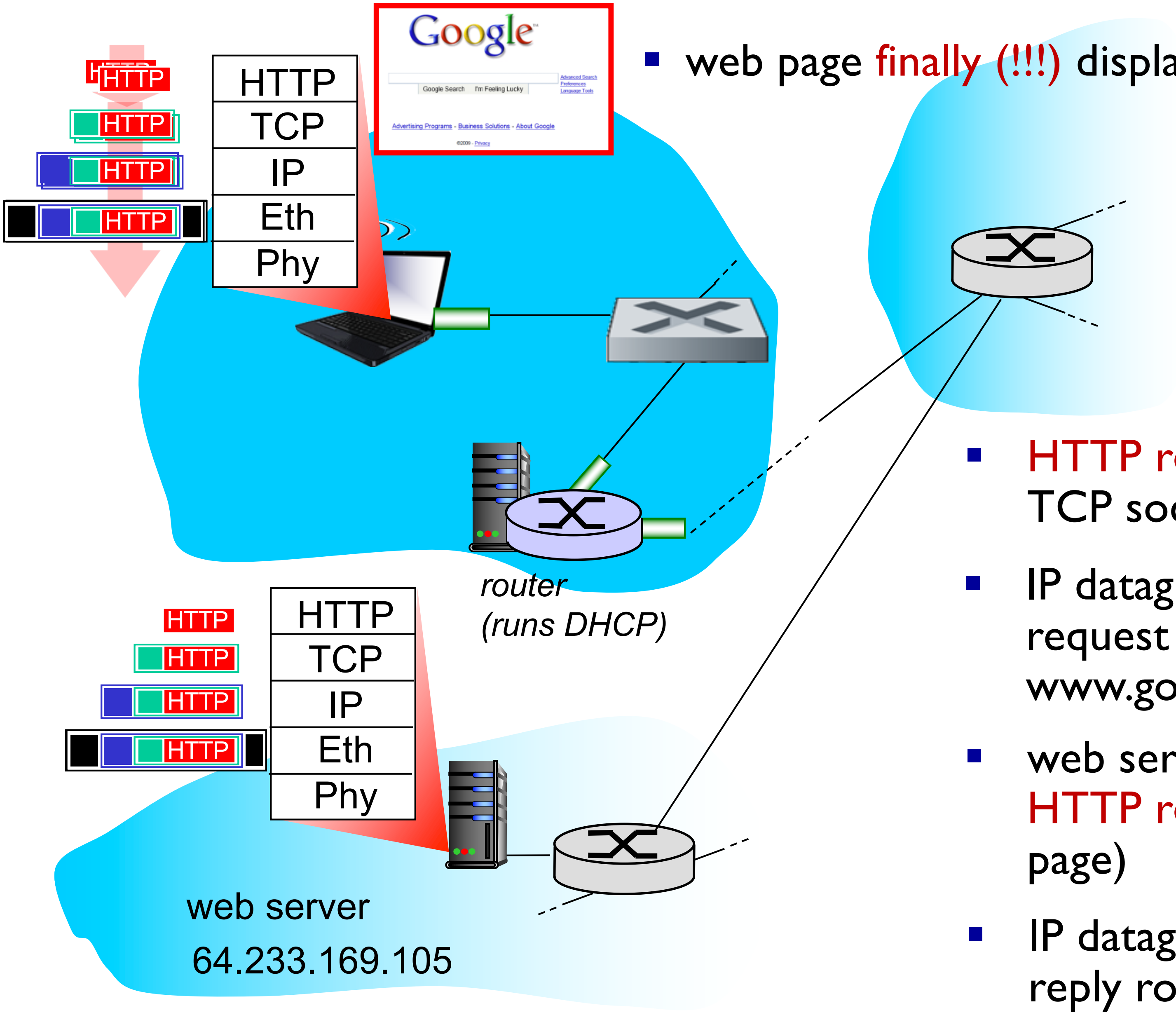
- IP datagram forwarded from campus network into Comcast network, routed (tables created by RIP, OSPF, IS-IS and/or BGP routing protocols) to DNS server
- demuxed to DNS server
- DNS server replies to client with IP address of www.google.com

A day in the life…TCP connection carrying HTTP



- to send HTTP request, client first opens TCP socket to web server
- TCP SYN segment (step 1 in 3-way handshake) inter-domain routed to web server
- web server responds with TCP SYNACK (step 2 in 3-way handshake)
- TCP connection established!

A day in the life… HTTP request/reply



- web page finally (!!!) displayed

- HTTP request sent into TCP socket
- IP datagram containing HTTP request routed to www.google.com
- web server responds with HTTP reply (containing web page)
- IP datagram containing HTTP reply routed back to client

Next Topic

One more thing:

Wireless and Mobile Network

Wireless and Mobile Networks

Background:

- # wireless (mobile) phone subscribers now exceeds # wired phone subscribers (5-to-1)!
- # wireless Internet-connected devices equals # wireline Internet-connected devices
  - laptops, Internet-enabled phones promise anytime untethered Internet access
- two important (but different) challenges
  - *wireless:* communication over wireless link
  - *mobility:* handling the mobile user who changes point of attachment to network

Outline

7.1 Introduction

Wireless

7.2 Wireless links, characteristics

6.73 IEEE 802.11 wireless LANs ("Wi-Fi")

67.4 Cellular Internet Access

- architecture
- standards (e.g., 3G, LTE)

Mobility

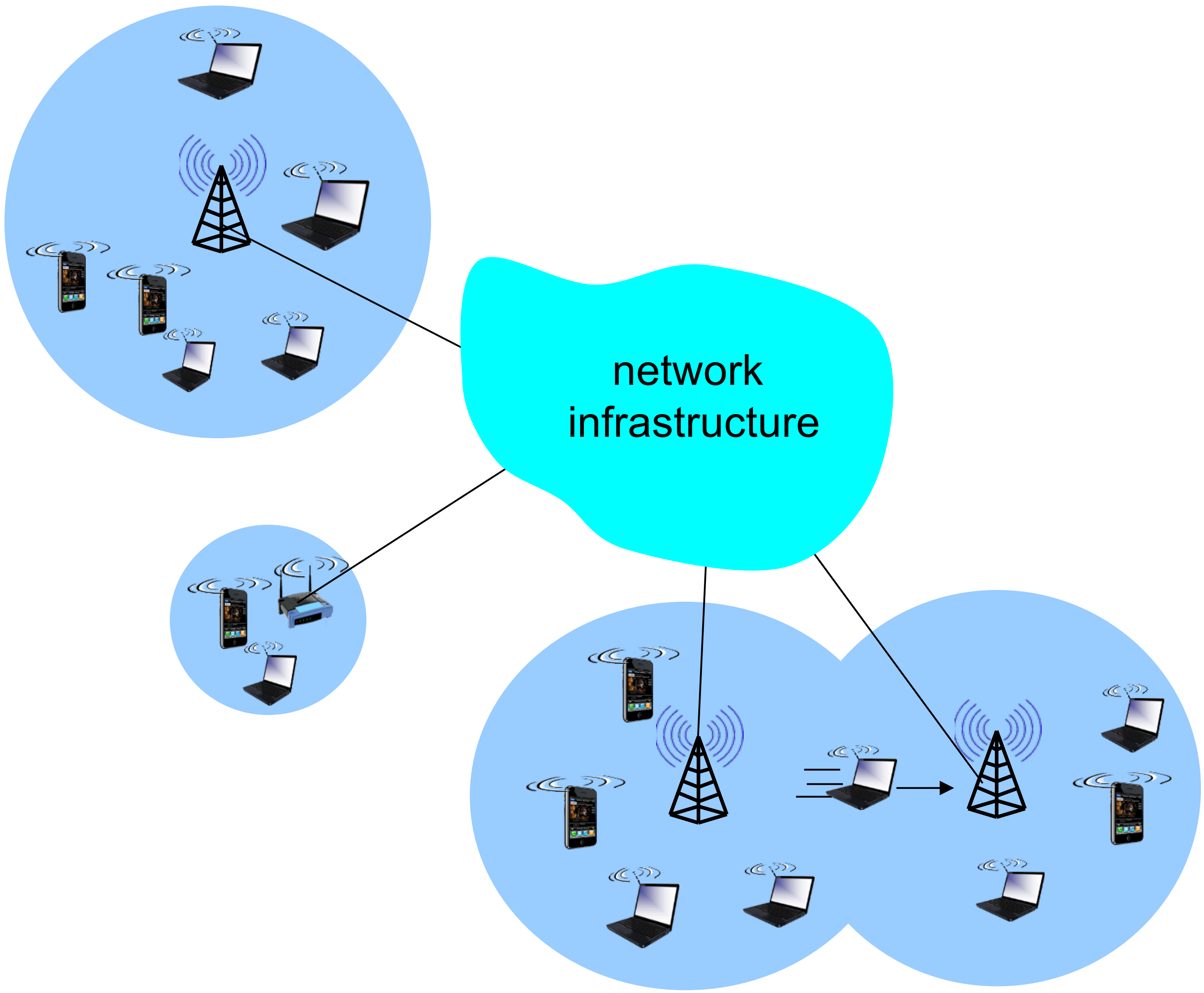
7.5 Principles: addressing and routing to mobile users

7.6 Mobile IP

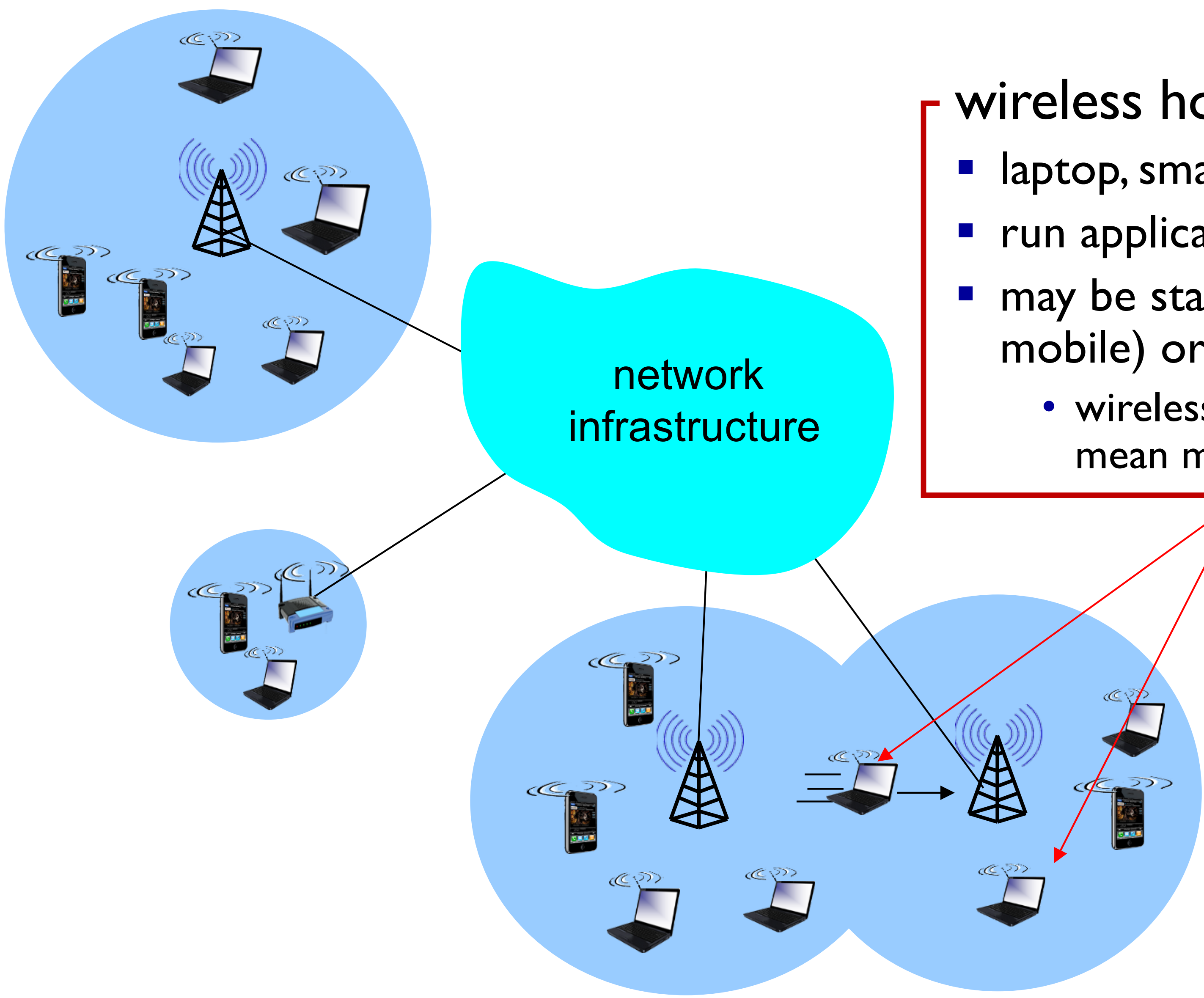
7.7 Handling mobility in cellular networks

7.8 Mobility and higher-layer protocols

Elements of a wireless network



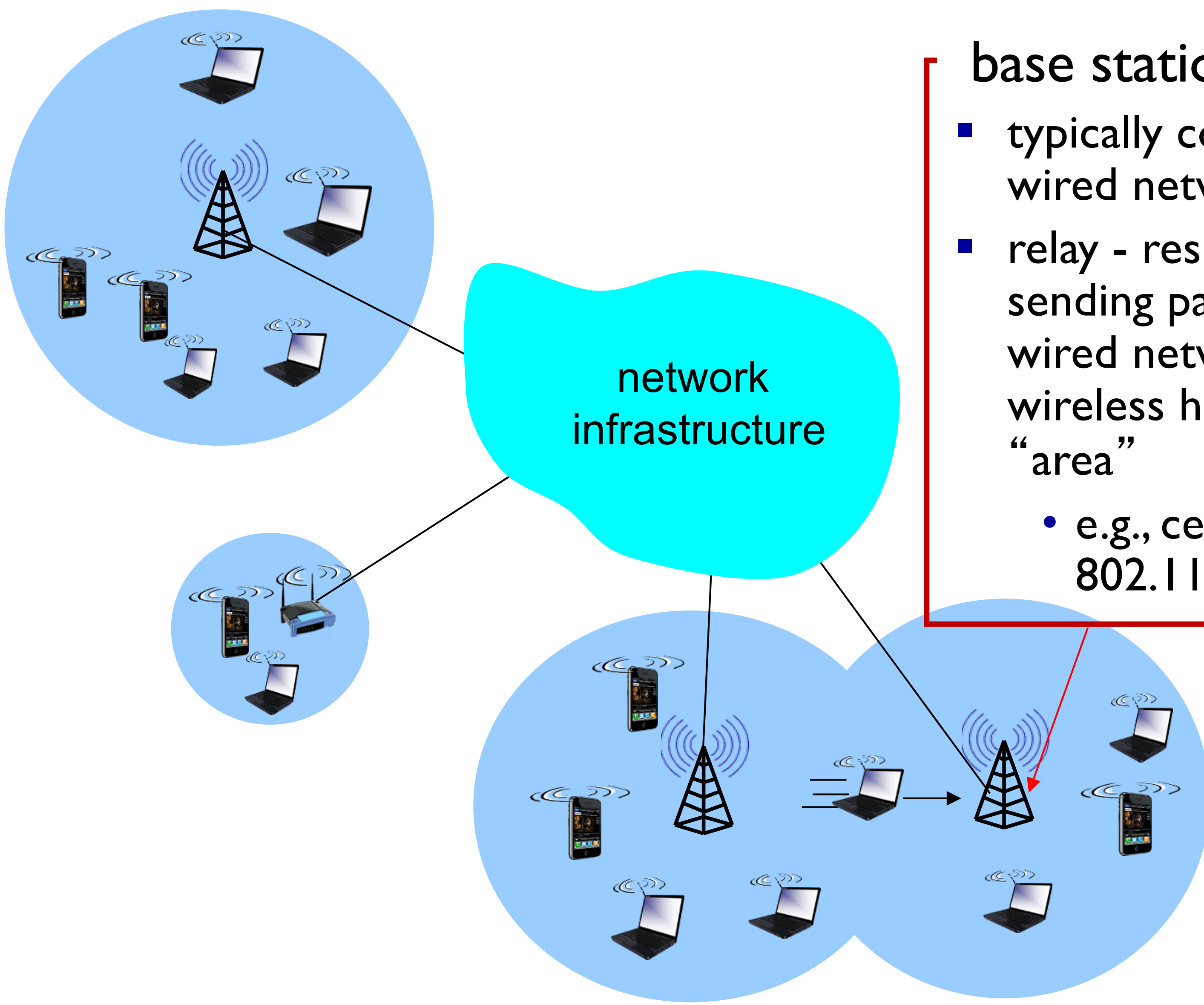
Elements of a wireless network



wireless hosts

- laptop, smartphone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

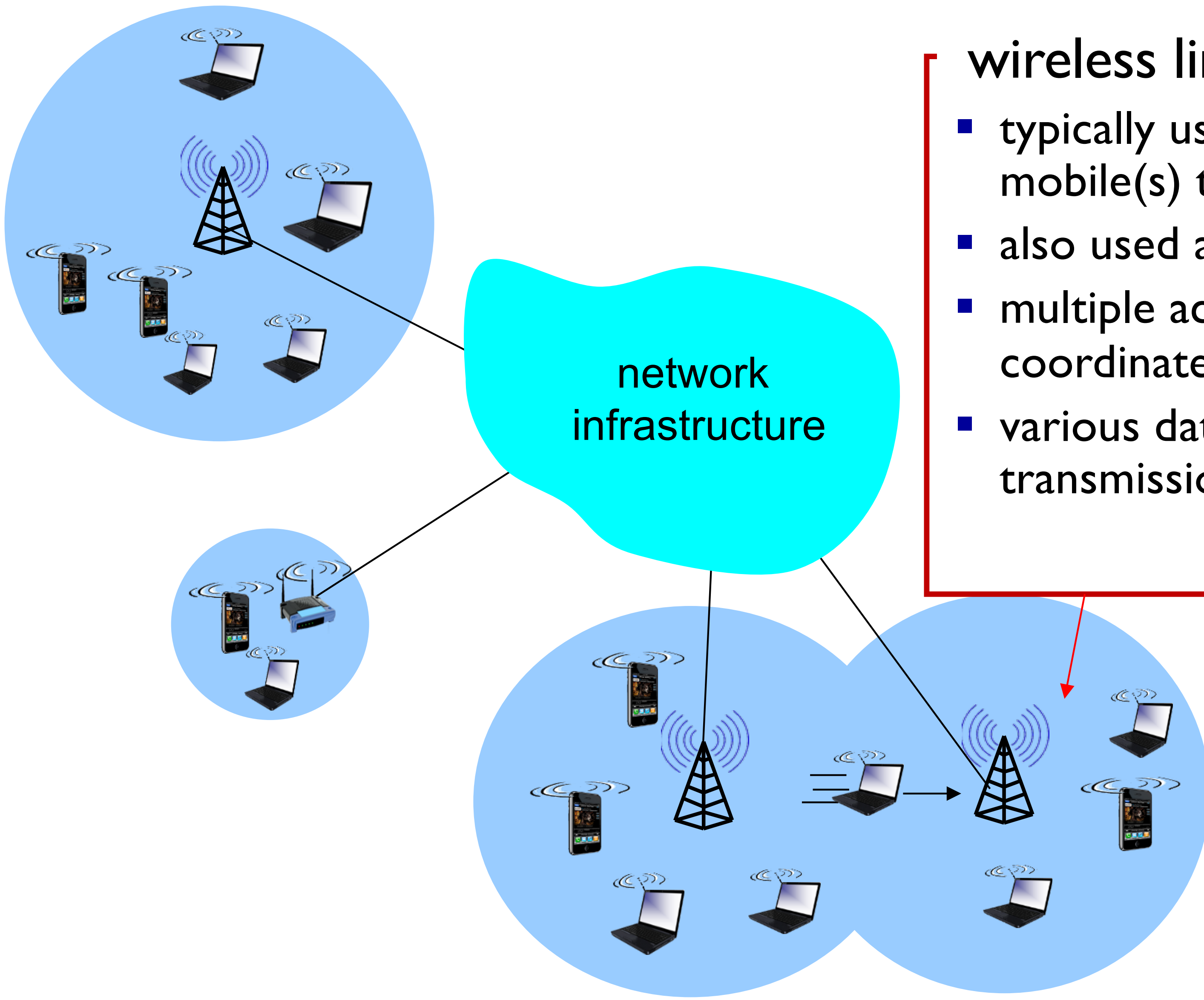
Elements of a wireless network



base station

- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - e.g., cell towers, 802.11 access points

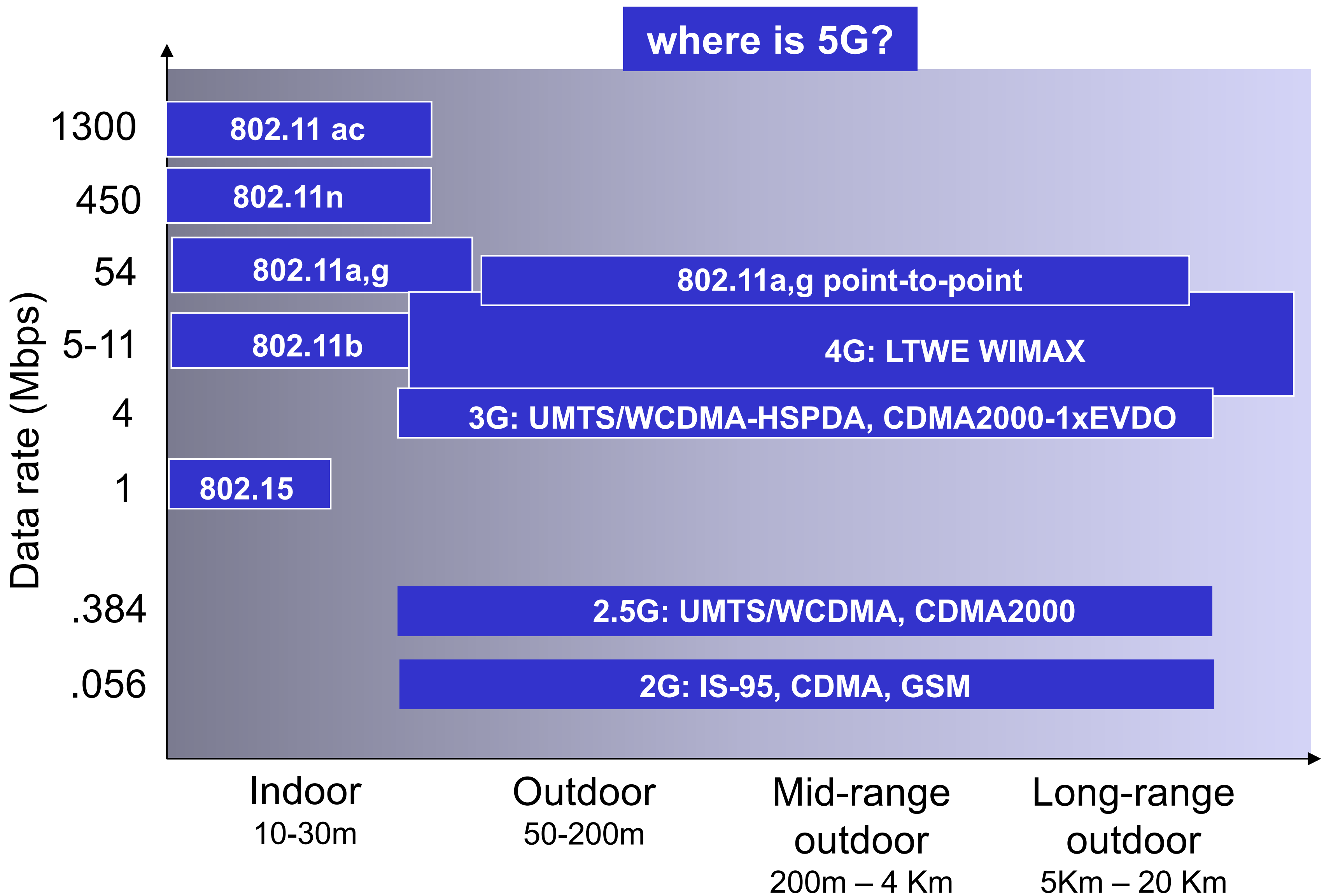
Elements of a wireless network



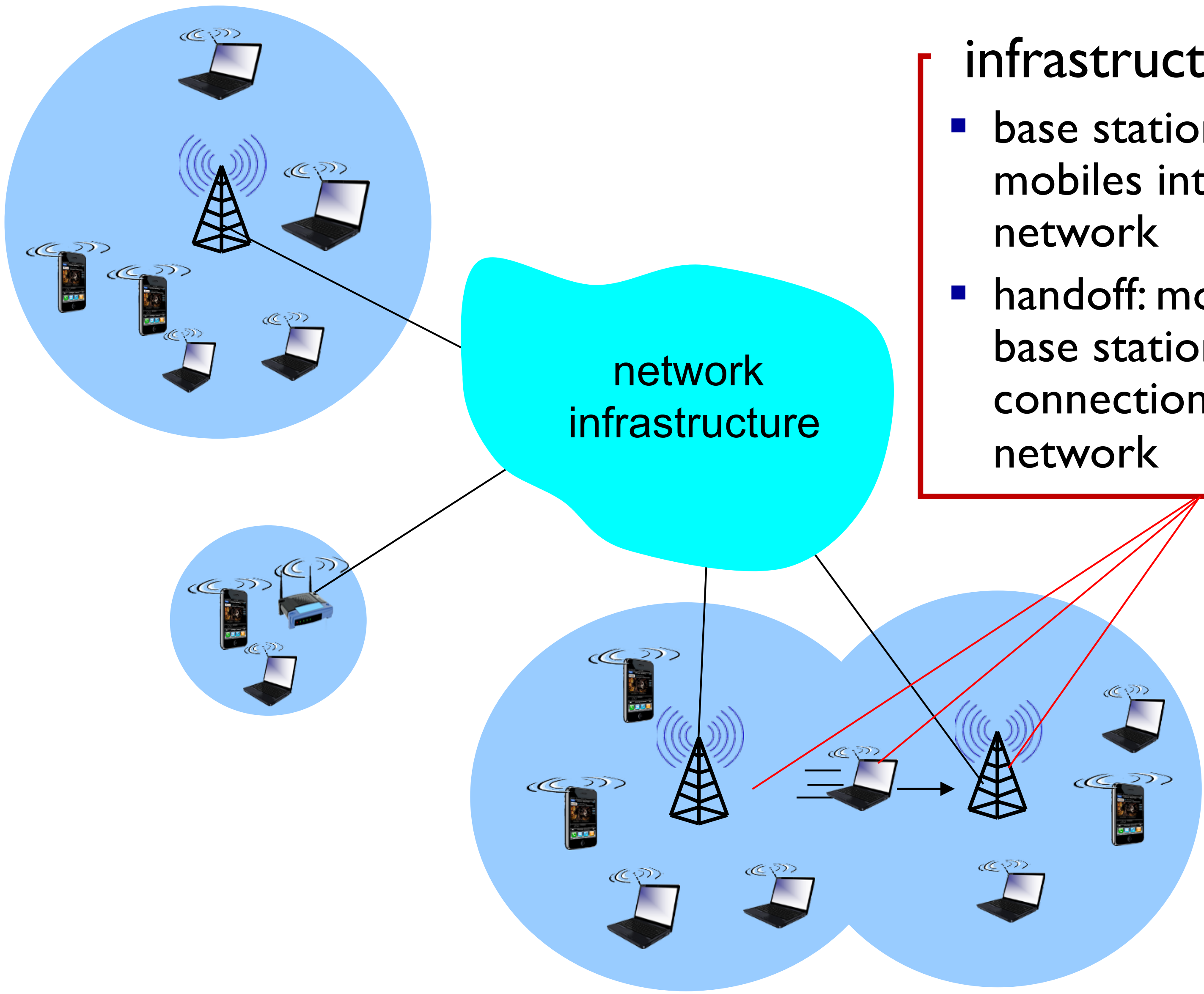
wireless link

- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

Characteristics of selected wireless links



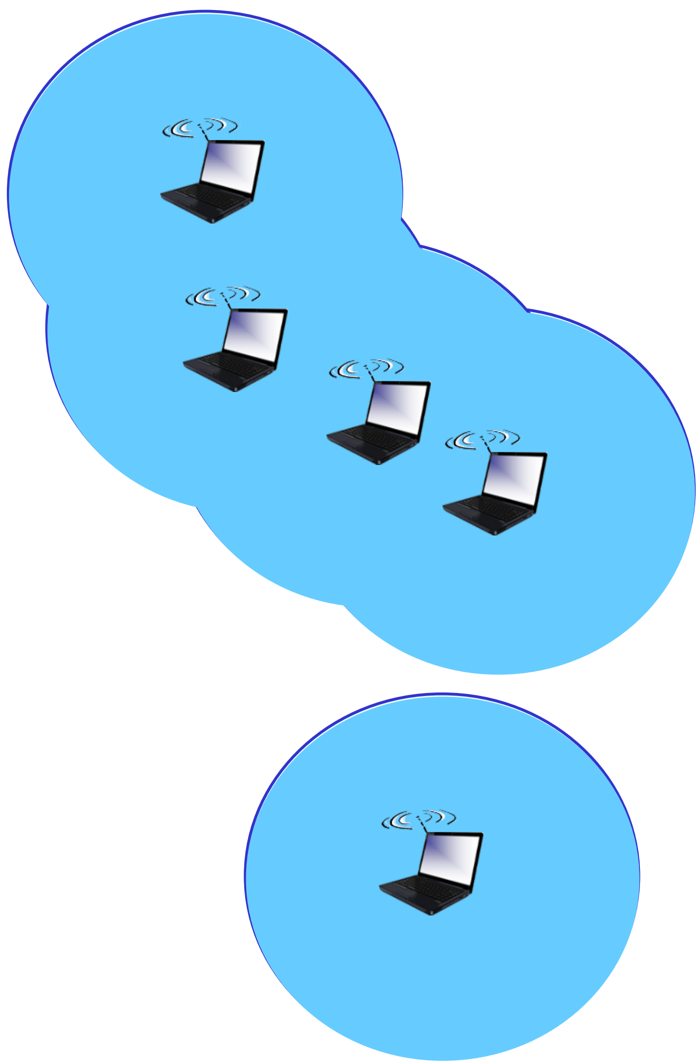
Elements of a wireless network



infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

Elements of a wireless network



ad hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

Outline

7.1 Introduction

Wireless

7.2 Wireless links, characteristics
- CDMA

7.3 IEEE 802.11 wireless LANs ("Wi-Fi")

7.4 Cellular Internet Access
- architecture
- standards (e.g., 3G, LTE)

Mobility

7.5 Principles: addressing and routing to mobile users

7.6 Mobile IP

7.7 Handling mobility in cellular networks

IEEE 802.11 Wireless LAN

802.11b
- 2.4-5 GHz unlicensed spectrum
- up to 11 Mbps

802.11a
- 5-6 GHz range
- up to 54 Mbps

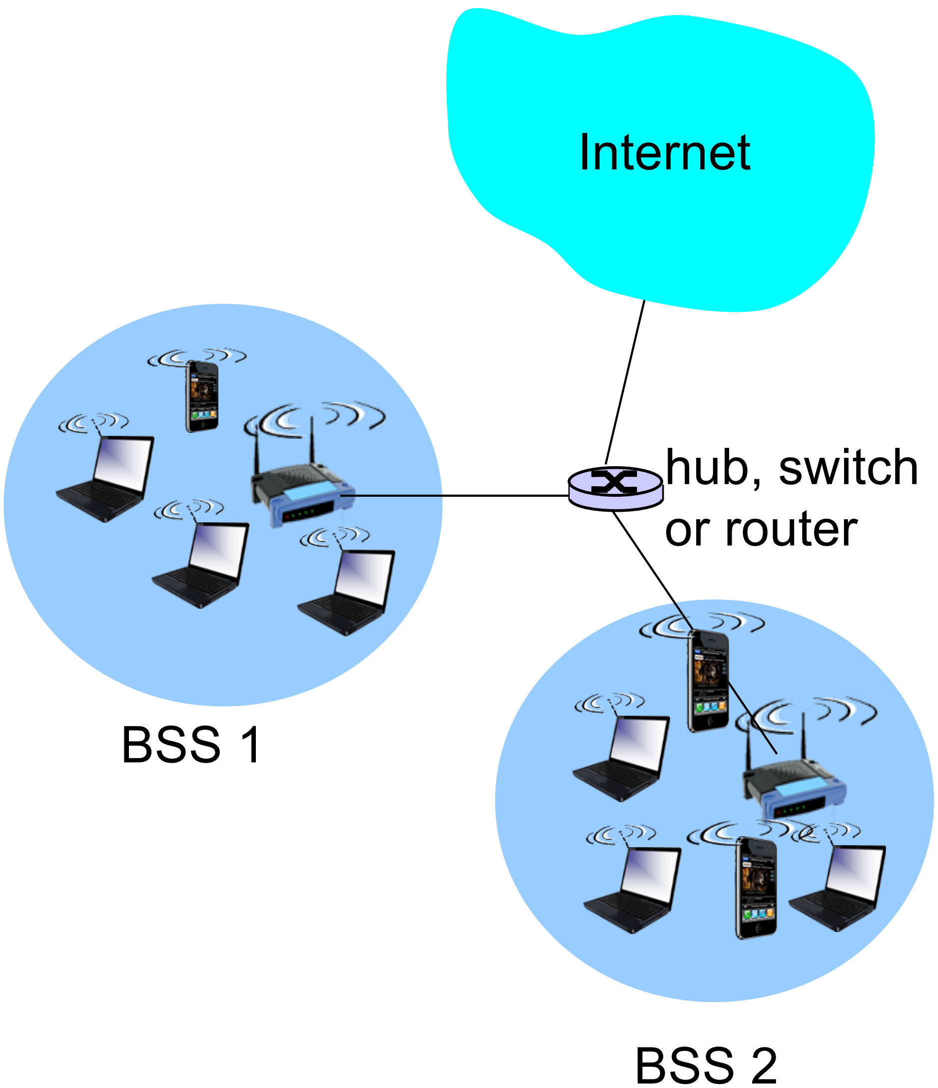
802.11g
- 2.4-5 GHz range
- up to 54 Mbps

802.11n: multiple antennae
- 2.4-5 GHz range
- up to 600 Mbps

802.11ac: multiple antennae
- 2.4-5 GHz range
- up to 1300 Mbps

- all use CSMA/CA for multiple access
- all have base-station and ad-hoc network versions

802.11 LAN architecture

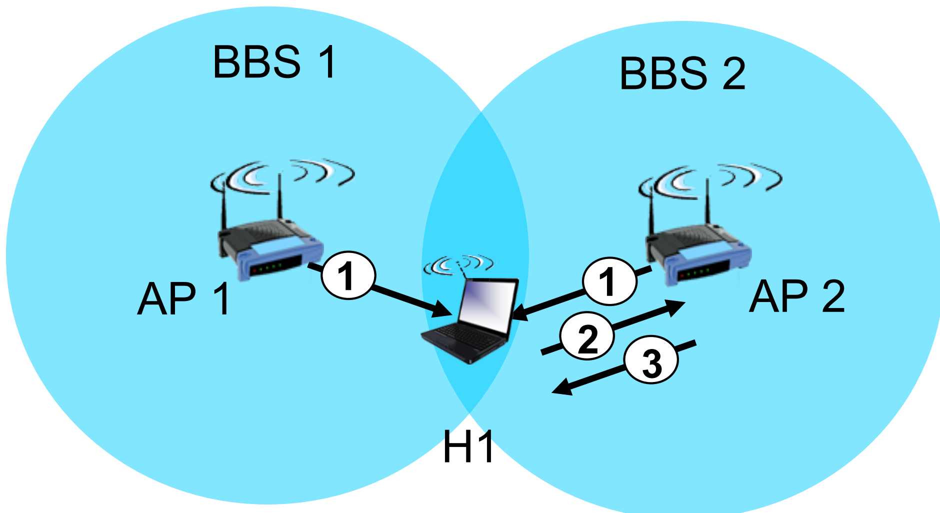


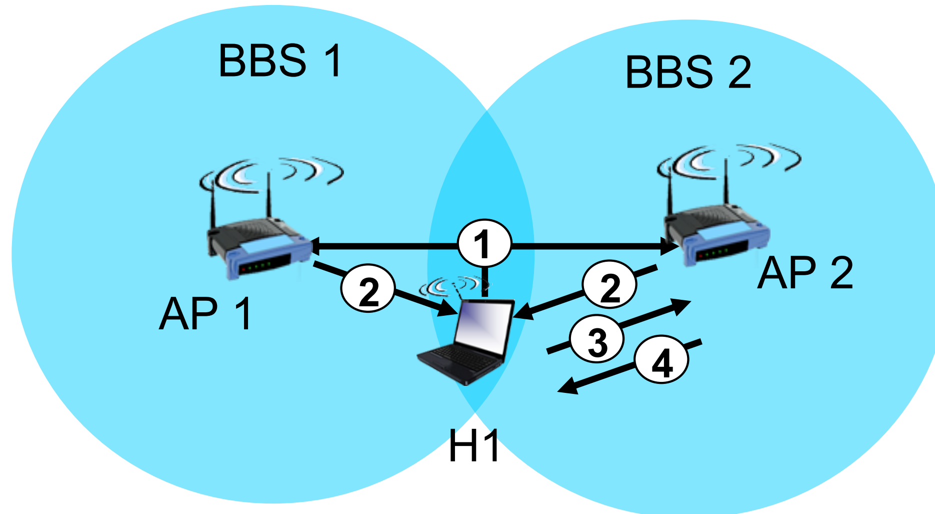
- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station

802.11: Channels, association

- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
  - selects AP to associate with
  - may perform authentication
  - will typically run DHCP to get IP address in AP's subnet

802.11: passive/active scanning





passive scanning:

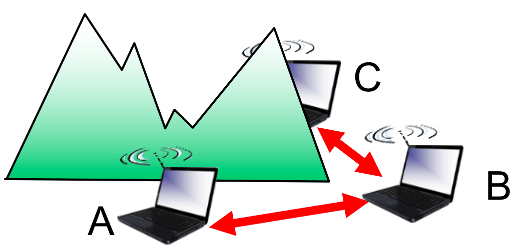
(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent from selected AP to H1

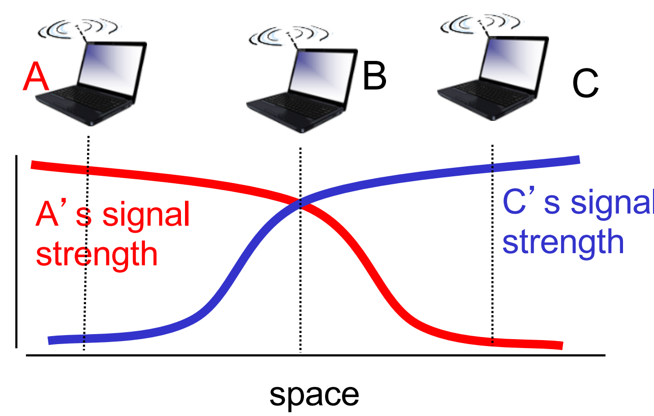
active scanning:

(1) Probe Request frame broadcast from H1
(2) Probe Response frames sent from APs
(3) Association Request frame sent: H1 to selected AP
(4) Association Response frame sent from selected AP to H1

IEEE 802.11: multiple access

- avoid collisions: 2[+] nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - can't sense all collisions: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/CA (Collision Avoidance)





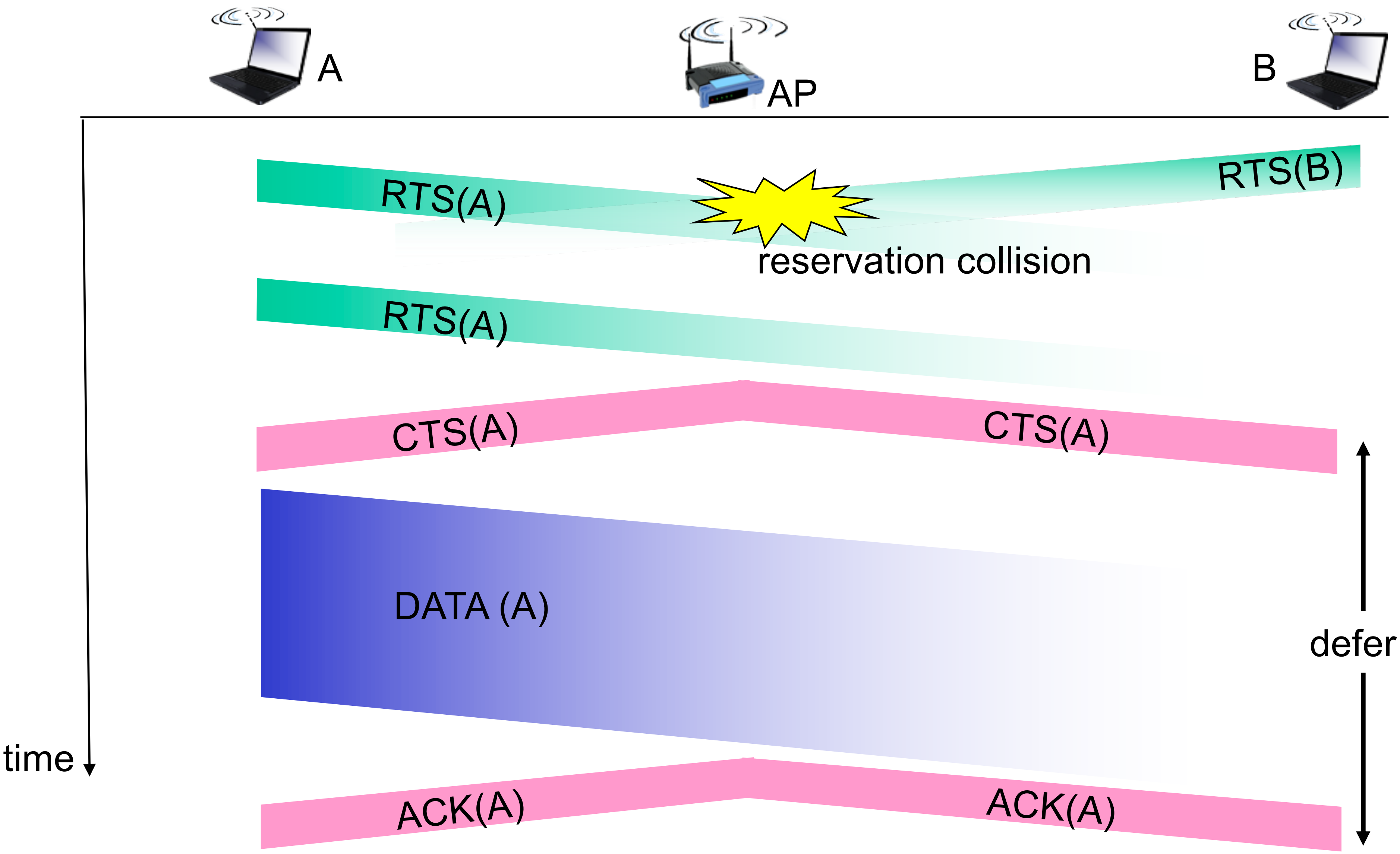
Avoiding collisions

idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they' re short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS (with sender's ID) heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



Next Week

- Cellular network
- Exam review