Wireless link layer: Cellular Networks; Mobility

CS 352, Lecture 17

http://www.cs.rutgers.edu/~sn624/352-S19

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(heavily adapted from slides by the textbook authors)

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Review: The wireless link layer

- Wireless medium is very different from wired
  - Signal attenuation (“fading”) much more important to handle
  - Hidden terminal problem
- Consequences of differences:
  - Link-layer ACKs
  - Transmission delays to control contention: SIFS, DIFS
  - Link reservation (RTS/CTS)
- Medium access control
  - Frequency division multiple access (AP channels in WiFi)
  - Random access (CSMA/CA for transmitting to/from WiFi AP)
  - Code division multiple access (simultaneous transmission in cellular networks)

Cellular networks: Overview

2G, 3G, 4G, 5G

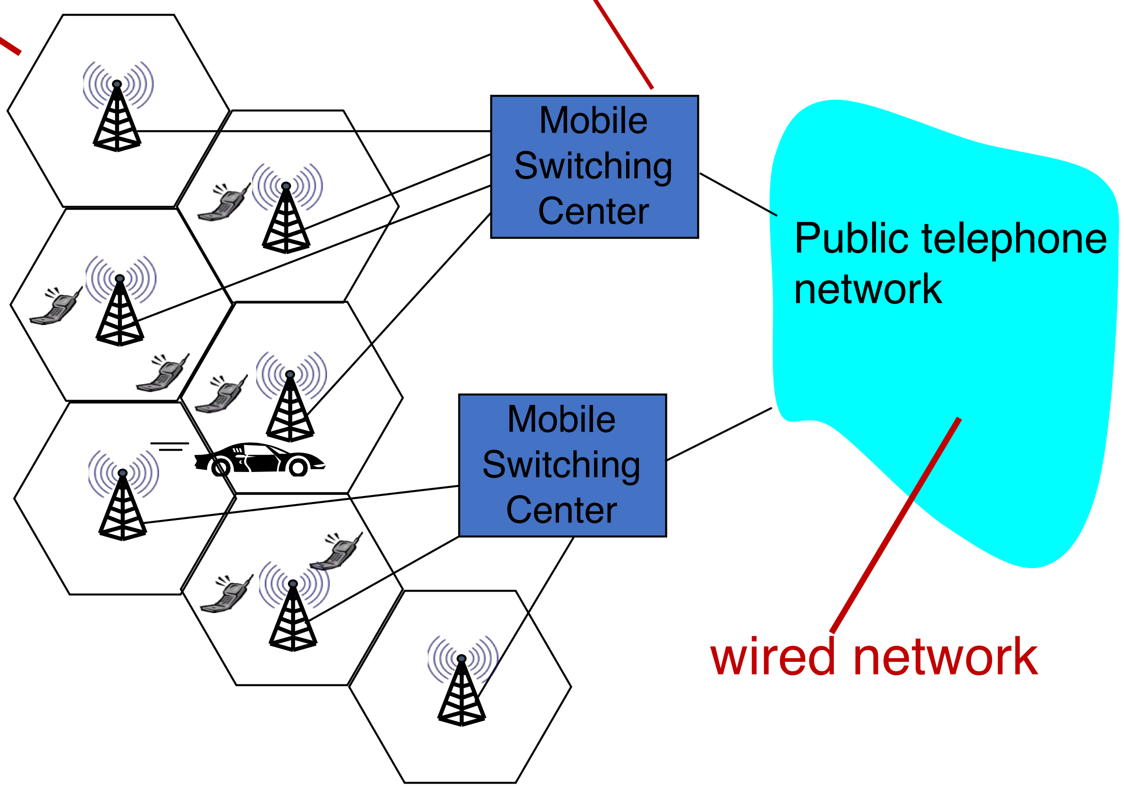
Components of cellular network architecture

MSC

- connects cells to wired tel. net.
- manages call setup (more later!)
- handles mobility (more later!)

cell

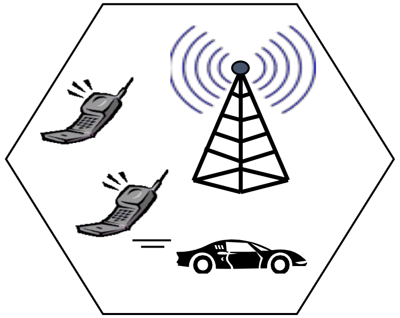
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS

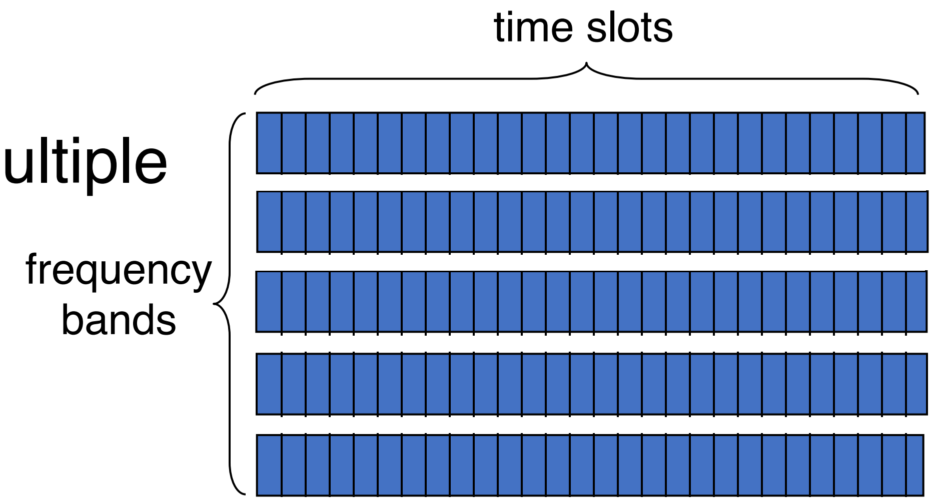


Cellular networks: the first hop

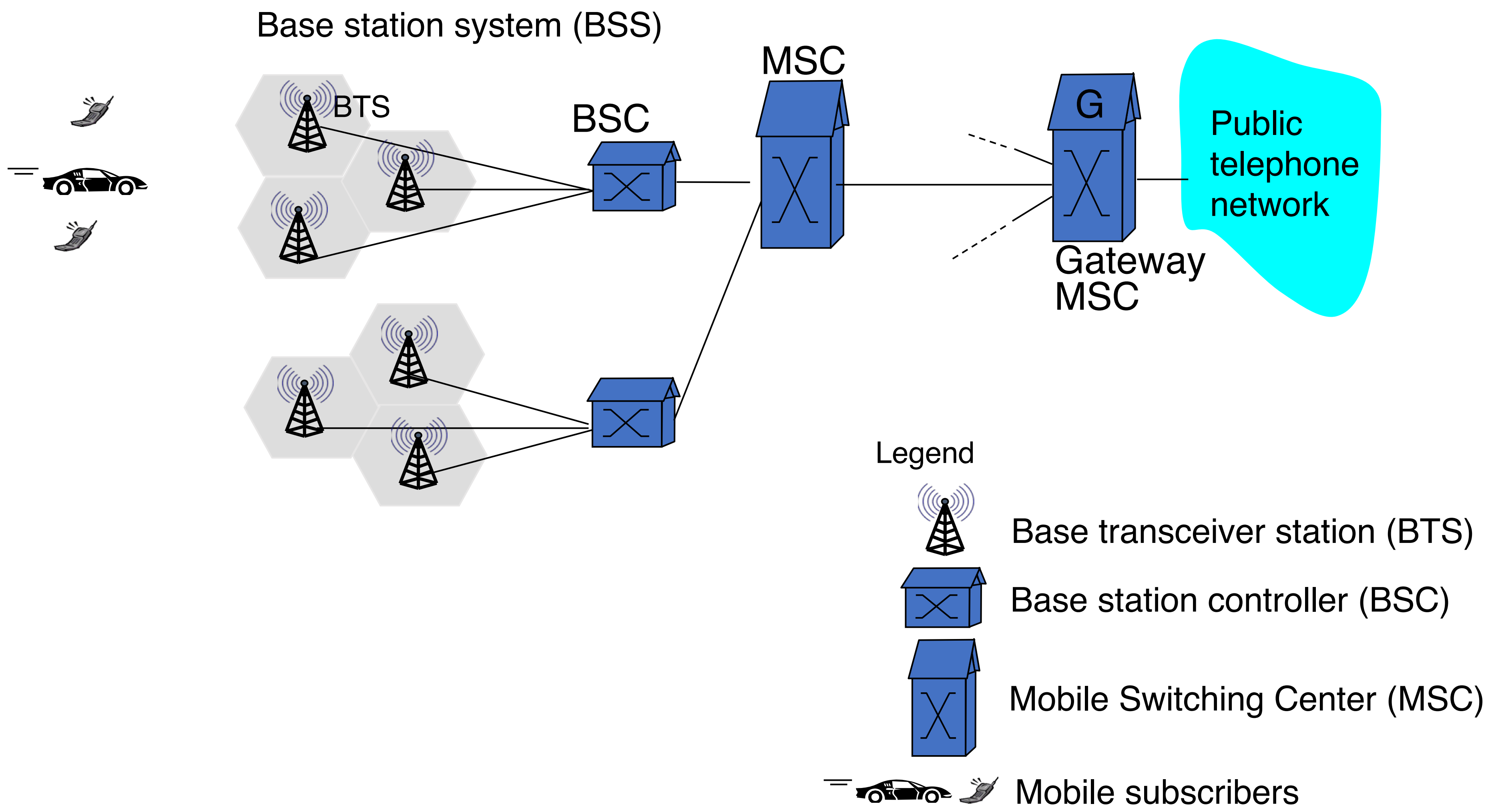
Two techniques for sharing mobile-to-BS radio spectrum

- combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots
- CDMA: code division multiple access

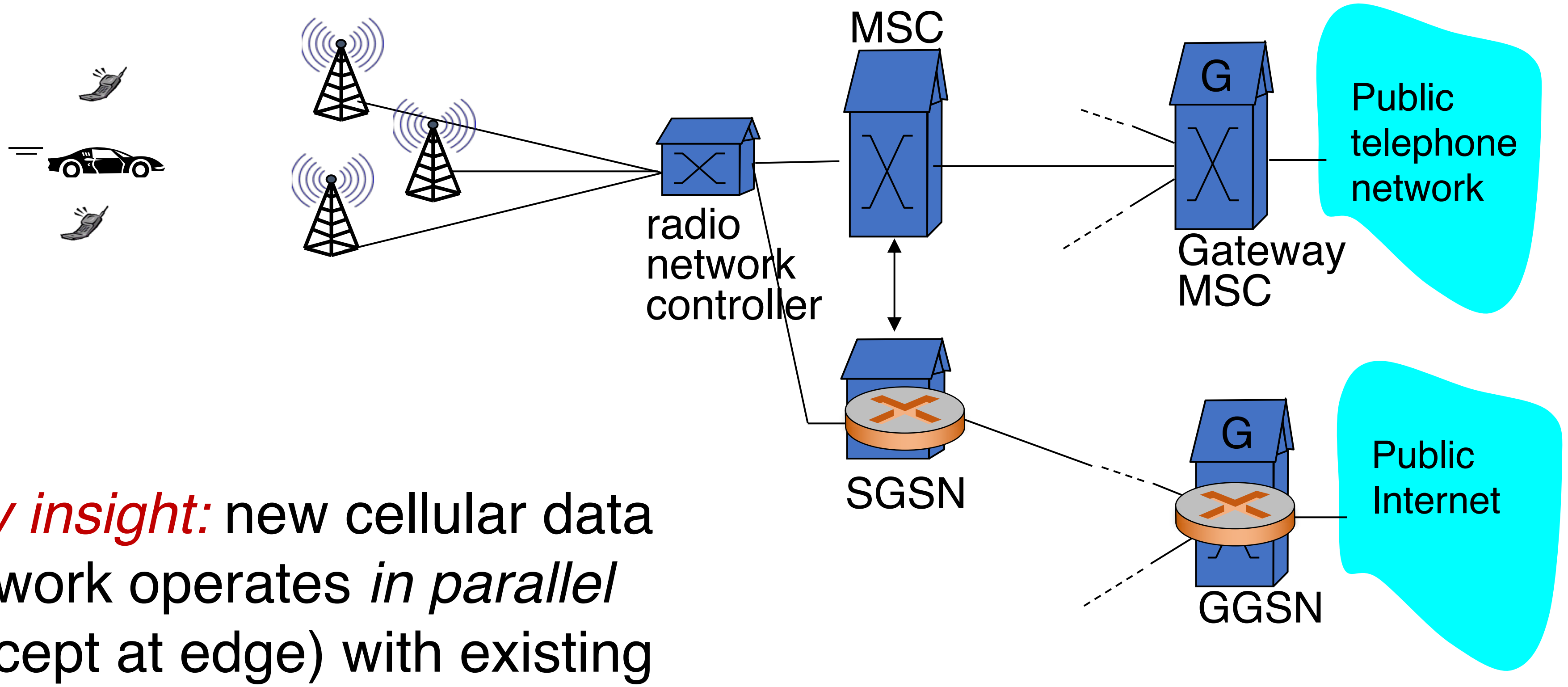


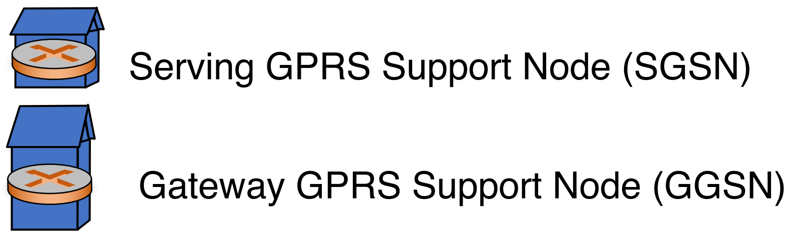


2G (voice) network architecture



3G (voice+data) network architecture

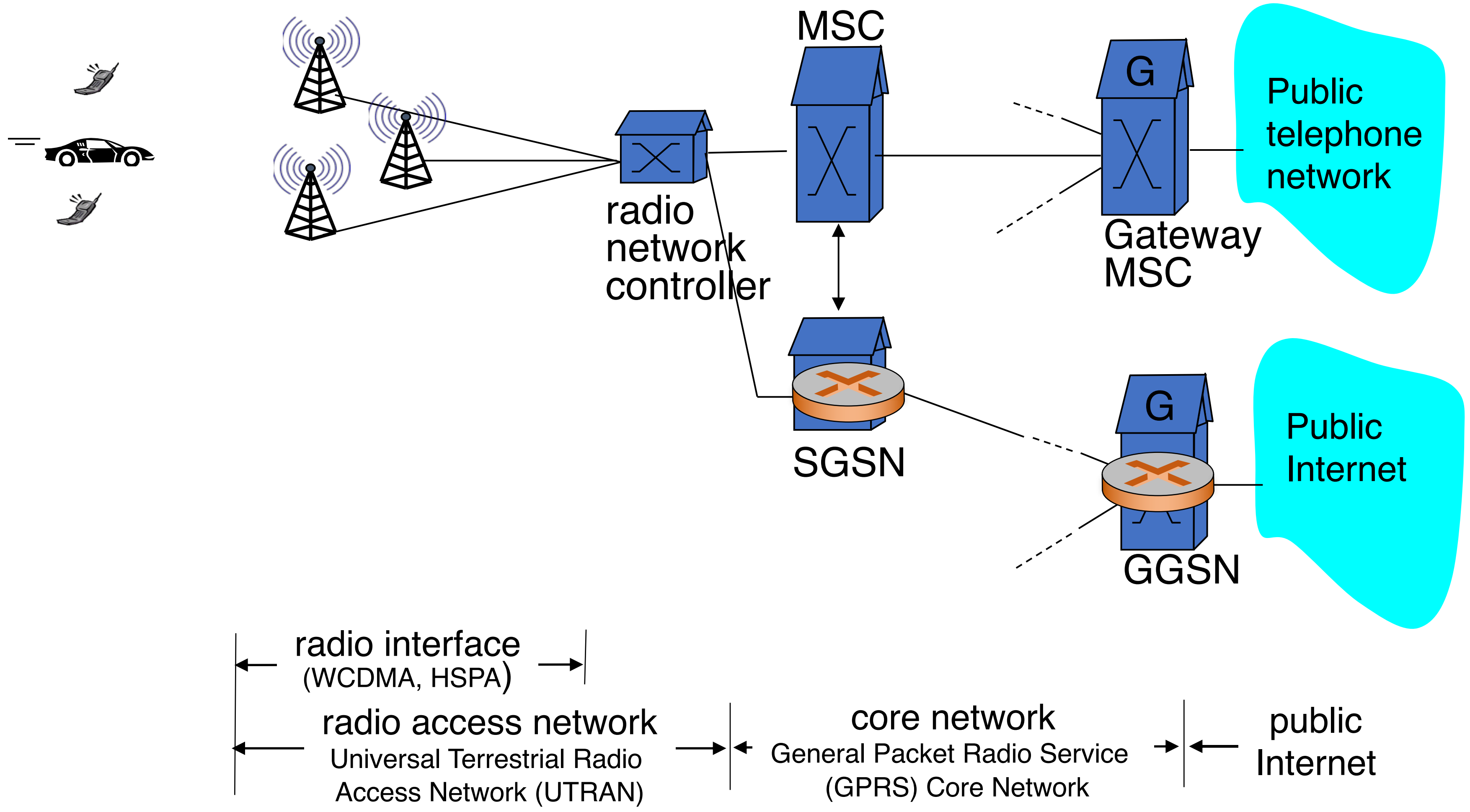




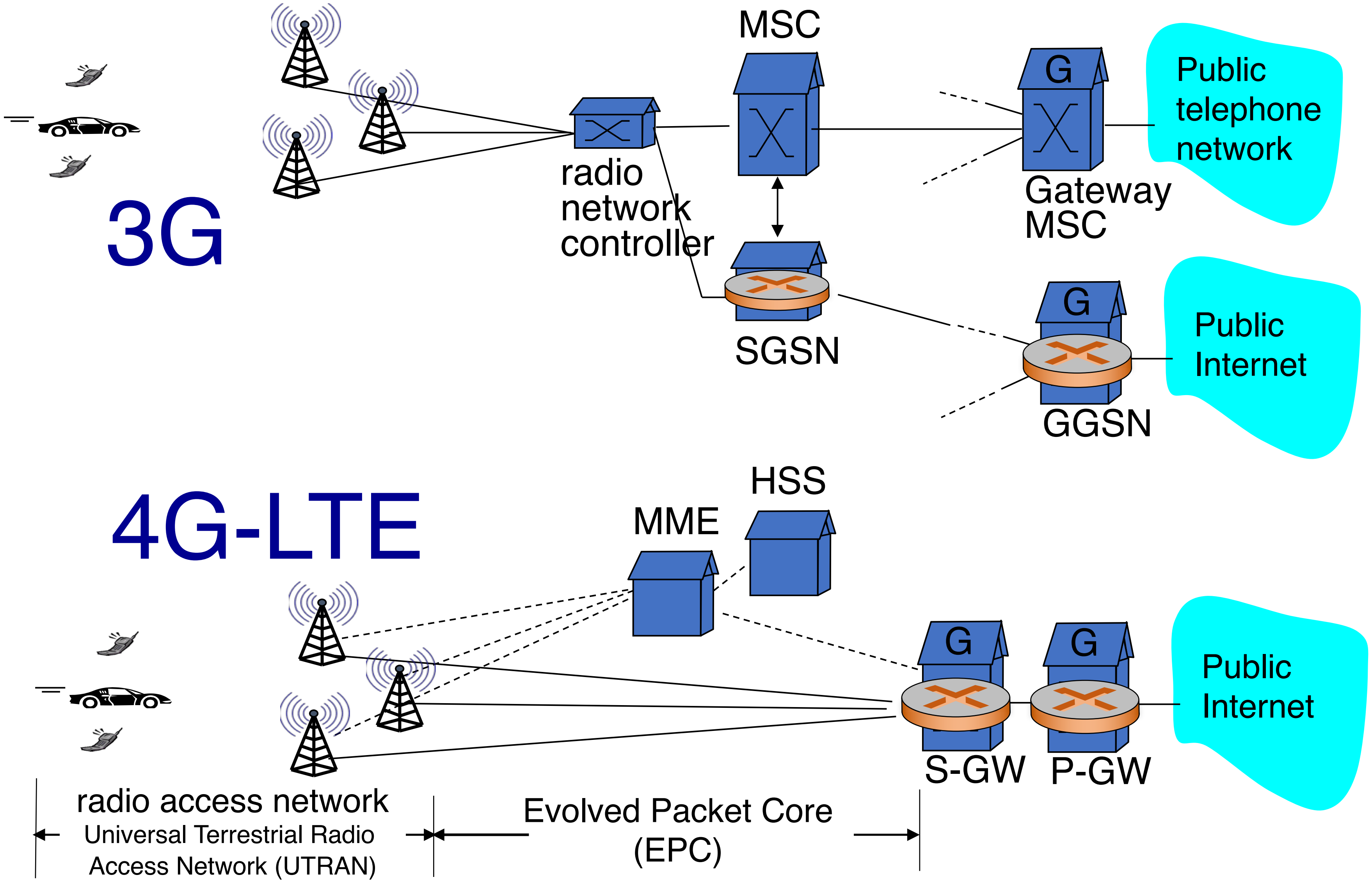
Key insight: new cellular data network operates *in parallel* (except at edge) with existing cellular voice network

- voice network *unchanged* in core
- data network operates in parallel

3G (voice+data) network architecture

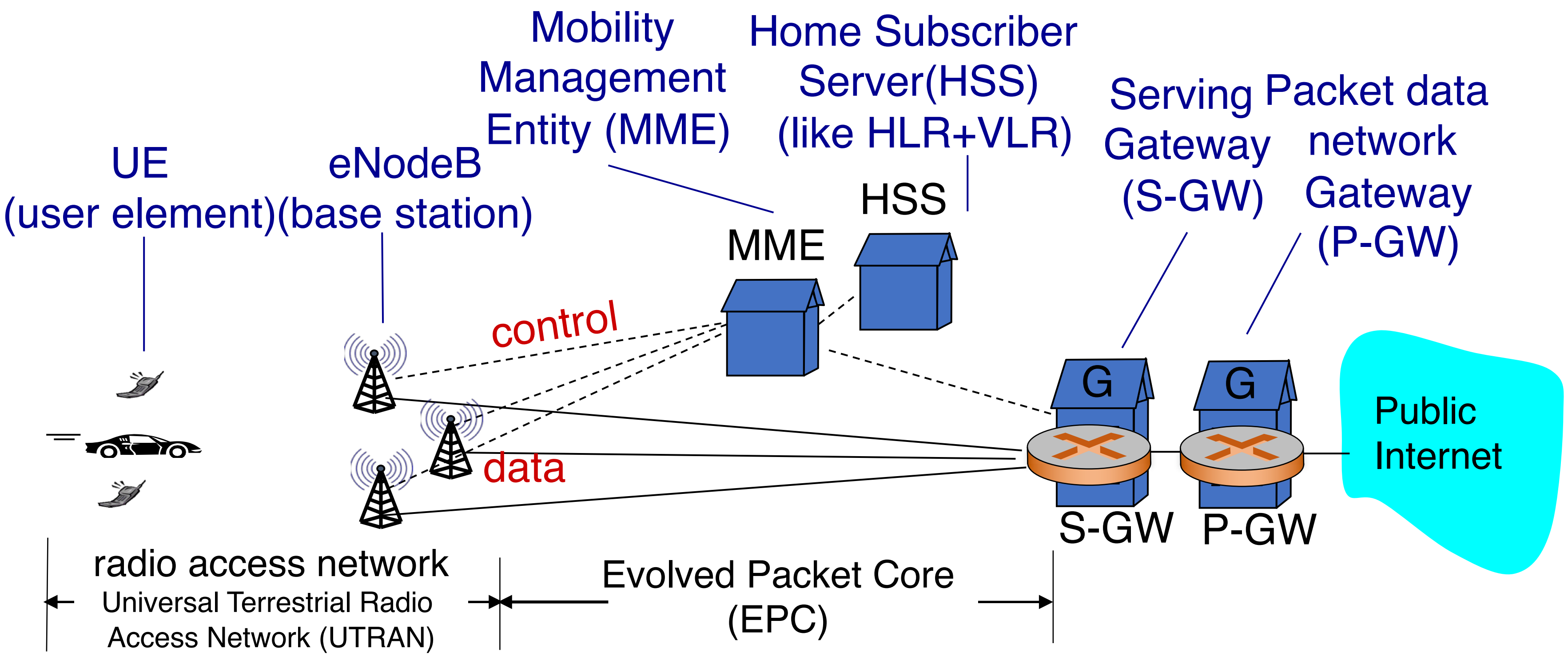


3G versus 4G LTE network architecture



4G: differences from 3G

- all IP core: IP packets tunneled (through core IP network) from base station to gateway
- no separation between voice and data – all traffic carried over IP core to gateway



5G: the next generation

- Goal: higher data rates, lower delays

- Enabled by better transmission technology
  - (you don’t need to know what these terms mean:)
  - Multiple input multiple output antennas
  - New radio frequency bands
  - Beamforming

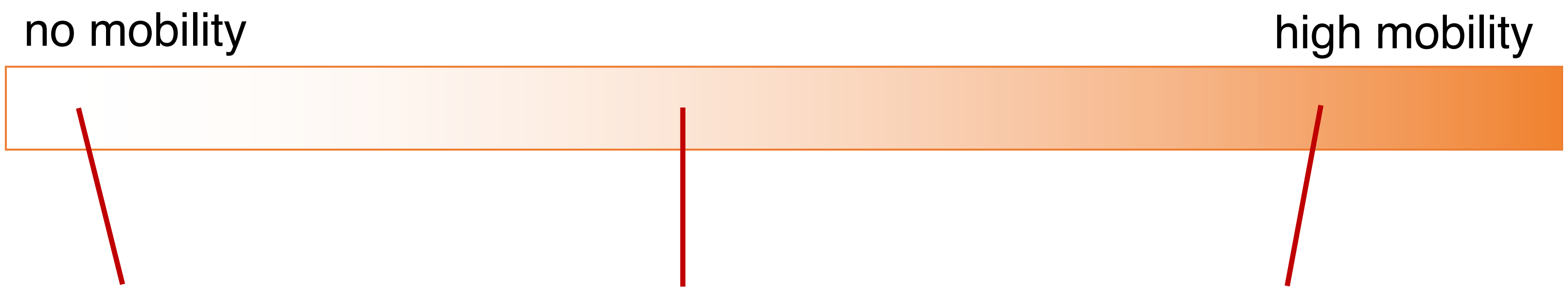
- To support novel applications
  - IoTs, edge networking, SDN, NFV, …

Mobility

How do hosts move and still retain network connectivity?

What is mobility?

- spectrum of mobility, from the *network* perspective:



mobile wireless user, using same access point

mobile user, connecting/ disconnecting from network using DHCP.

mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

Questions: IP addresses and routing

- An IP address refers to the point of attachment of a host to a network
- So, when a host moves, should its IP address change?
- What is the impact on the higher layers of the protocol stack?
- How will remote hosts reach (route to) the mobile host?
  - New connections?
  - Ongoing connections?

How do *you* contact a mobile friend:

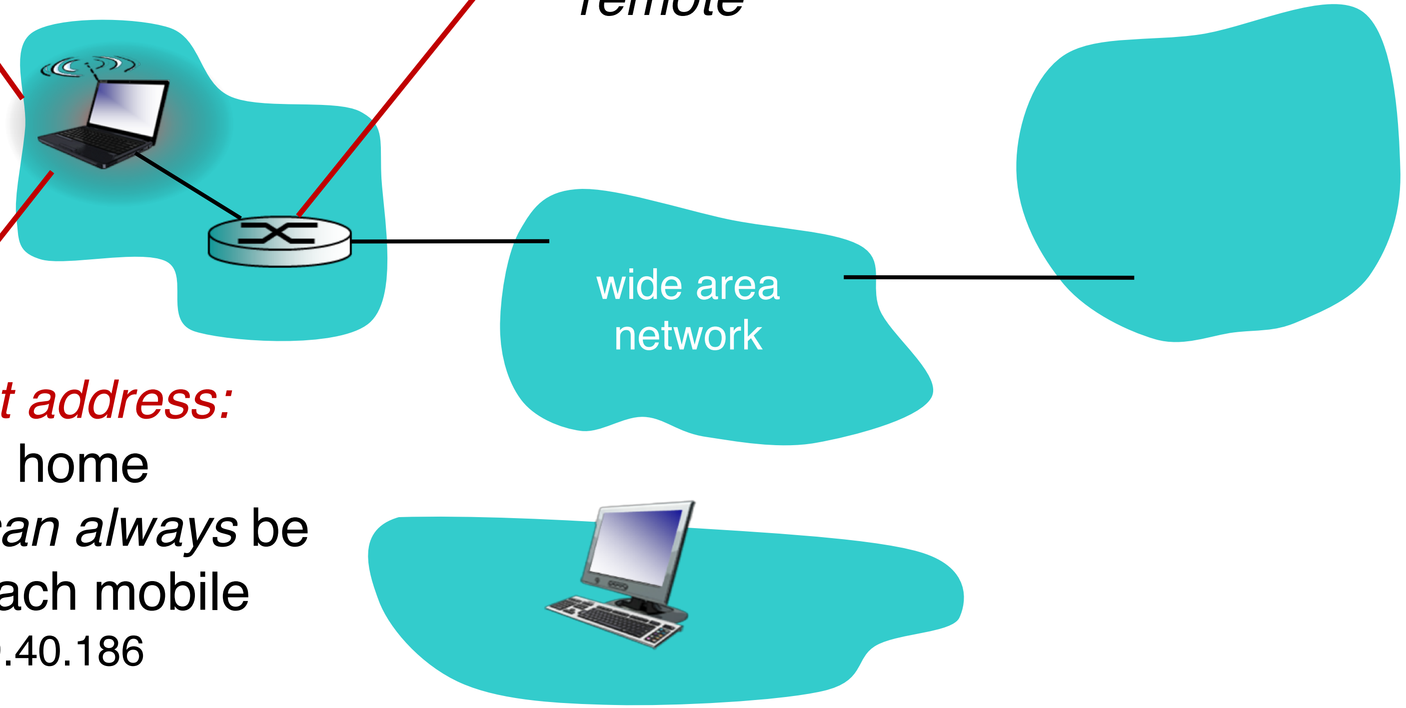
Consider friend frequently changing addresses, how do you find her?

- search all phone books?
- call her parents?
- expect her to let you know where he/she is?
- Facebook!

Mobility: vocabulary

home network: permanent "home" of mobile
(e.g., 128.119.40/24)

home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote



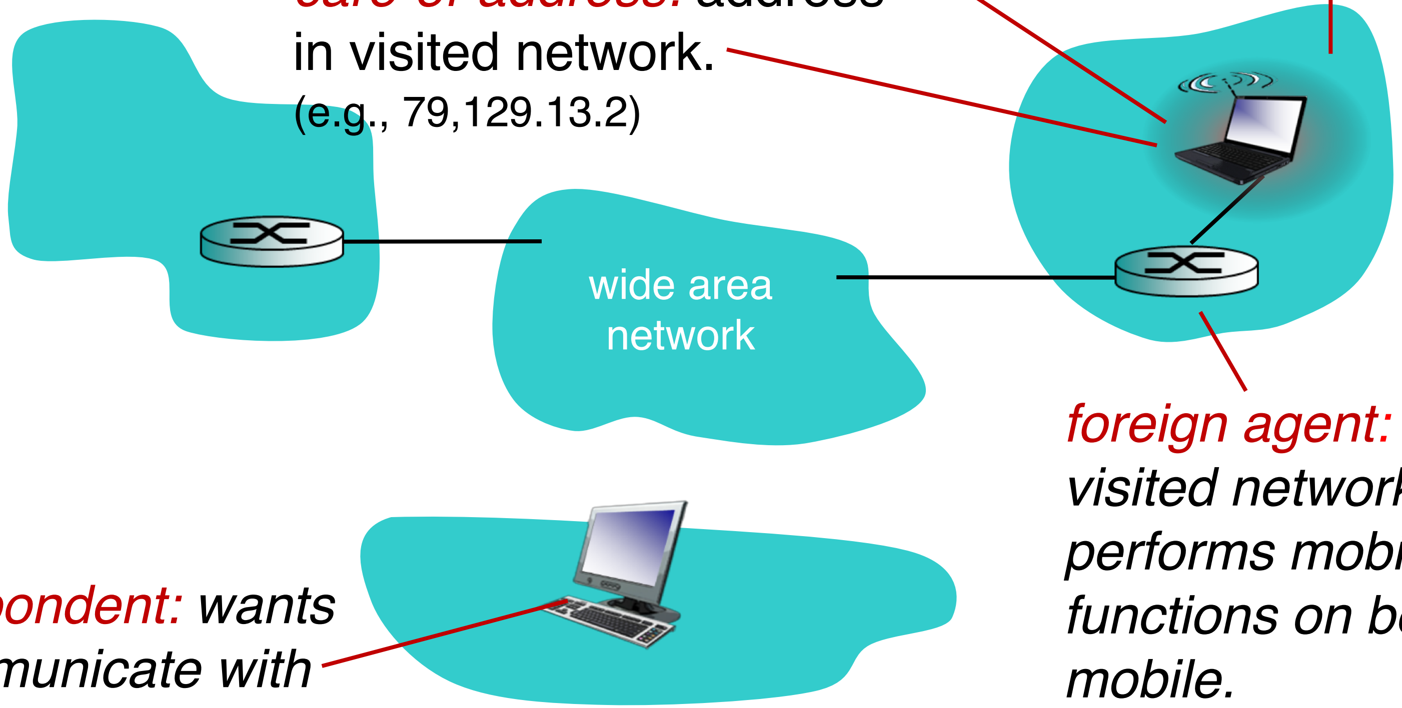
permanent address:
address in home network, *can always* be used to reach mobile
e.g., 128.119.40.186

Mobility: more vocabulary

permanent address: remains constant (e.g., 128.119.40.186)

visited network: network in which mobile currently resides (e.g., 79.129.13/24)

care-of-address: address in visited network. (e.g., 79,129.13.2)



foreign agent: entity in visited network that performs mobility functions on behalf of mobile.

correspondent: wants to communicate with mobile

Mobility: approaches

- *let routing handle it:* routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
  - routing tables indicate where each mobile located
  - no changes to end-systems
- *let end-systems handle it:*
  - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
  - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

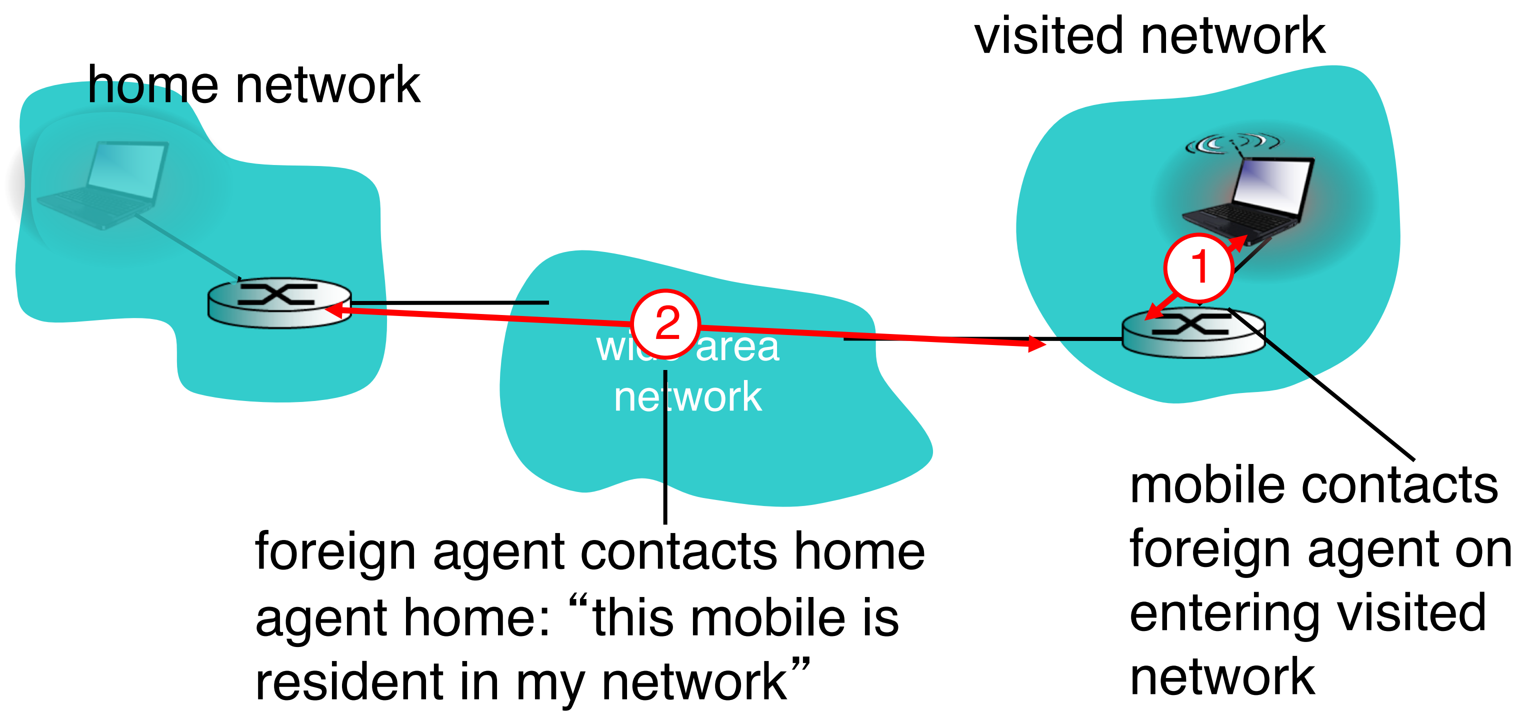
Mobility: approaches

- *let routing handle it:* routers advertise permanent address of mobile ... -residence via usual routing table exc...
  - routing table... ere each mobile located
  - no changes to e... ems

not scalable to millions of mobiles

- *let end-systems handle it:*
  - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
  - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

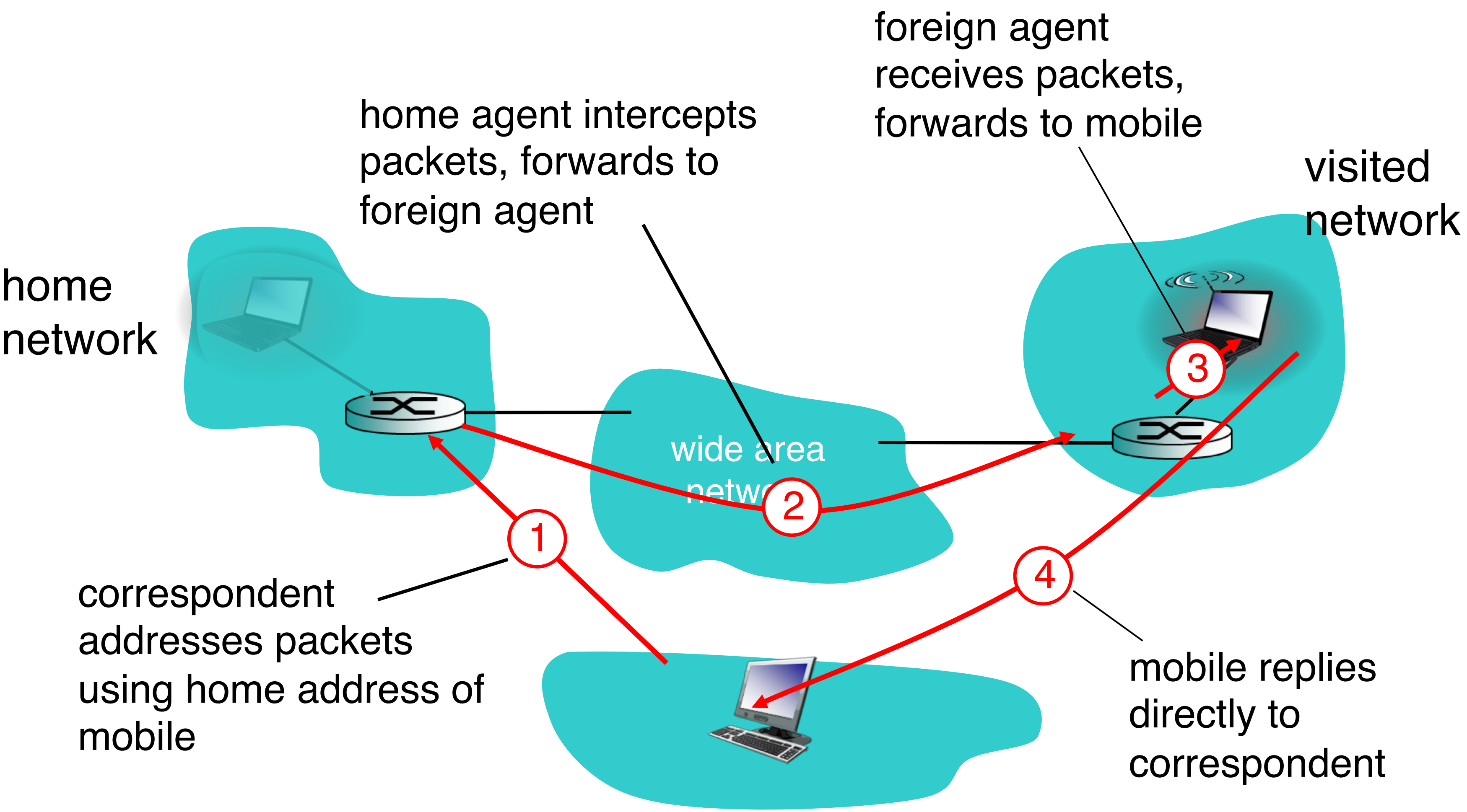
Mobility: registration



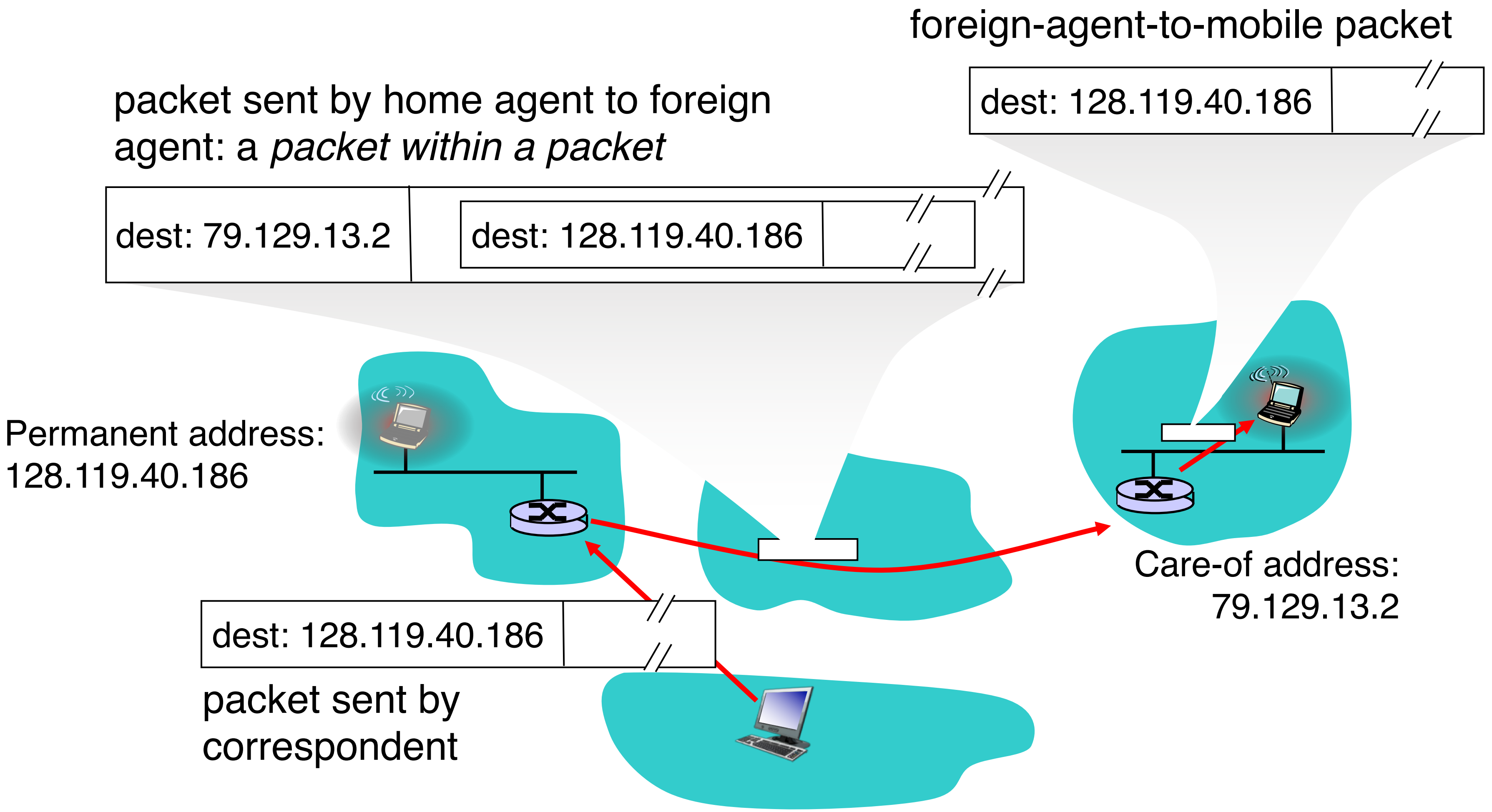
end result:

- foreign agent knows about mobile
- home agent knows location of mobile

Mobility via indirect routing

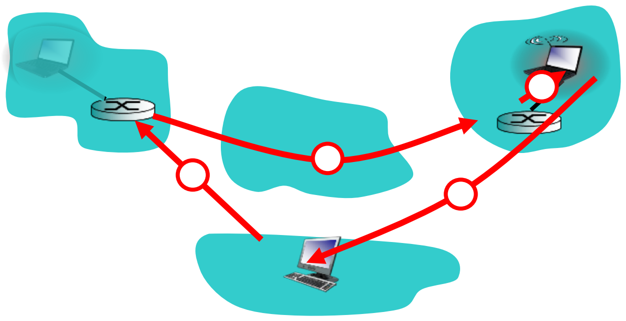


Mobile IP: indirect routing



Indirect Routing: comments

- mobile uses two addresses:
  - permanent address: used by correspondent (hence mobile location is *transparent* to correspondent)
  - care-of-address: used by home agent to forward datagrams to mobile
- foreign agent functions may be done by mobile itself
- triangle routing: correspondent-home-network-mobile
  - inefficient when correspondent, mobile are in same network

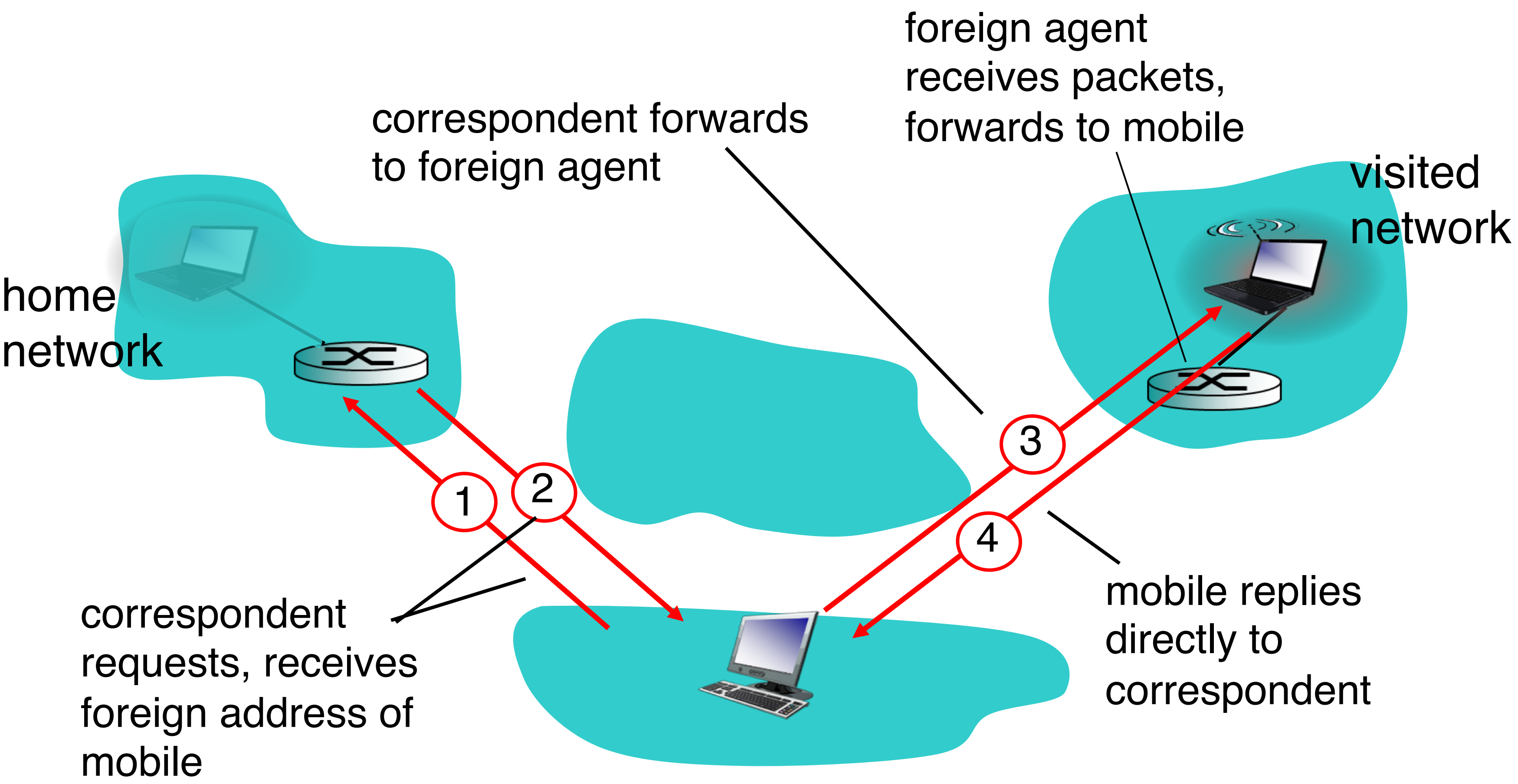


Indirect routing: moving between networks

- suppose mobile user moves to another network
  - registers with new foreign agent
  - new foreign agent registers with home agent
  - home agent update care-of-address for mobile
  - packets continue to be forwarded to mobile (but with new care-of-address)

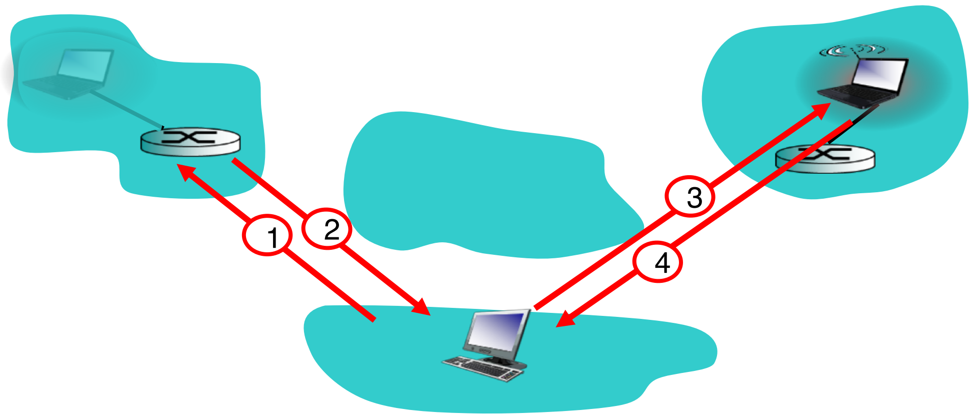
- mobility, changing foreign networks transparent: *on going connections can be maintained!*

Mobility via direct routing



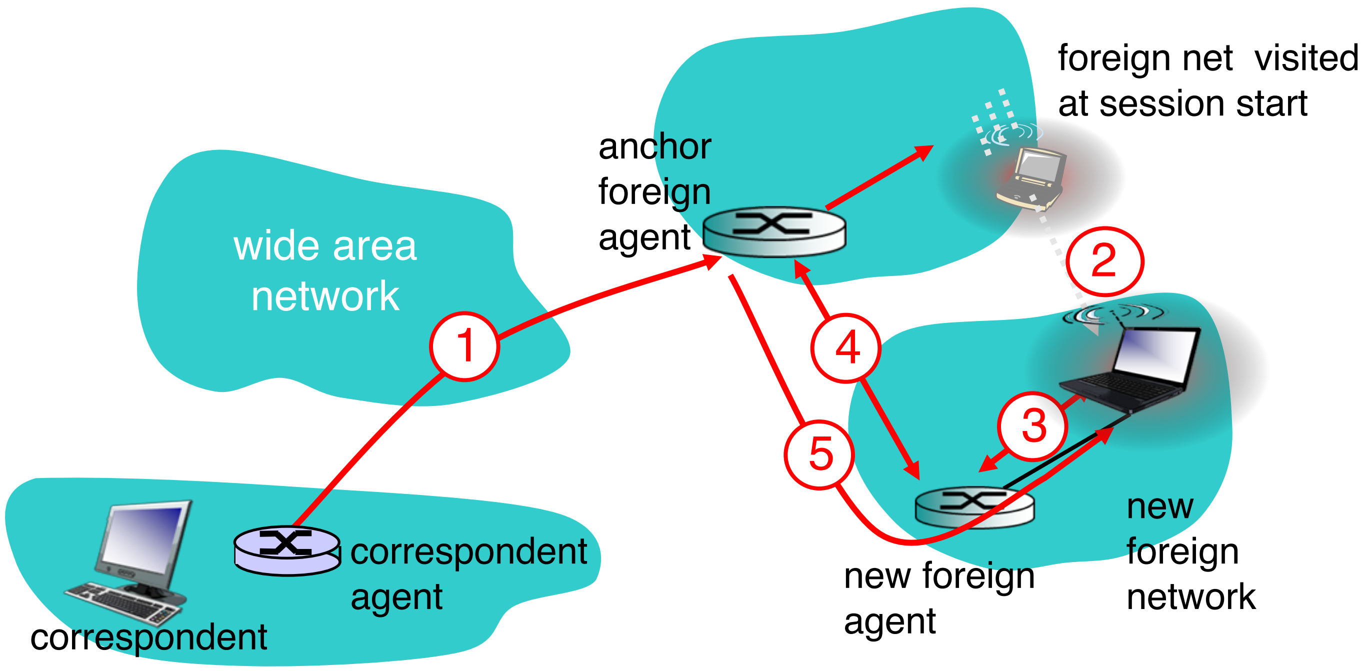
Mobility via direct routing: comments

- overcome triangle routing problem
- *non-transparent to correspondent:* correspondent must get care-of-address from home agent
  - what if mobile changes visited network?



Accommodating mobility with direct routing

- anchor foreign agent: FA in first visited network
- data always routed first to anchor FA
- when mobile moves: new FA arranges to have data forwarded from old FA (chaining)



Real implementations of mobility (1)

- Mobile IP: an extension to the IP protocol for mobility
  - RFC 3344
- Uses indirect routing + packet encapsulation
  - Registration protocol for home agent when mobile visits a different net
  - Agent discovery to let home agent know about foreign agent

Real implementations of mobility (2)

- Cellular network handoff
  - Can change base station associated with your phone due to better signal strength, load shedding, and yes, mobility :)
- Handoff between base stations uses indirect routing
  - Lots of resources set up to ensure calls don’t get dropped
  - Corresponding overheads
- Handoff between multiple Mobile Switching Stations (MSCs)
  - “Anchor MSC” from the first visited MSC
  - Chain of MSCs forwards packets

Impact of mobility on higher-layer protocols

Wireless, mobility: impact on higher layer protocols

- logically, impact *should* be minimal …
  - best effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- … but performance-wise:
  - packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handoff
  - TCP interprets loss as congestion, will decrease congestion window un-necessarily
  - delay impairments for real-time traffic
  - limited bandwidth of wireless links

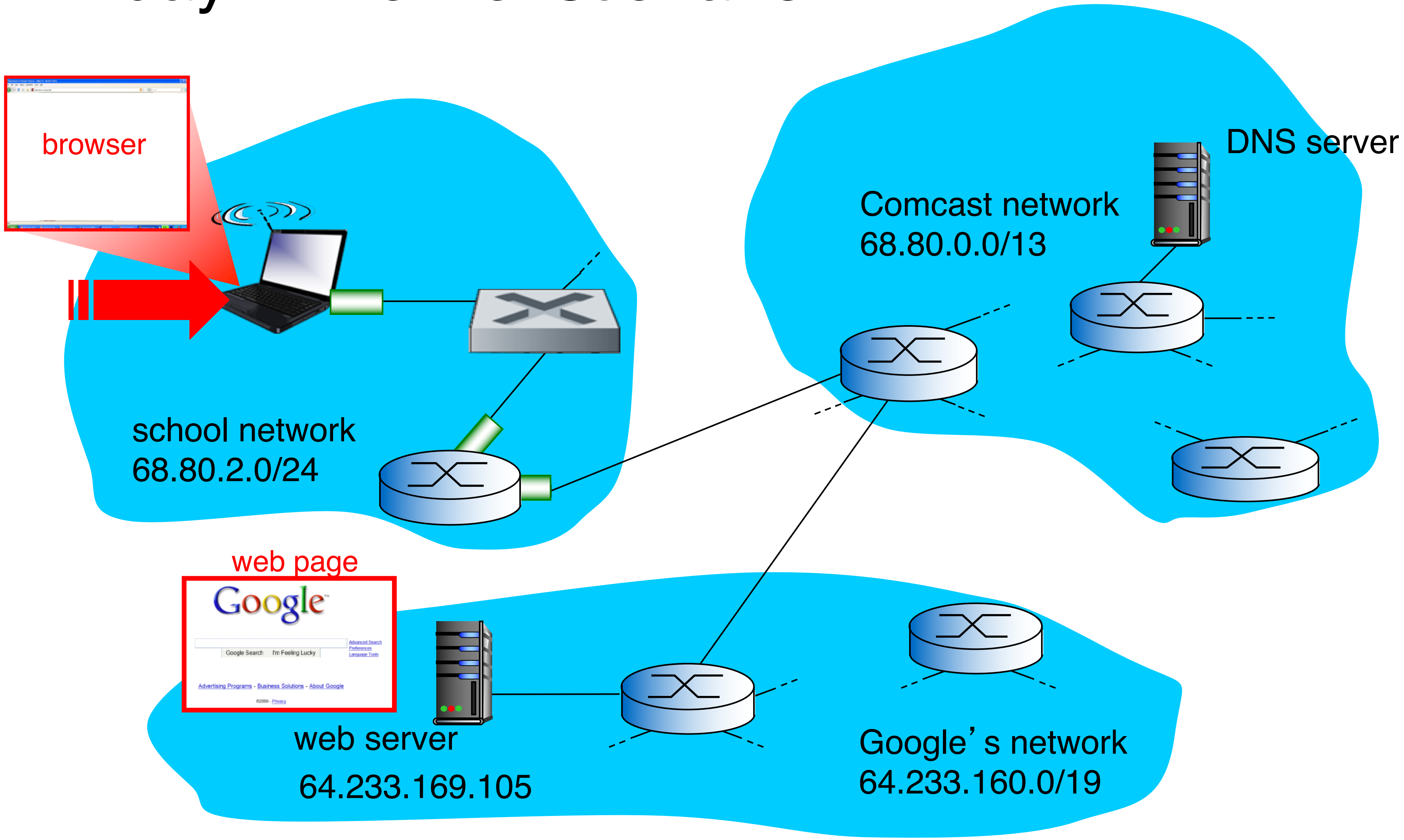
Synthesis of protocols

Synthesis: a day in the life of a web request

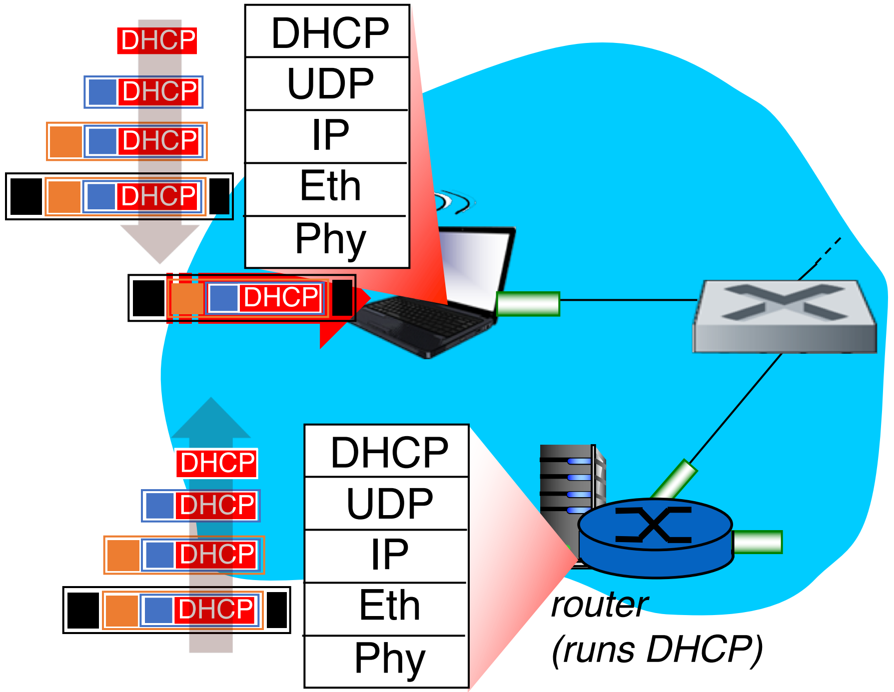
- Our journey down protocol stack complete!
  - application, transport, network, link

- 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



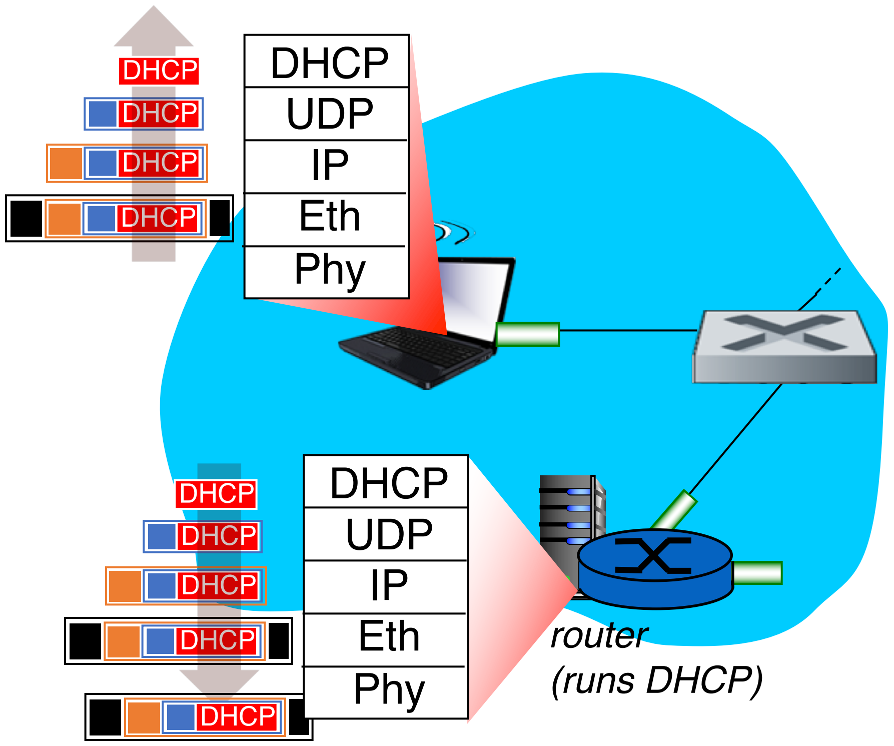
- connecting laptop needs to get its own IP address, addr of first-hop router, addr of DNS server: use *DHCP*

- 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



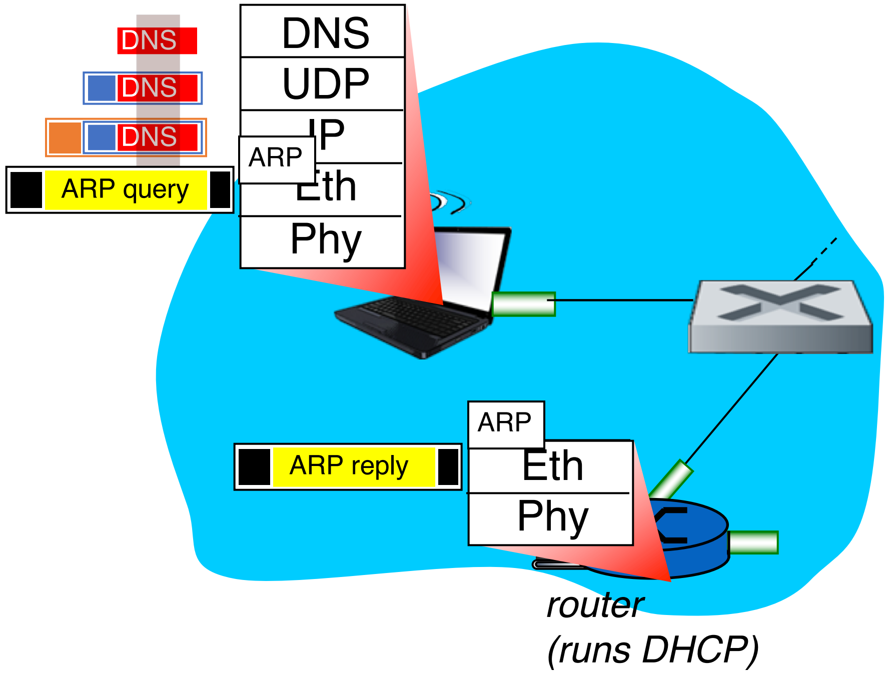
- DHCP server formulates *DHCP ACK* containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server

- 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)

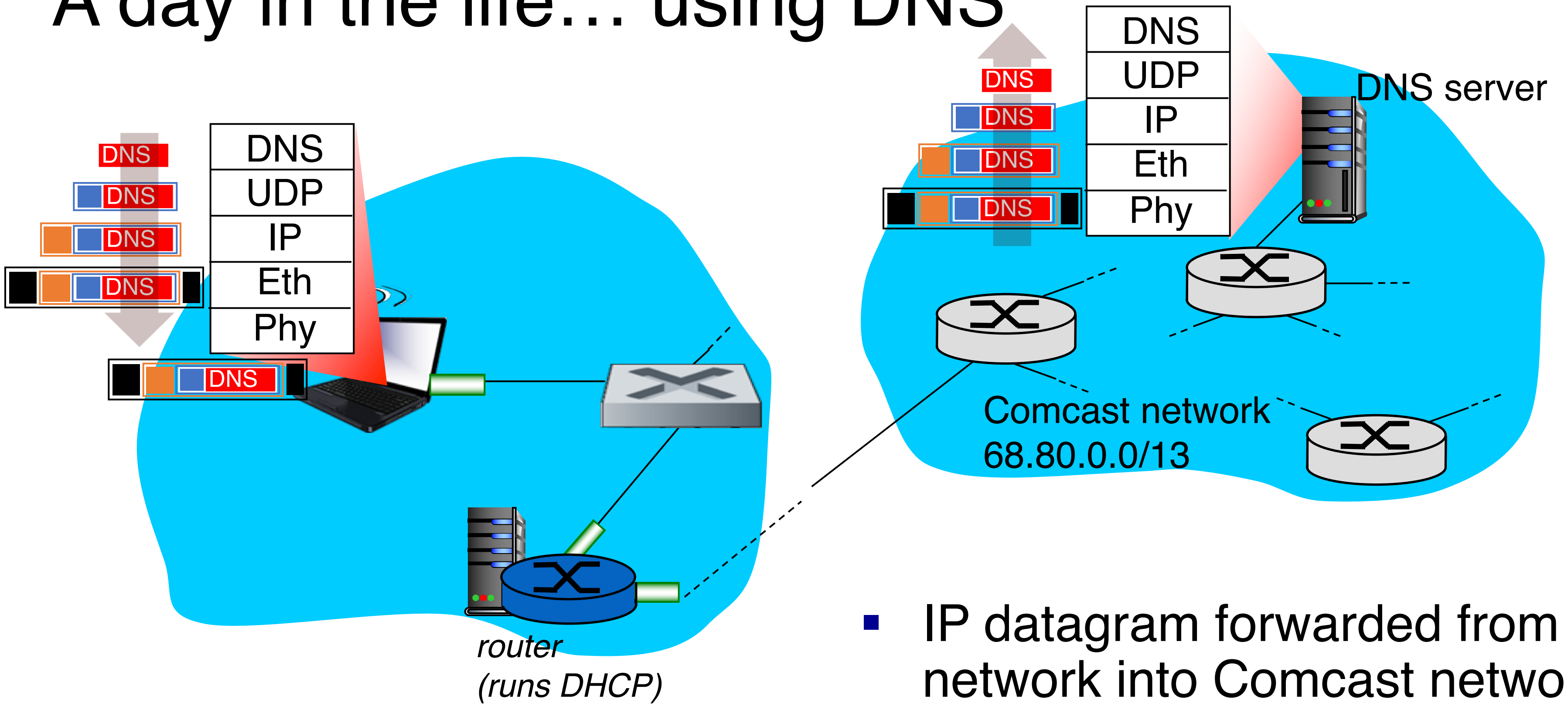


- before sending *HTTP* request, need IP address of www.google.com: *DNS*

- 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

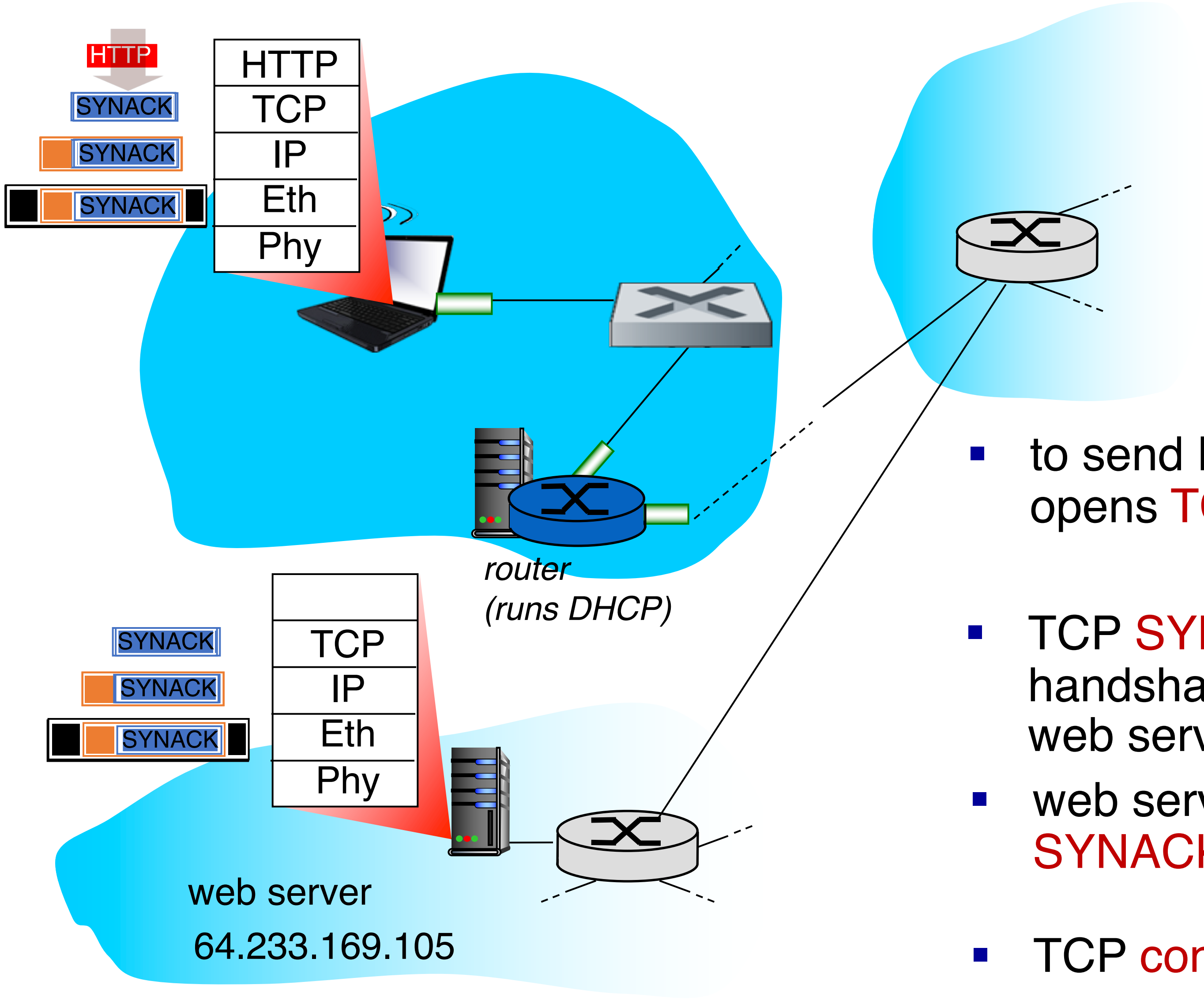


- IP datagram containing DNS query forwarded via LAN switch from client to 1st hop router

- 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

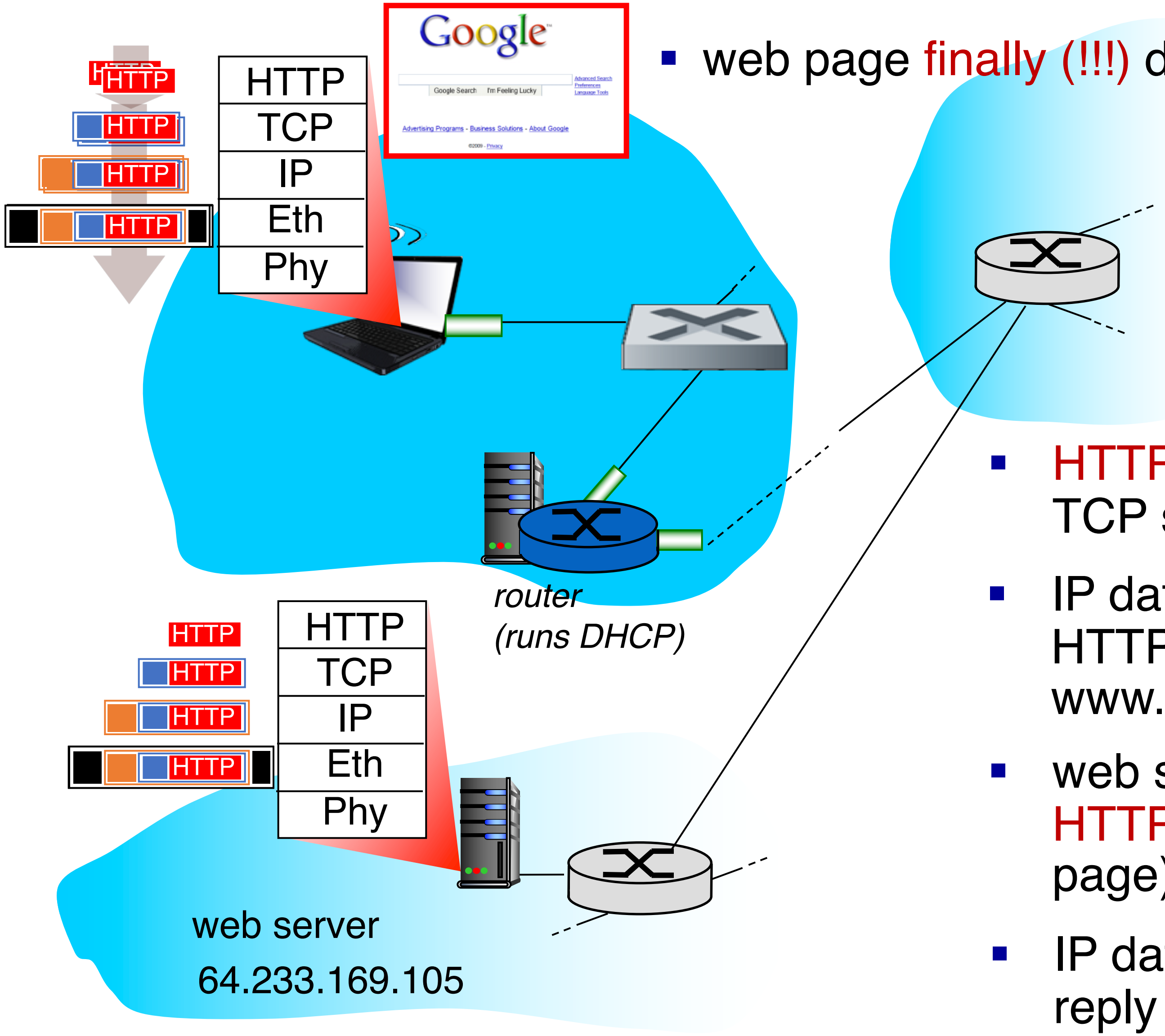
- demuxed to DNS server
- DNS server replies to client with IP address of www.google.com

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