CS 118 Discussion Week 9: The Link Layer and Wireless

Questions

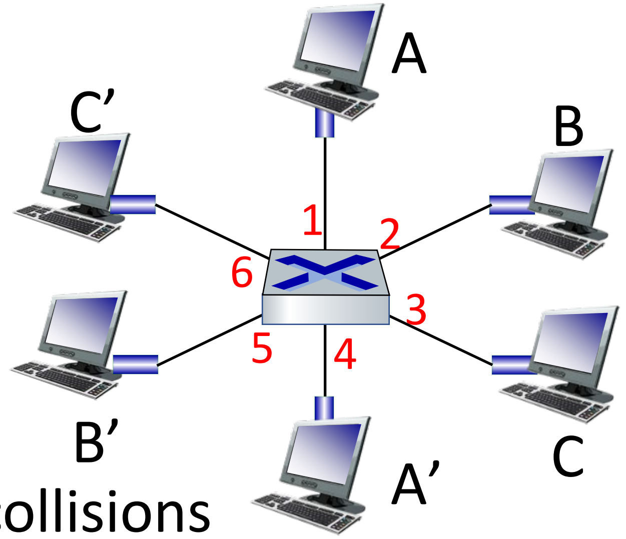
- Any questions from last week's material or Project 2?

Ethernet Switches

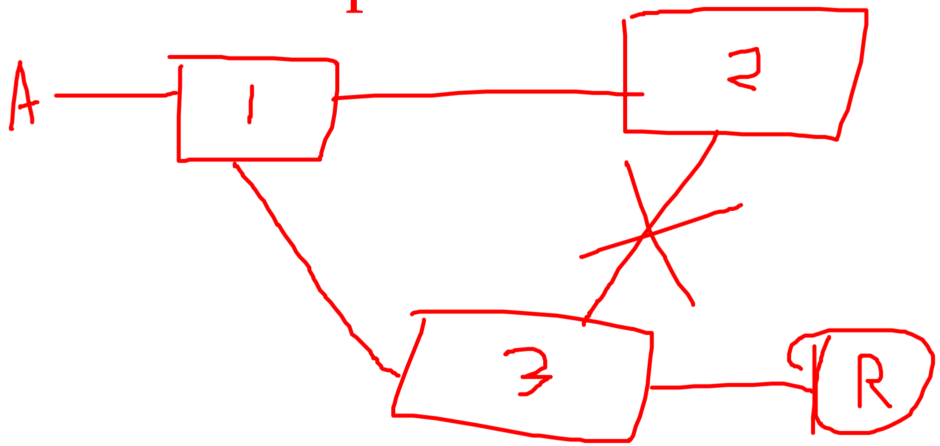
- Link Layer
  - store, forward Ethernet frames
  - examine incoming frame's MAC address, *selectively* forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses CSMA/CD to access segment
  - Sort of like a Layer 2 Router
- Transparent
- PnP, Self-Learning

Switches II

- Switches can take simultaneous transmissions.
  - A-to-A’ and B-to-B’ can transmit simultaneously, without collisions
  - but A-to-A’ and C to A’ can not happen simultaneously
- Self-learning: how does the switch learn hosts location?
- Interconnecting Switches
  - Spanning Tree Protocol



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



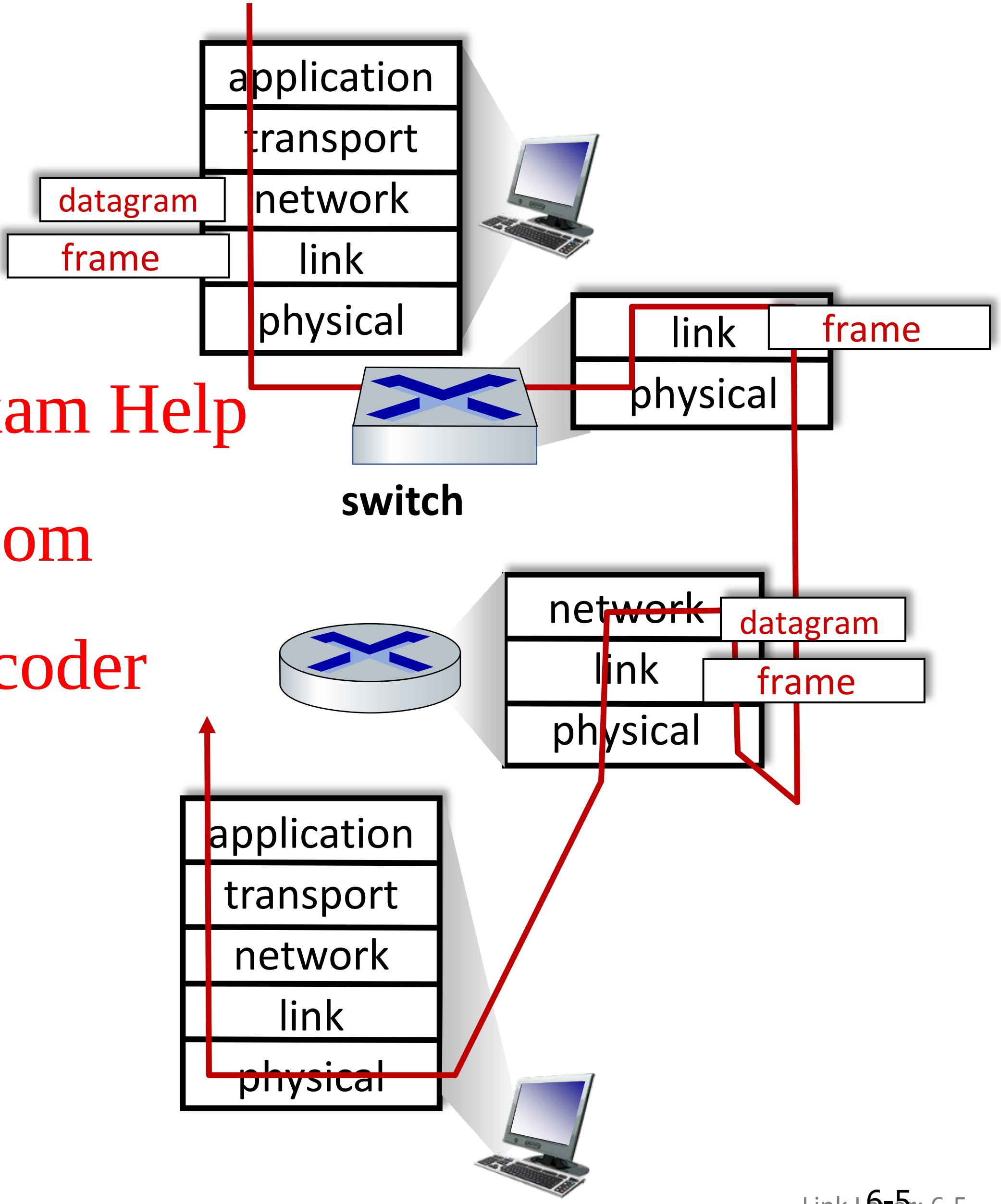
Switches vs. routers

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:

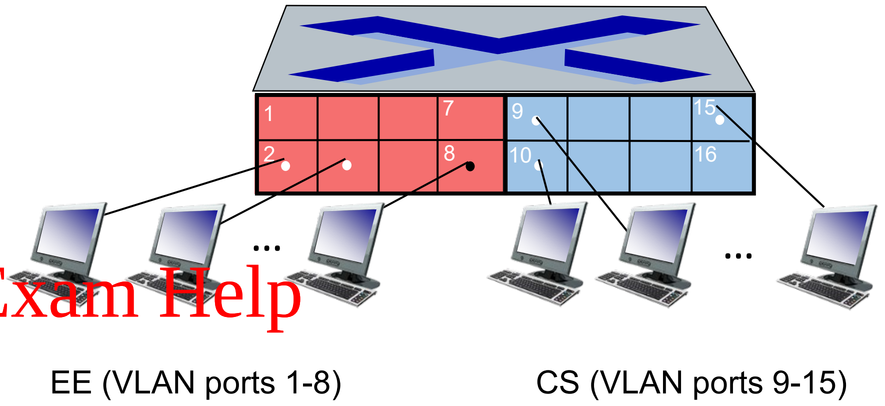
- *routers:* compute tables using routing algorithms, IP addresses
- *switches:* learn forwarding table using flooding, learning, MAC addresses



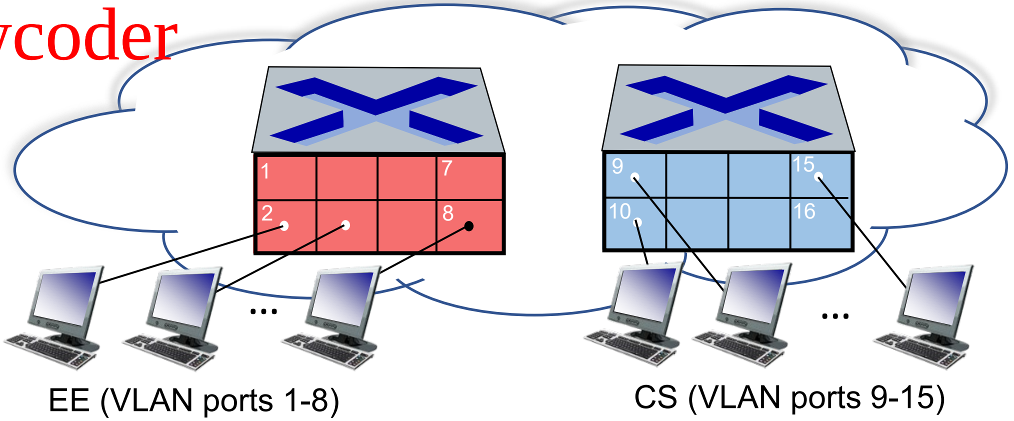
VLANs

- Why use VLANs?
  - Scalability
  - Administrative convenience
    - (logical location vs physical location)

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

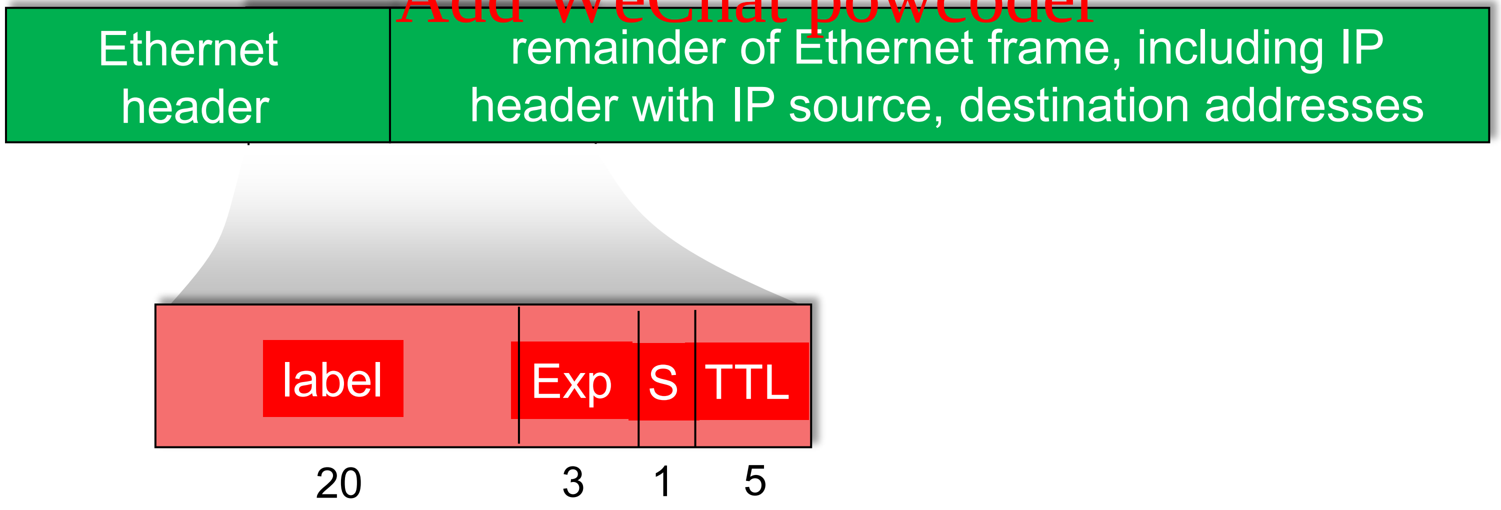


… operates as multiple virtual switches



MPLS

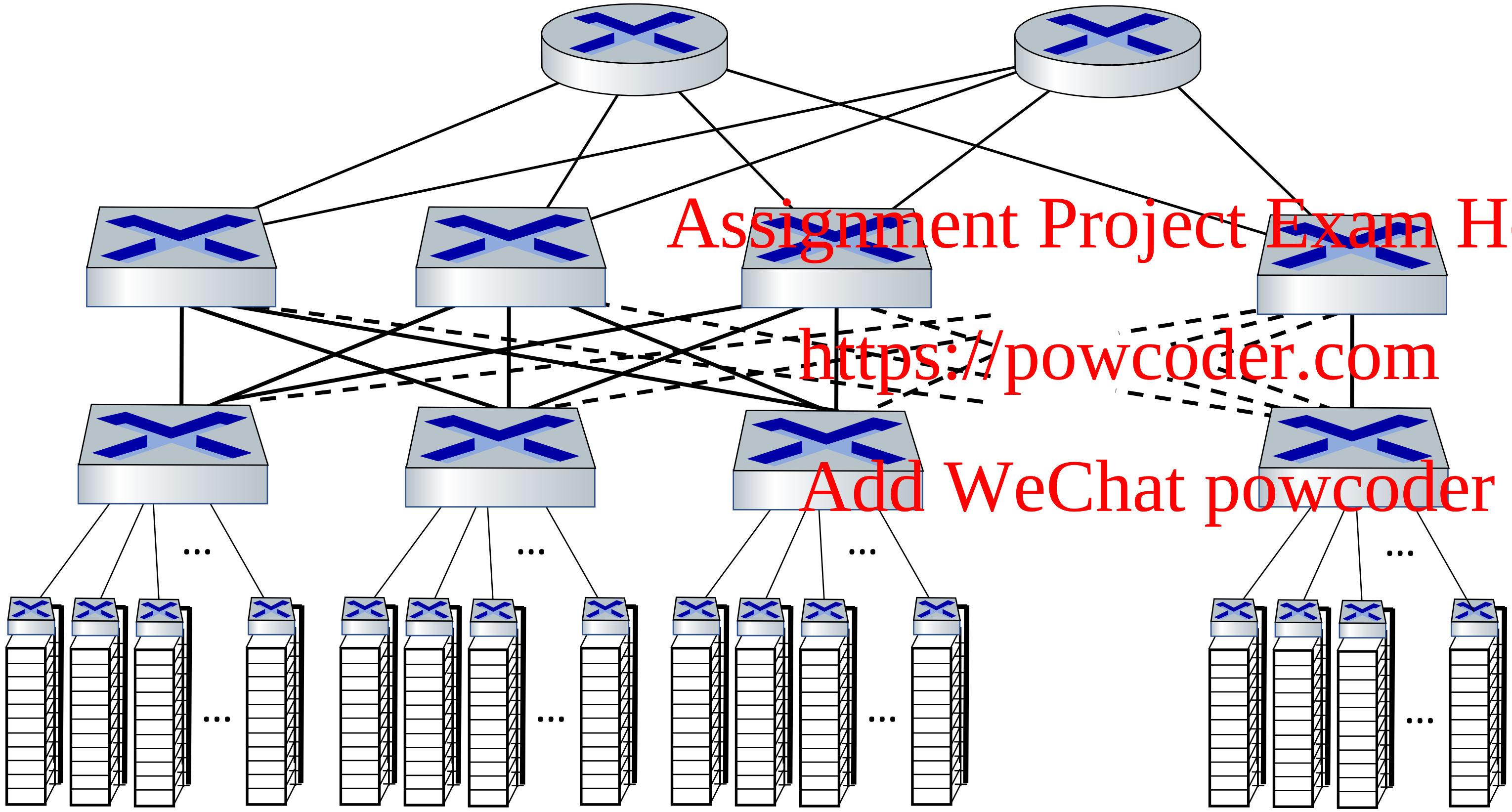
- goal: high-speed IP forwarding among network of MPLS-capable routers, using fixed length label (instead of shortest prefix matching)
  - faster lookup using fixed length identifier
  - borrowing ideas from Virtual Circuit (VC) approach
  - but IP datagram still keeps IP address!



Datacenters

- Extreme scale: 10,000-100,000+ hosts.
  - E.g. Amazon, Google, Netflix, etc
- Scale produces challenges
  - Multiple apps, huge number of clients
  - Reliability
  - Managing/balancing load, avoiding processing, Networking/data bottlenecks

Datacenter networks: network elements



Border routers
- connections outside datacenter

Tier-1 switches
- connecting to ~16 T-2s below

Tier-2 switches
- connecting to ~16 TORs below

Top of Rack (TOR) switch
- one per rack
- 40-100Gbps Ethernet to blades

Server racks
- 20- 40 server blades: hosts

Datacenter networks: protocol innovations

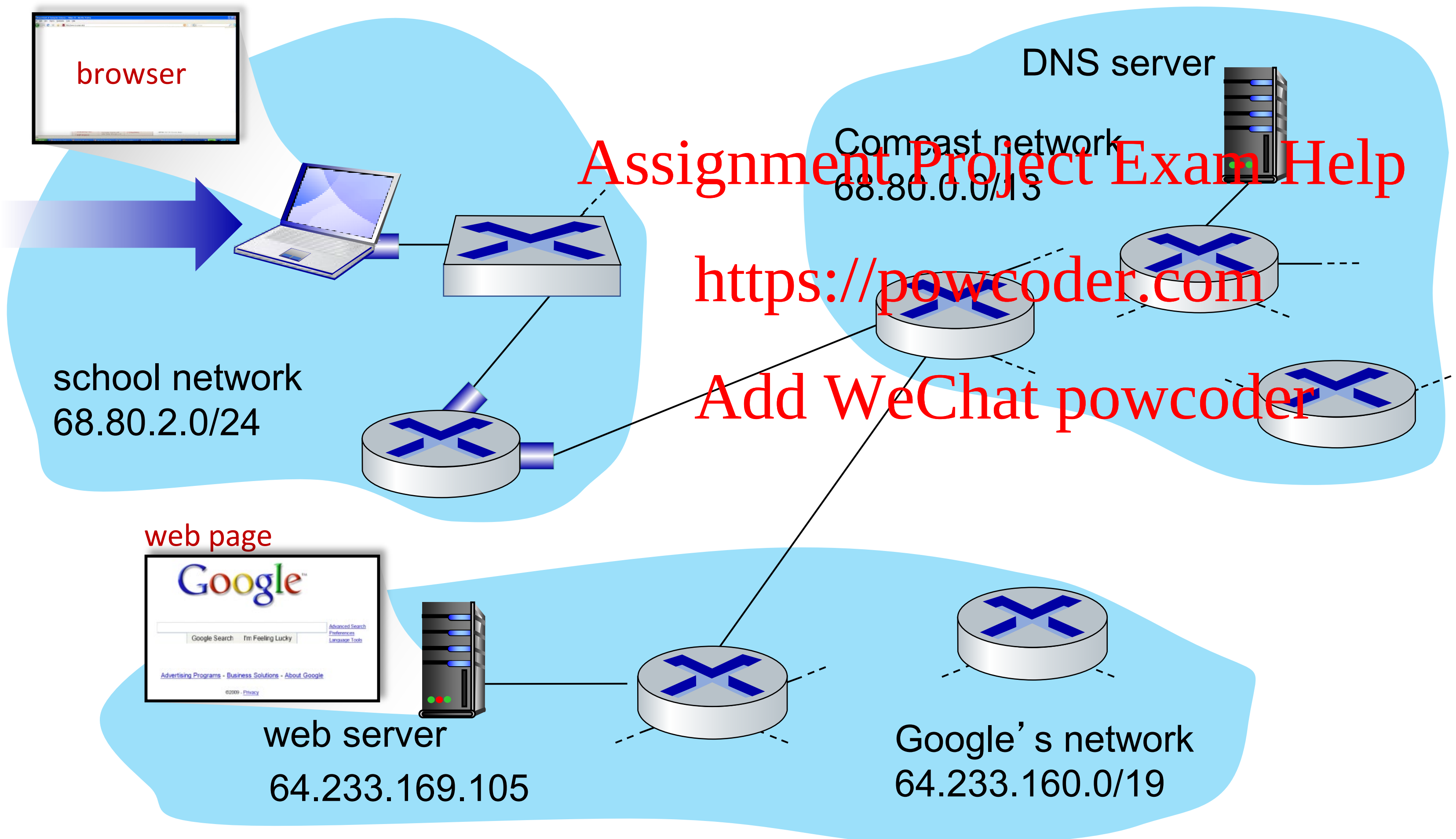
- link layer:
  - RoCE: remote DMA (RDMA) over Converged Ethernet
- transport layer:
  - ECN (explicit congestion notification) used in transport-layer congestion control (DCTCP, DCQCN)
  - experimentation with hop-by-hop (backpressure) congestion control
- routing, management:
  - SDN widely used within/among organizations' datacenters
  - place related services, data as close as possible (e.g., in same rack or nearby rack) to minimize tier-2, tier-1 communication

Putting everything Together

- We've now covered basically the whole protocol stack!

- Let's go over a quick example (web request)

A day in the life: scenario

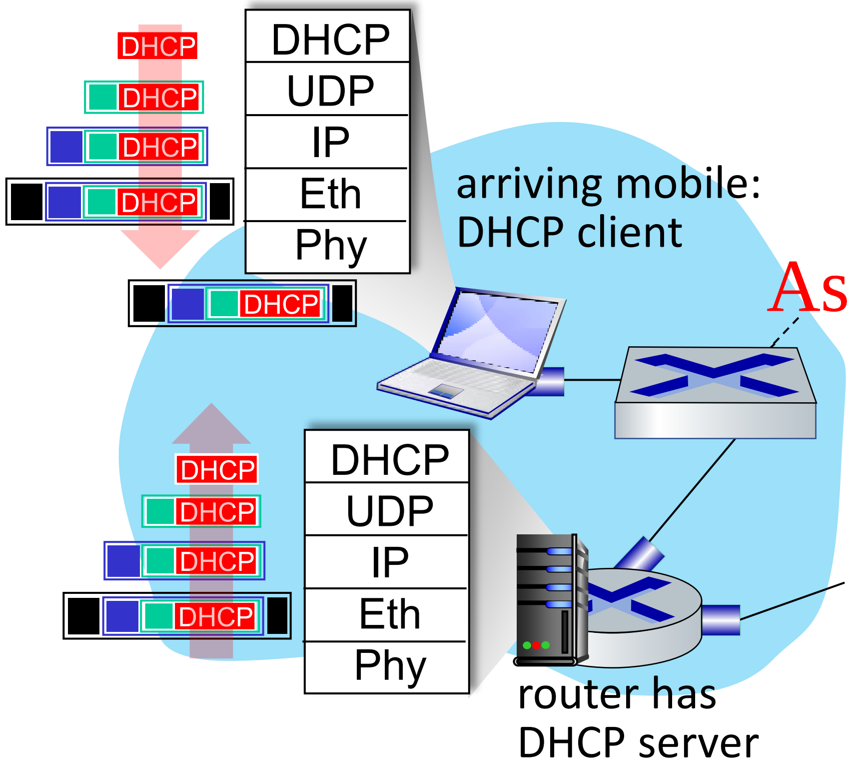


scenario:

- arriving mobile client attaches to network …
- requests web page: www.google.com

Sounds simple!

A day in the life: connecting to the Internet

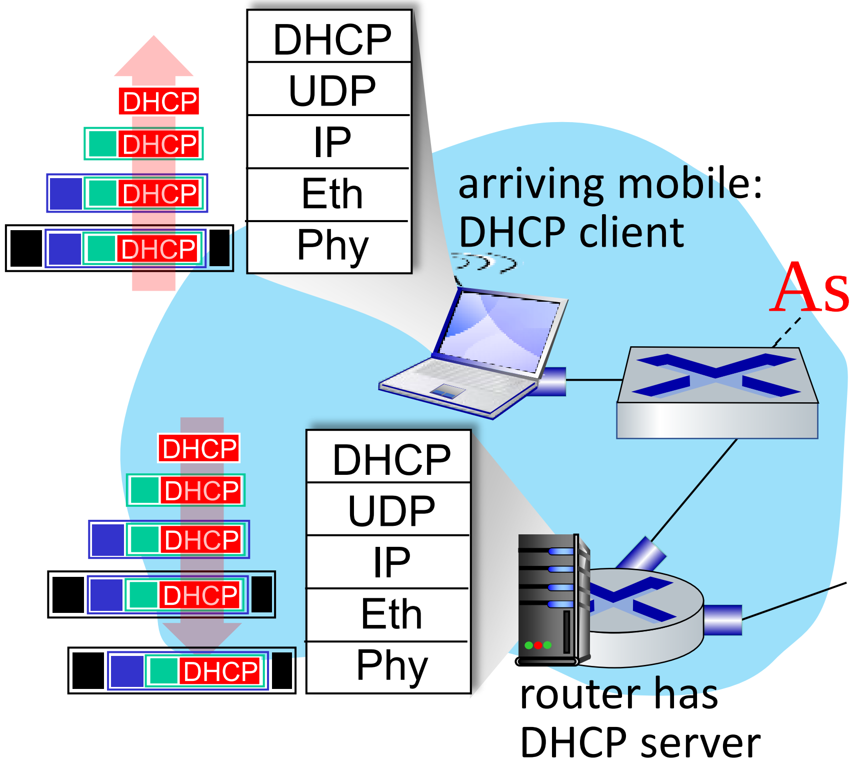


- connecting laptop needs to get its own IP address, addr of first-hop router, addr of DNS server: use DHCP

- 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

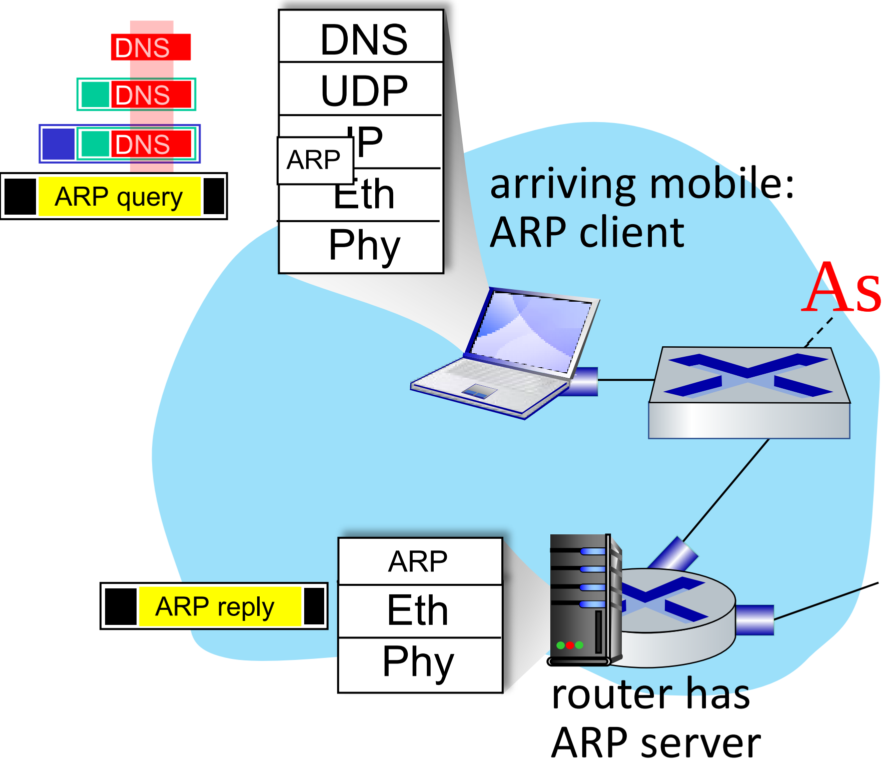
A day in the life: connecting to the Internet



- 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

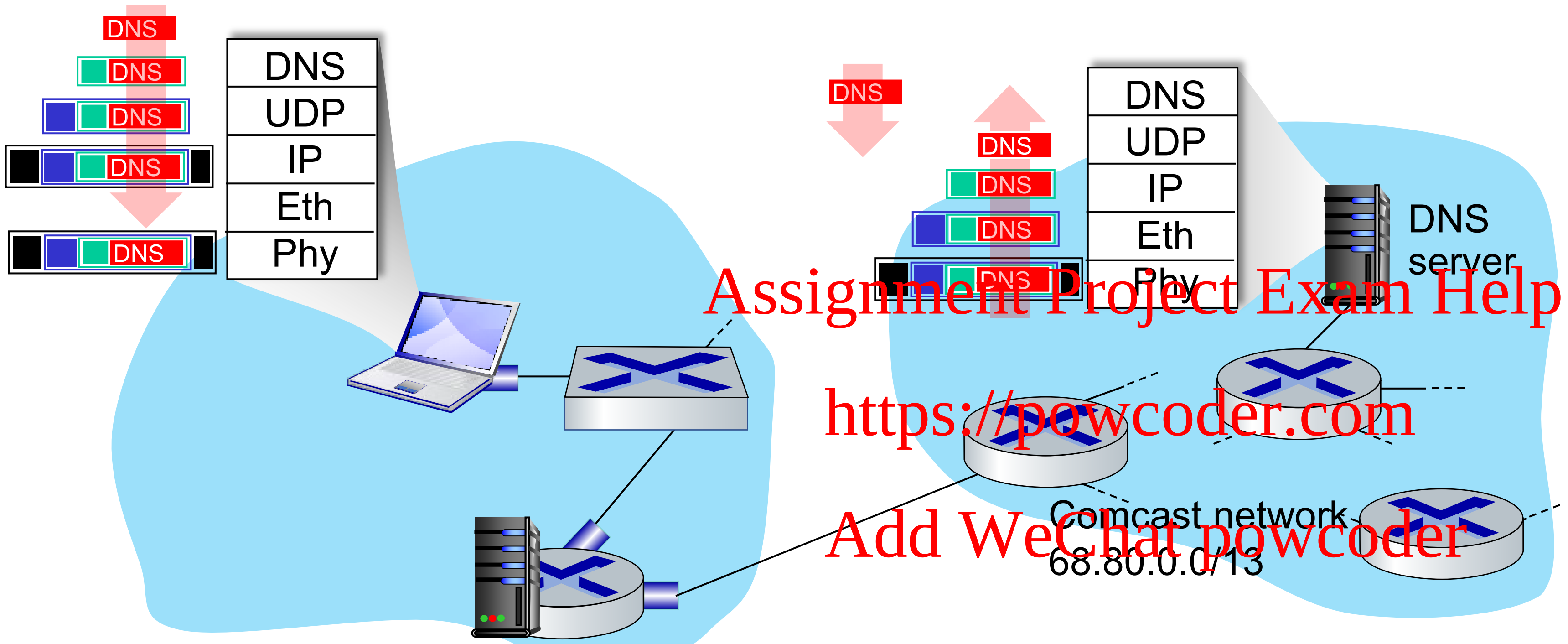
Client now has IP address, knows name & addr of DNS server, IP address of its first-hop router

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

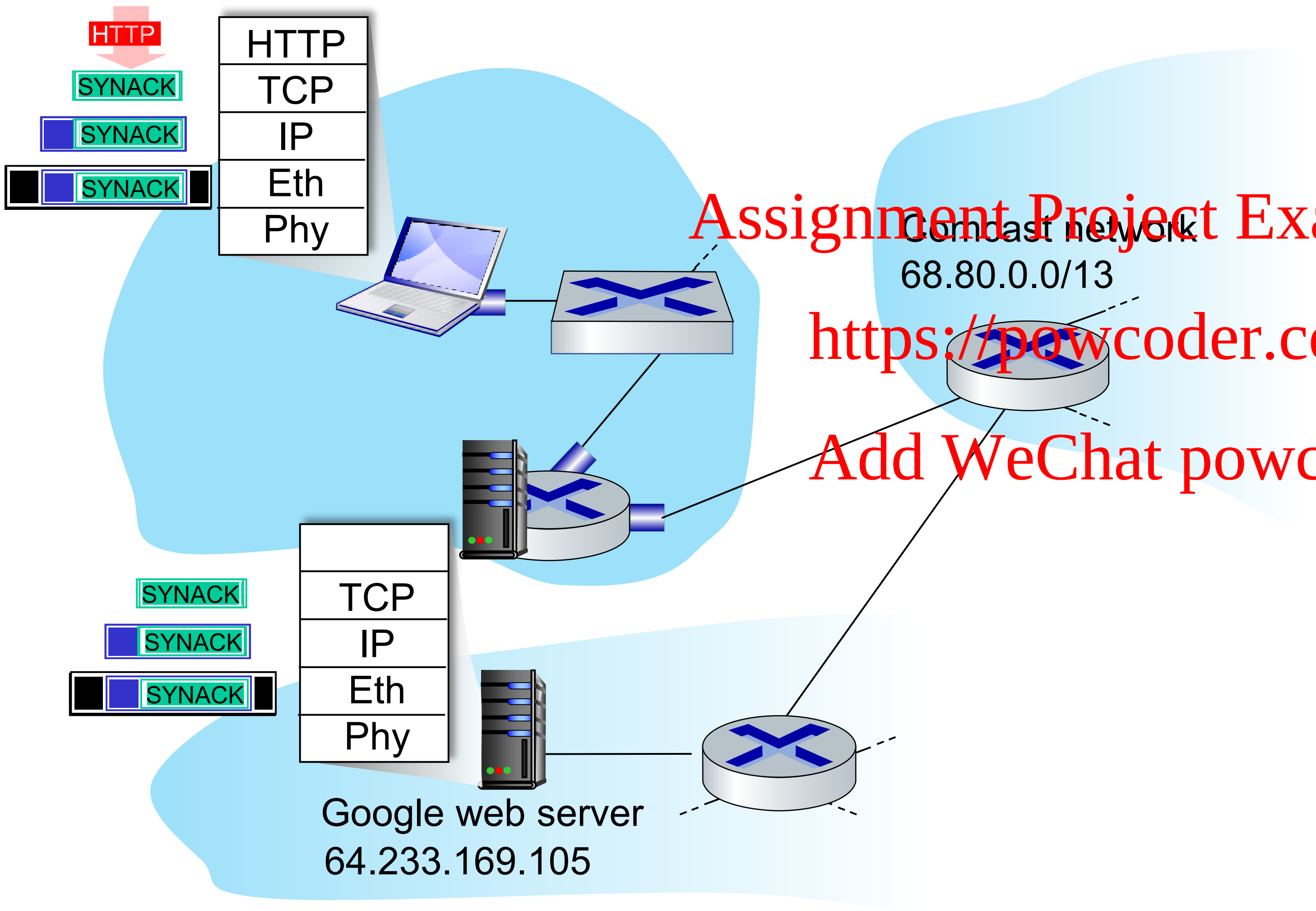


- demuxed to DNS
- DNS replies to client with IP address of www.google.com

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

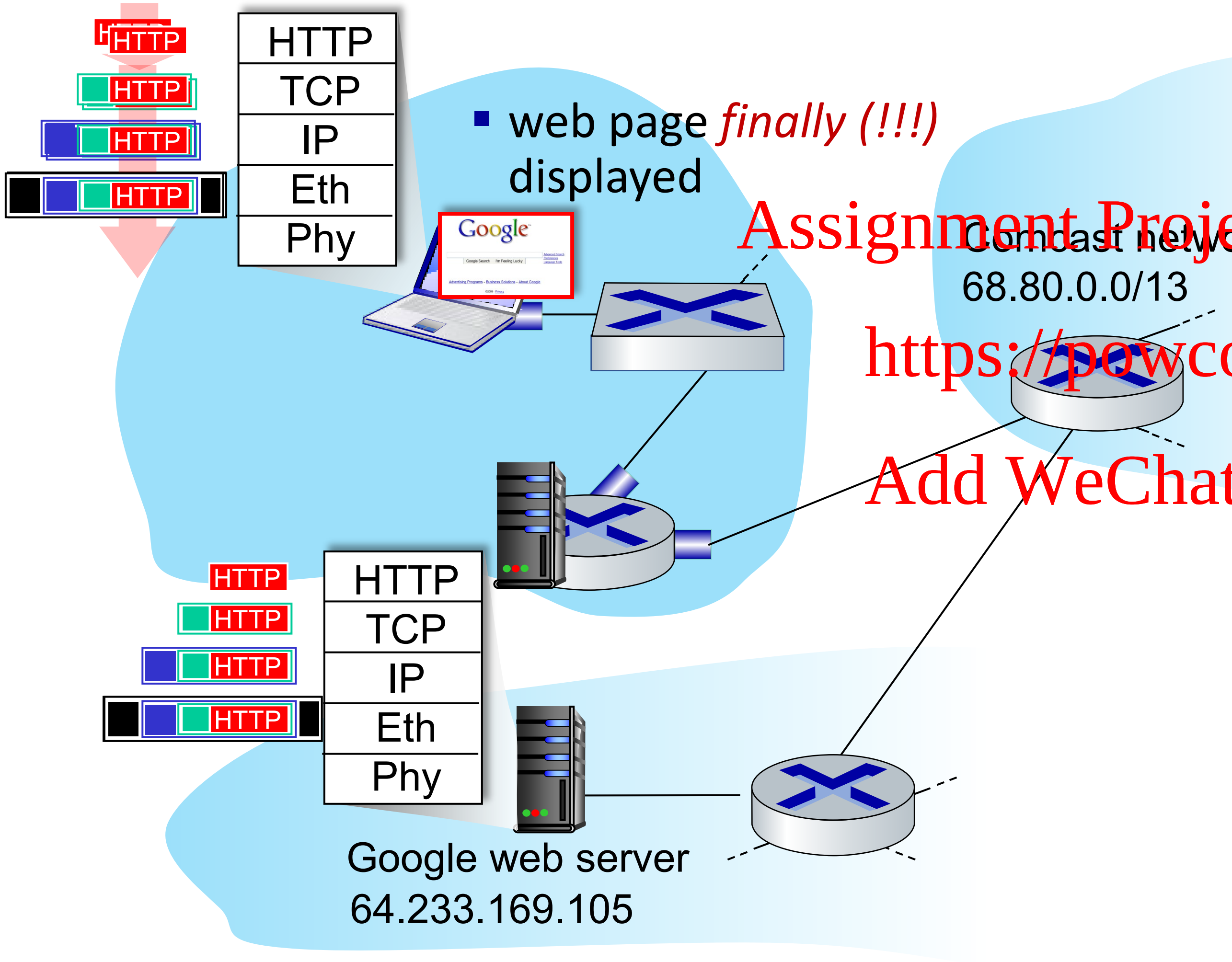
- IP datagram forwarded from campus network into Comcast network, routed (tables created by RIP, OSPF, IS-IS and/or BGP routing protocols) to DNS server

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 TCP 3-way handshake) inter-domain routed to web server
- web server responds with TCP SYNACK (step 2 in TCP 3-way handshake)
- TCP connection established!

A day in the life... HTTP request/reply

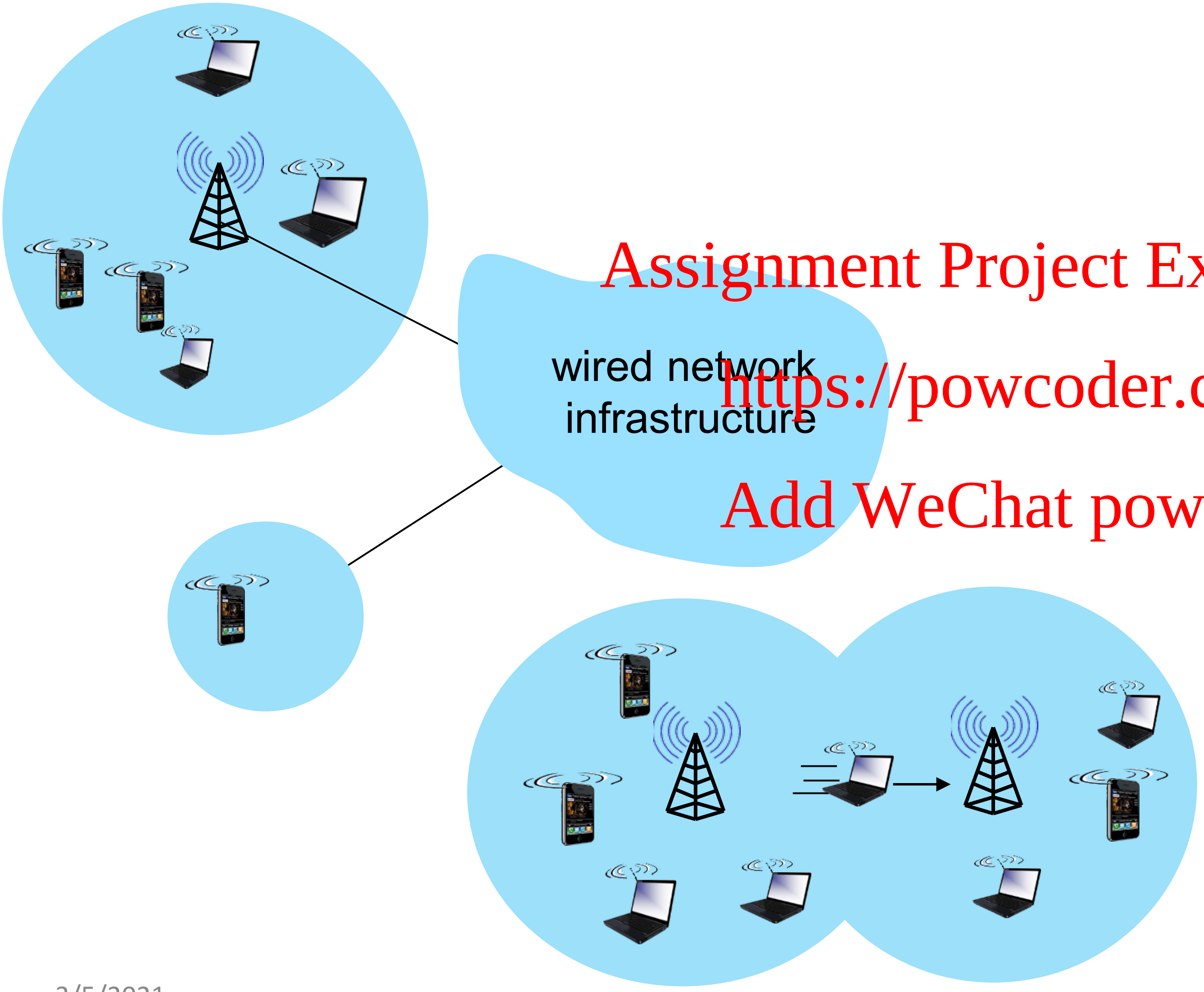


- HTTP request sent into TCP socket
- IP datagram containing HTTP request routed to www.google.com
- web server responds with HTTP reply (containing web page)
- IP datagram containing HTTP reply routed back to client

Wireless

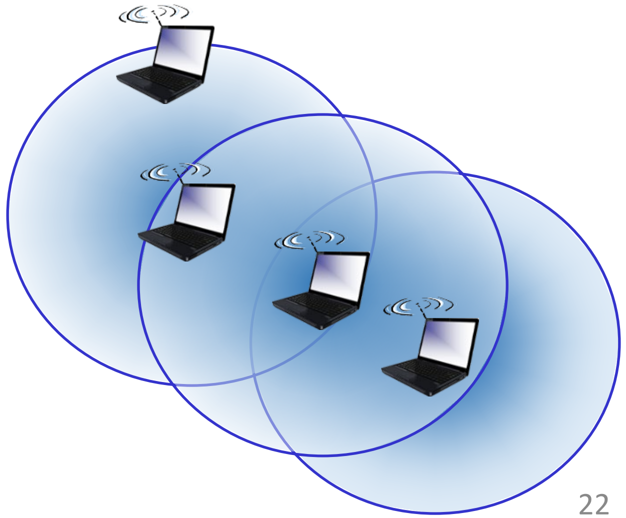
Elements in a Wireless Network (Infrastructure Mode)

- Wireless Hosts
  - E.g. laptops, smartphones
- Base Stations
  - Connected to wired network
  - Works as a relay
    - Connects mobiles into the wired network (acts as a relay)
- Wireless Links
  - typically used to connect mobile(s) to base station, also used as backbone link

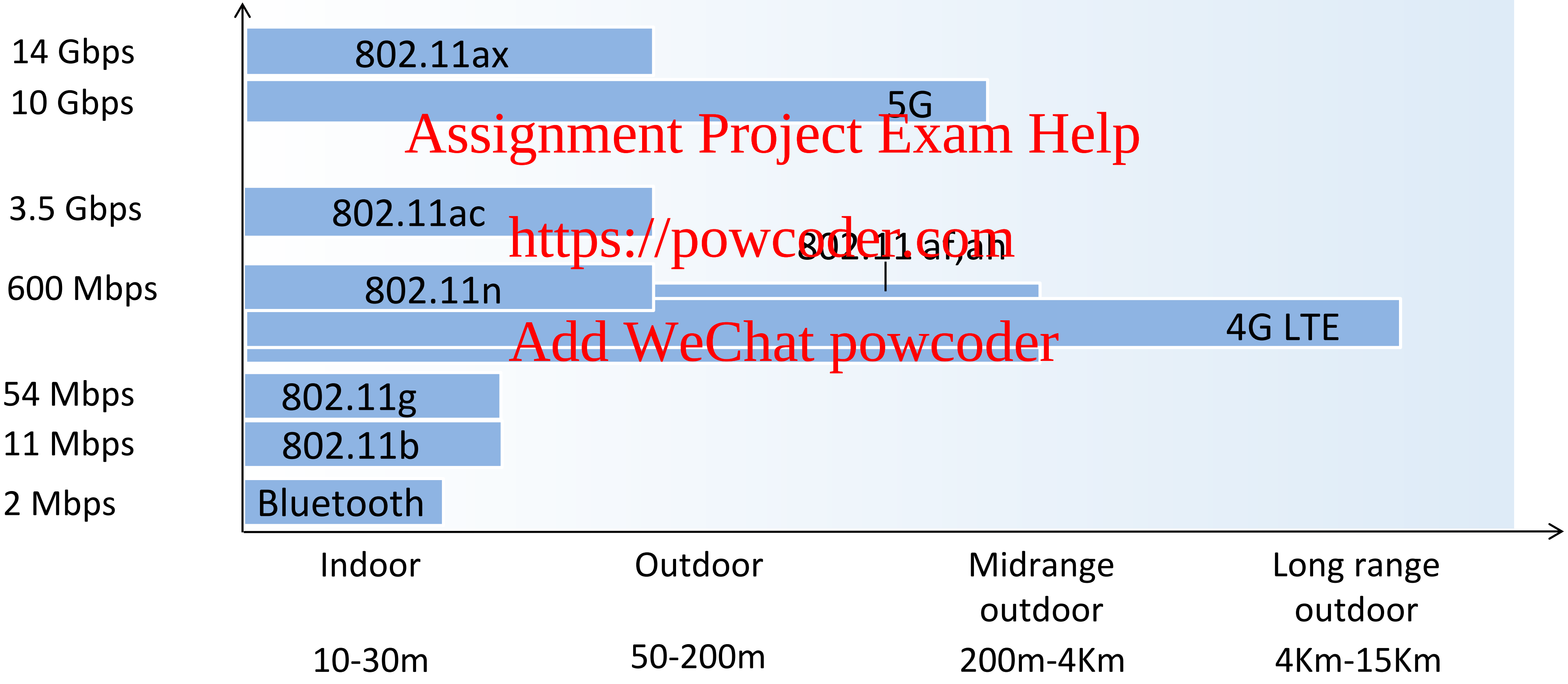

wired network
infrastructure

Elements of a Wireless Network

- Can also run in ‘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



Characteristics of selected wireless links



Wireless Links

- Now that we know what the network looks like, what do the links look like?

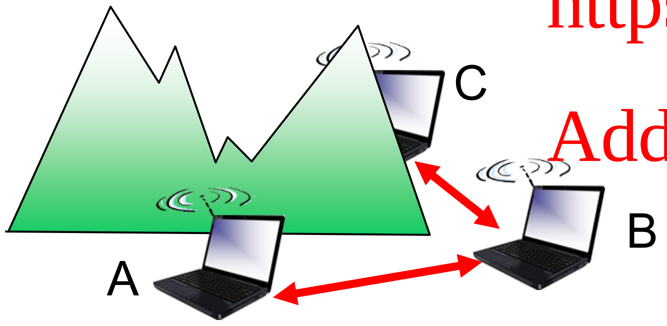
- Important differences from a wired link:
  - Decreased signal strength over distance

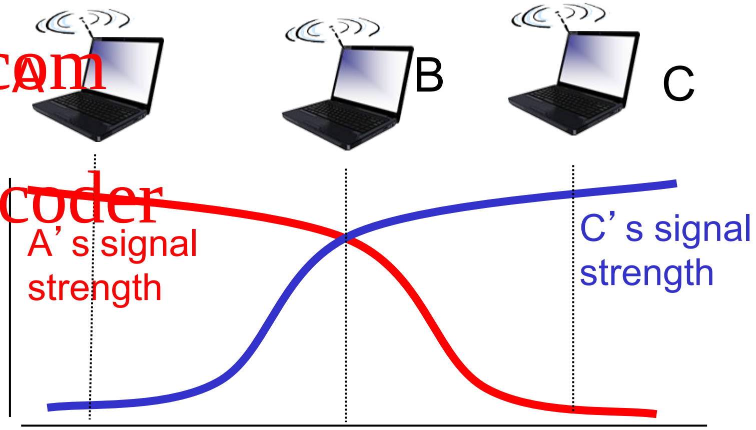
  - Interference

  - Multipath propagation
  - etc

More Wireless Link Issues

- Hidden Terminal Problem
  - Results in signal attenuation

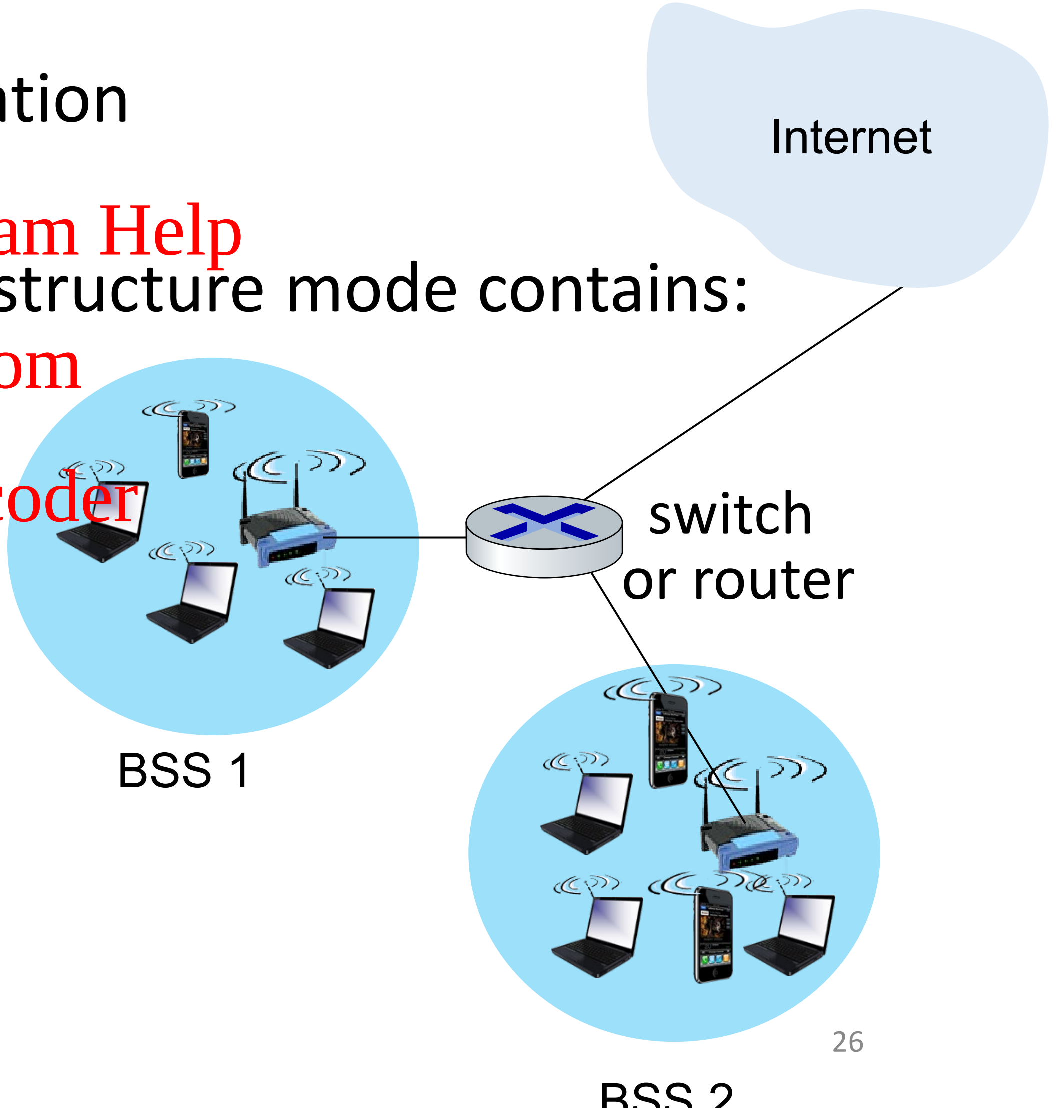




Wi-Fi (IEEE 802.11 Wireless LAN)

- 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
  - ad hoc mode: hosts only



802.11: Channels, association

- spectrum divided into channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!

- arriving 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
  - then may perform authentication [Chapter 8]
  - then typically run DHCP to get IP address in AP's subnet

802.11 frame: addressing

2	2	6	6	6	2	6	0 - 2312	4
frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC

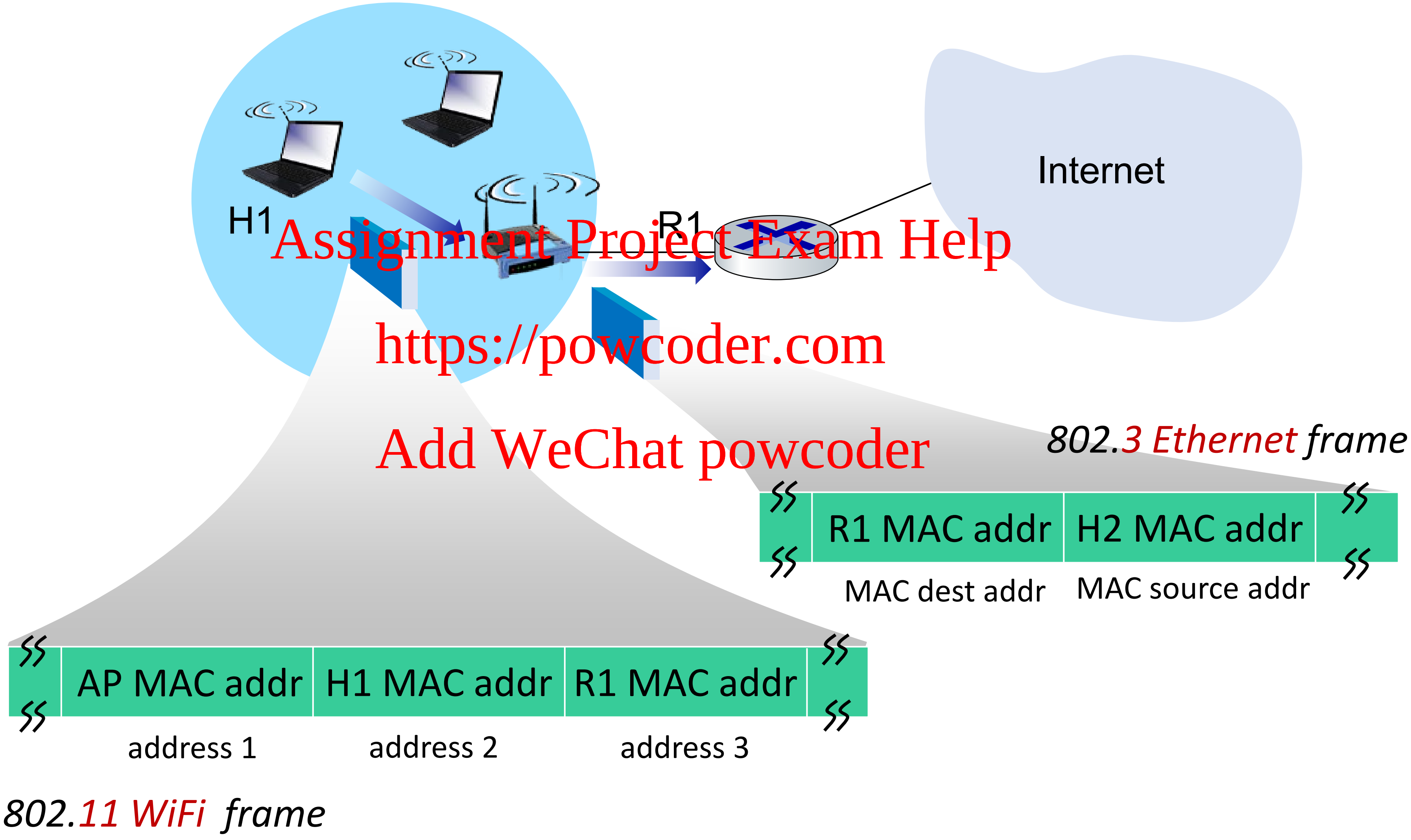
Address 1: MAC address of wireless host or AP to receive this frame

Address 2: MAC address of wireless host or AP transmitting this frame

Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

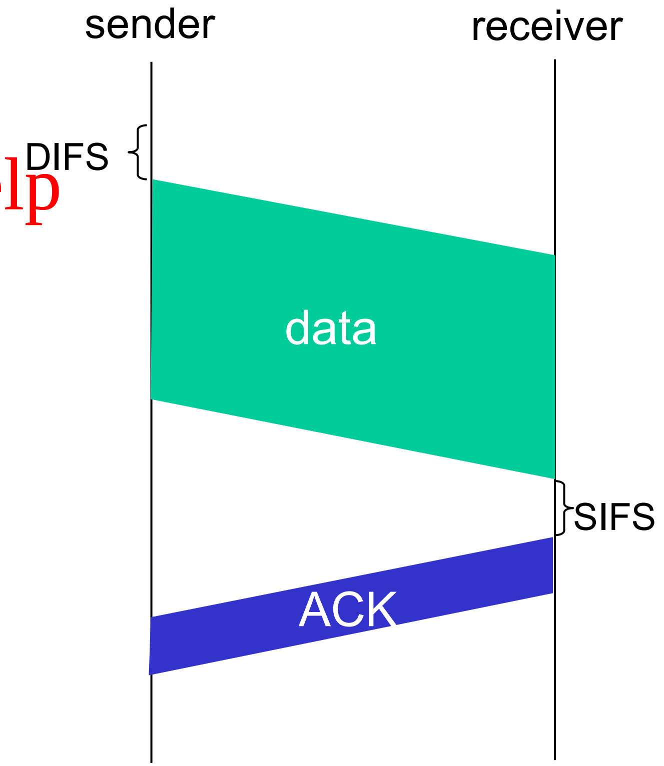


IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

1 if sense channel idle for **DIFS** then
  transmit entire frame (no CD)

2 if sense channel busy then
  start random backoff time
  timer counts down while channel idle
  transmit when timer expires
  if no ACK, increase random backoff interval, repeat 2



802.11 receiver

if frame received OK
  return ACK after **SIFS** (ACK needed due to hidden terminal problem)

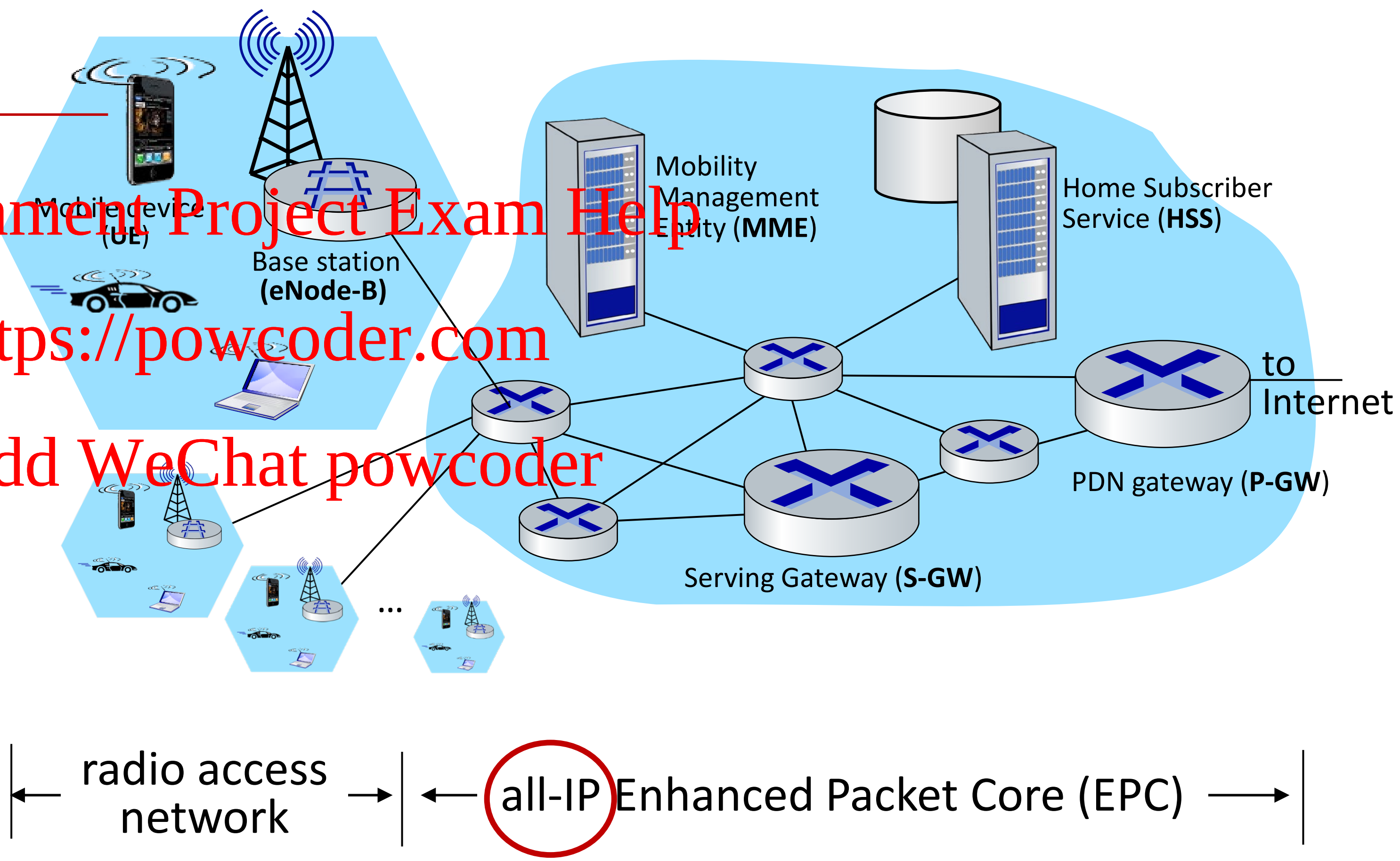
4G

- Feel free to make all relevant jokes here.
- How wide-spread mobility support for the Internet works.
- widespread deployment/use:
  - more mobile-broadband-connected devices than fixed-broadband-connected devices (5-1 in 2019)!
  - 4G availability: 97% of time in Korea (90% in US)
- transmission rates up to 100’s Mbps

Elements of 4G LTE architecture

Mobile device:

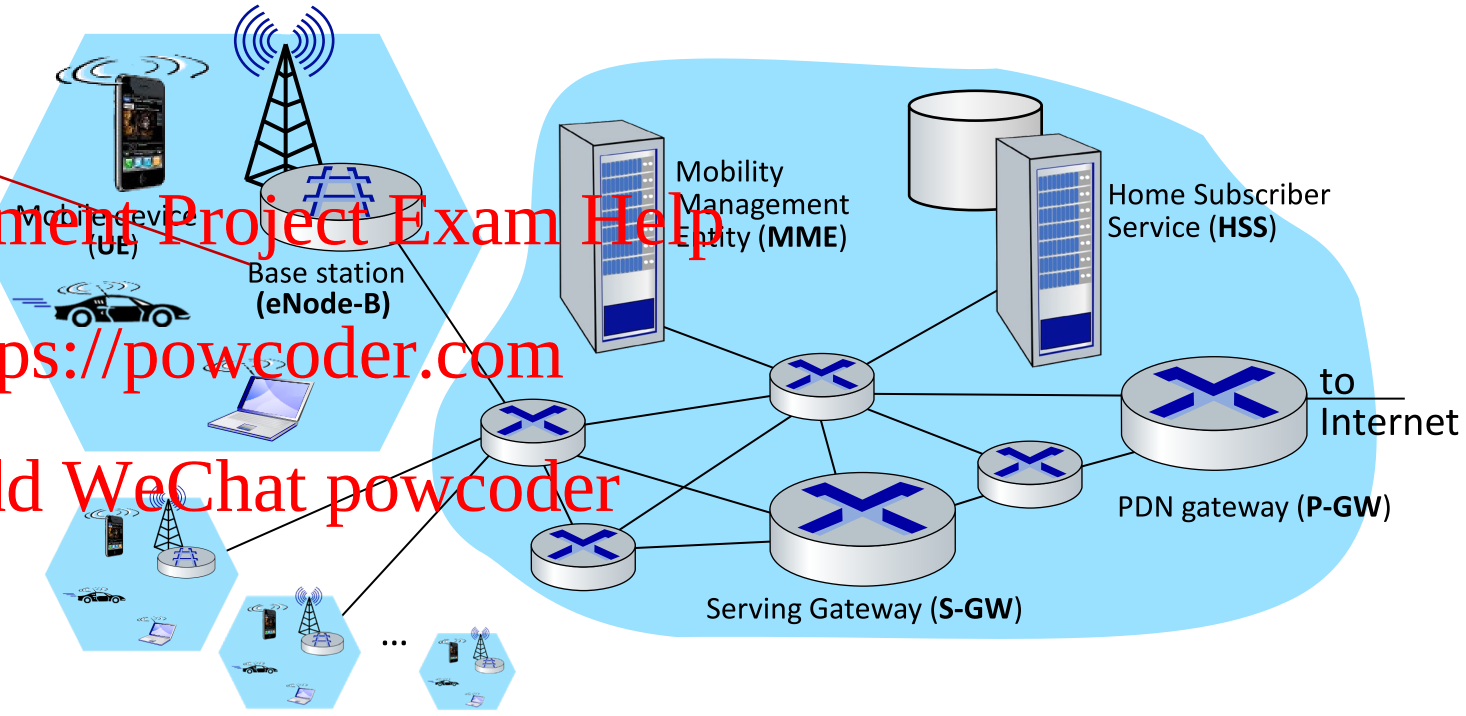
- smartphone, tablet, laptop, IoT, ... with 4G LTE radio
- 64-bit International Mobile Subscriber Identity (IMSI), stored on SIM (Subscriber Identity Module) card
- LTE jargon: User Equipment (UE)



Elements of 4G LTE architecture

Base station:

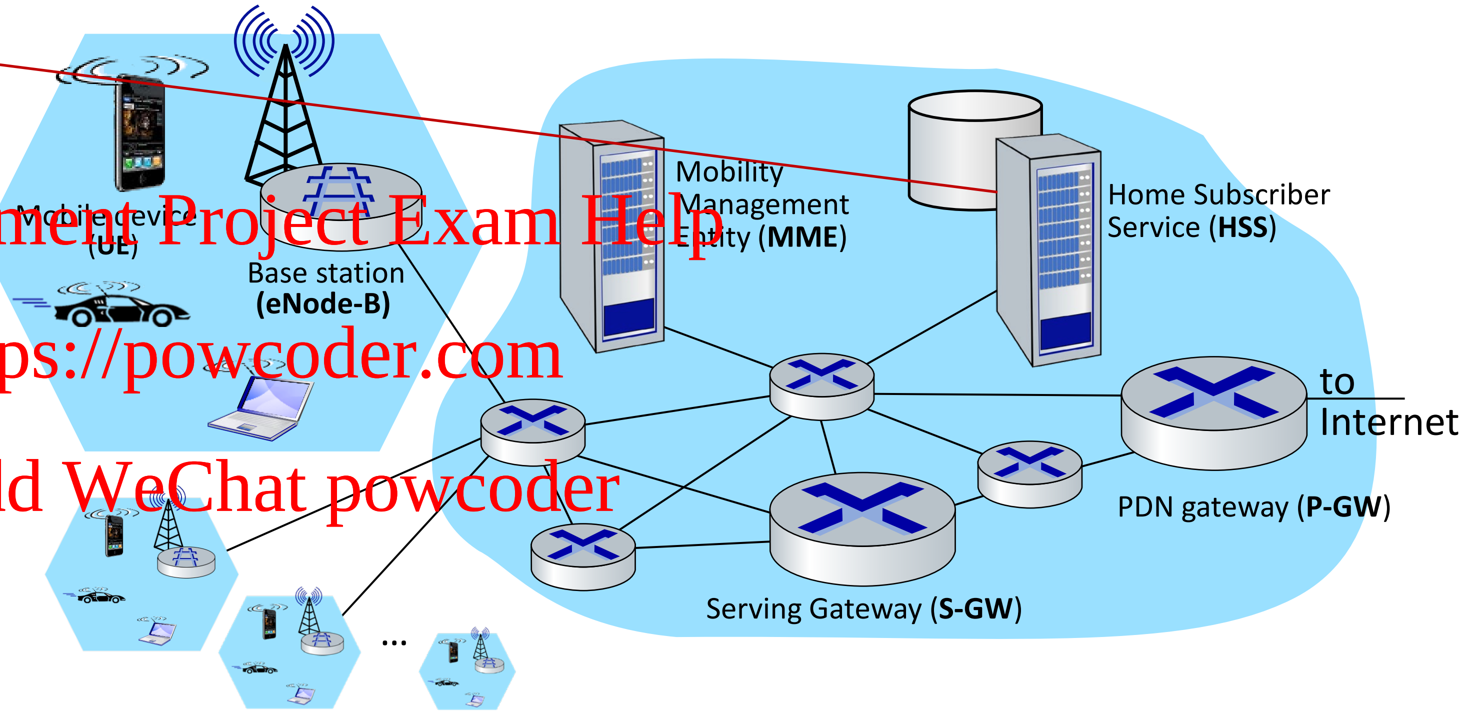
- at "edge" of carrier's network
- manages wireless radio resources, mobile devices in its coverage area ("cell")
- coordinates device authentication with other elements
- similar to WiFi AP but:
  - active role in user mobility
  - coordinates with nearly base stations to optimize radio use
- LTE jargon: eNode-B



Elements of 4G LTE architecture

Home Subscriber Service

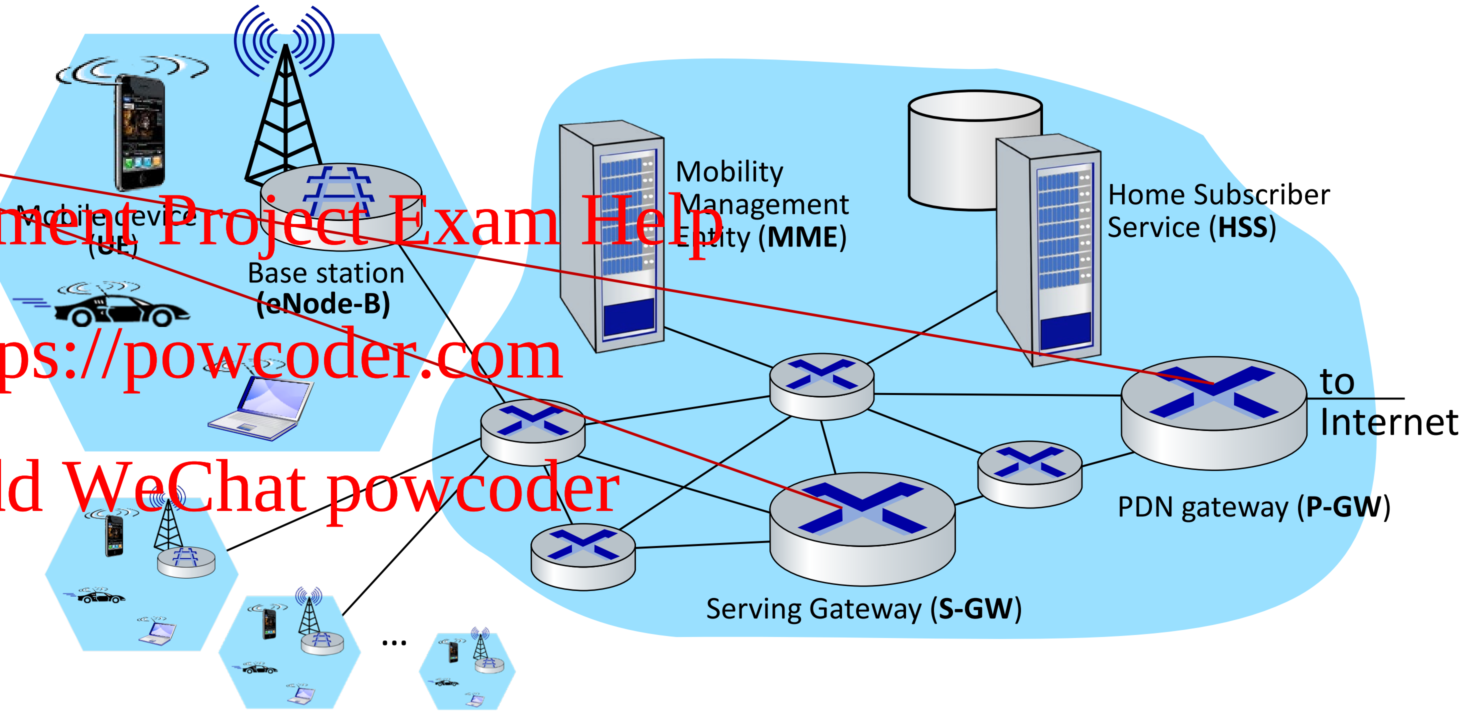
- stores info about mobile devices for which the HSS's network is their "home network"
- works with MME in device authentication



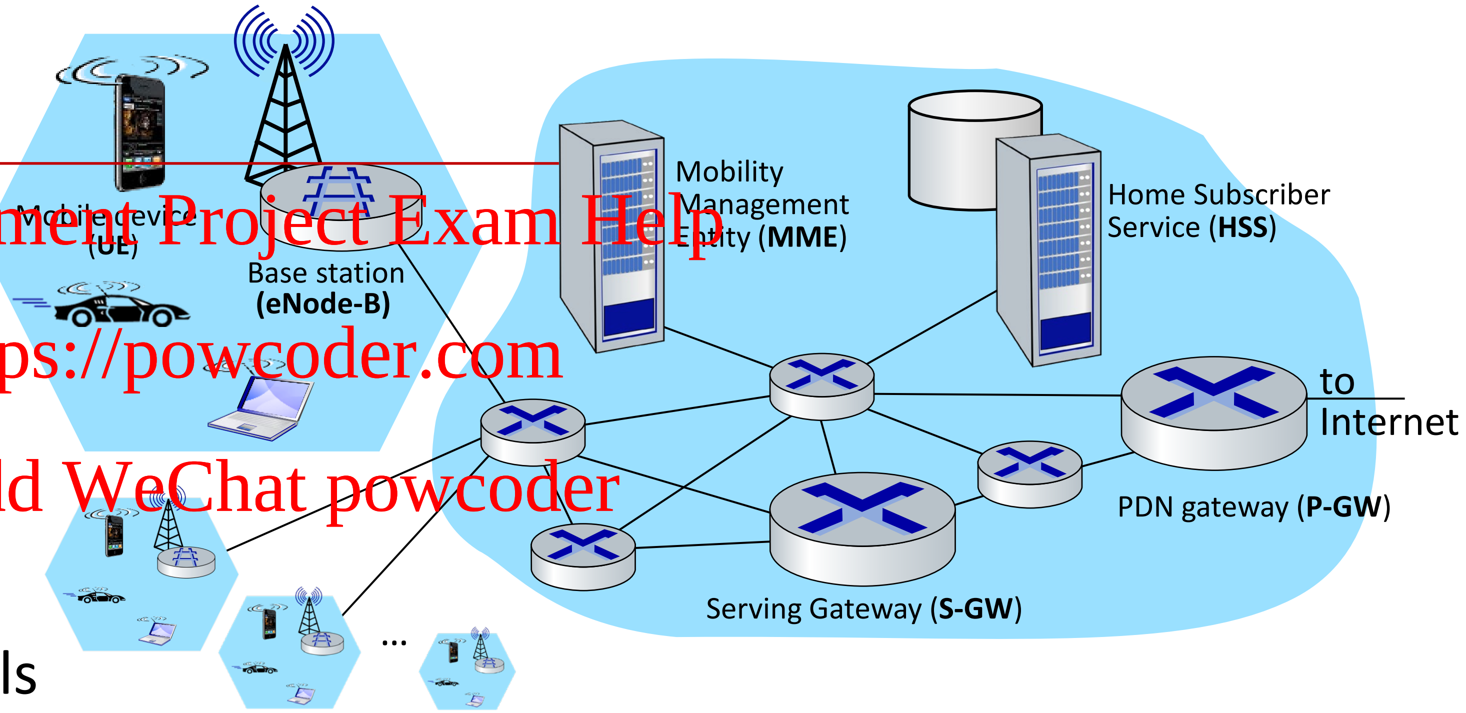
Elements of 4G LTE architecture

Serving Gateway (S-GW), PDN Gateway (P-GW)

- lie on data path from mobile to/from Internet
- P-GW
  - gateway to mobile cellular network
  - Looks like nay other internet gateway router
  - provides NAT services
- other routers:
  - extensive use of tunneling



Elements of 4G LTE architecture



Mobility Management Entity

- device authentication (device-to-network, network-to-device) coordinated with mobile home network HSS
- mobile device management:
  - device handover between cells
  - tracking/paging device location
- path (tunneling) setup from mobile device to P-GW

5G

- goal: 10x increase in peak bitrate, 10x decrease in latency, 100x increase in traffic capacity over 4G
- 5G NR (new radio):
  - two frequency bands: FR1 (450 MHz–6 GHz) and FR2 (24 GHz–52 GHz): millimeter wave frequencies
  - not backwards-compatible with 4G
  - MIMO: multiple directional antennae
- millimeter wave frequencies: much higher data rates, but over shorter distances
  - pico-cells: cells diameters: 10-100 m
  - massive, dense deployment of new base stations required