UNIVERSITY OF SCIENCE AND TECHNOLOGY OF HANOI

USTH
VIETNAM FRANCE UNIVERSITY

Network Simulation

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Lecture 2:
Computer Networks revise

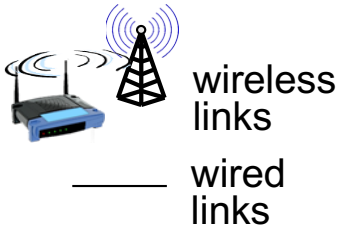
- Terminology
  - Internet
  - Protocol
  - Network edge
  - Network core
- Network performance
- Protocol layers and service models
- Link layer
- Wireless networks

Source: Computer Networking, A Top-Down Approach, J.F Kurose and K.W. Ross.

Terminology

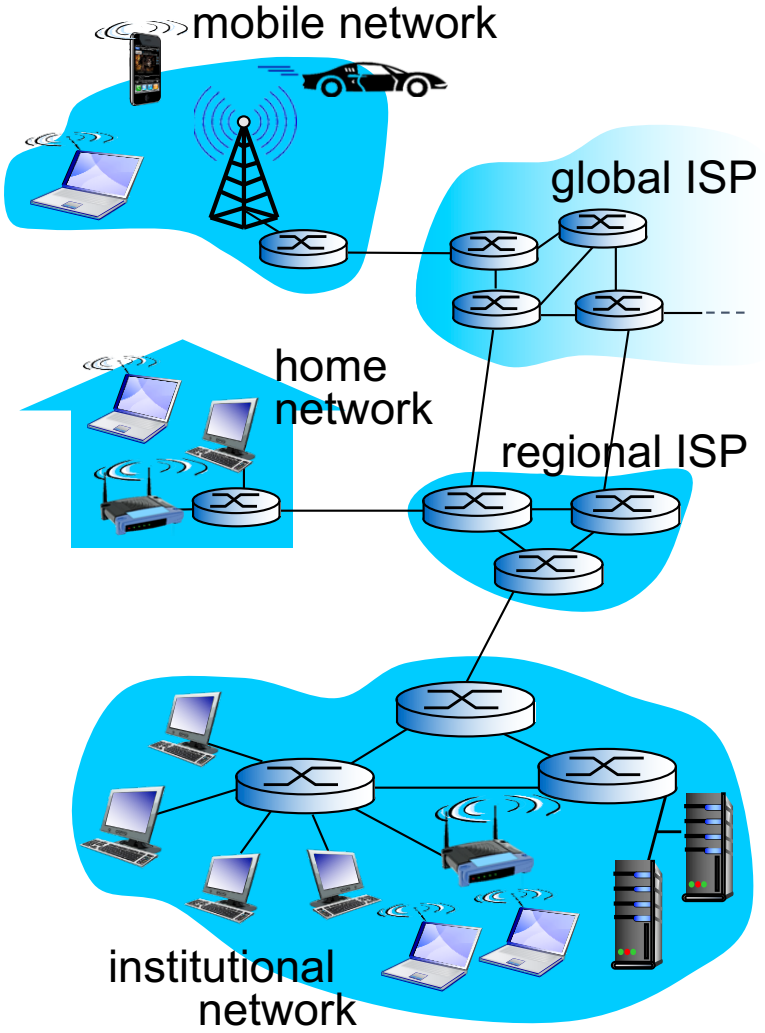
Internet

- millions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*



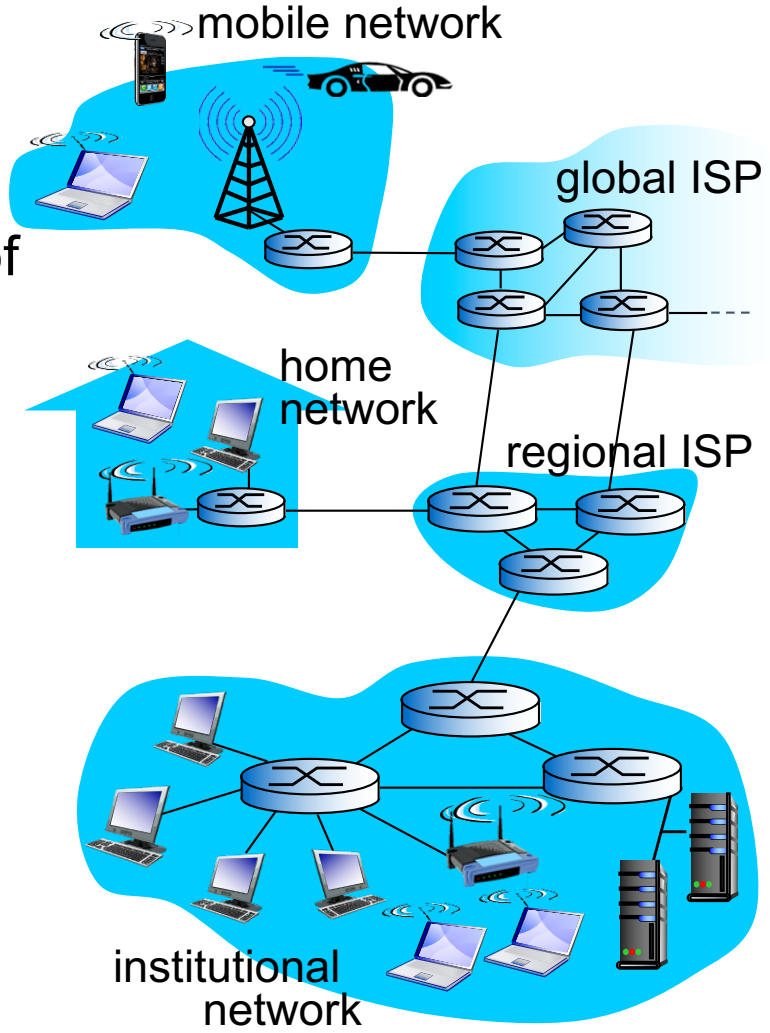
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

- *Packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



Internet

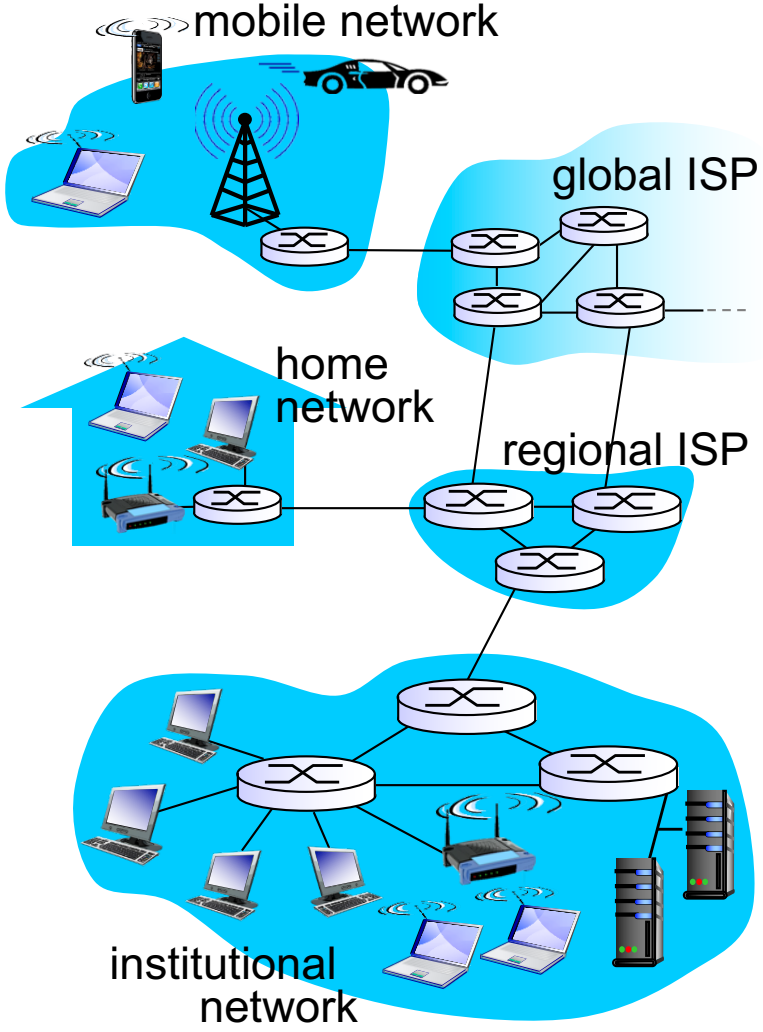
- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



Hardware vs Software

Infrastructure

- *providing services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *providing programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service



Protocols

human protocols:

- ?

… specific msgs sent

… specific actions taken when msgs received, or other events

network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

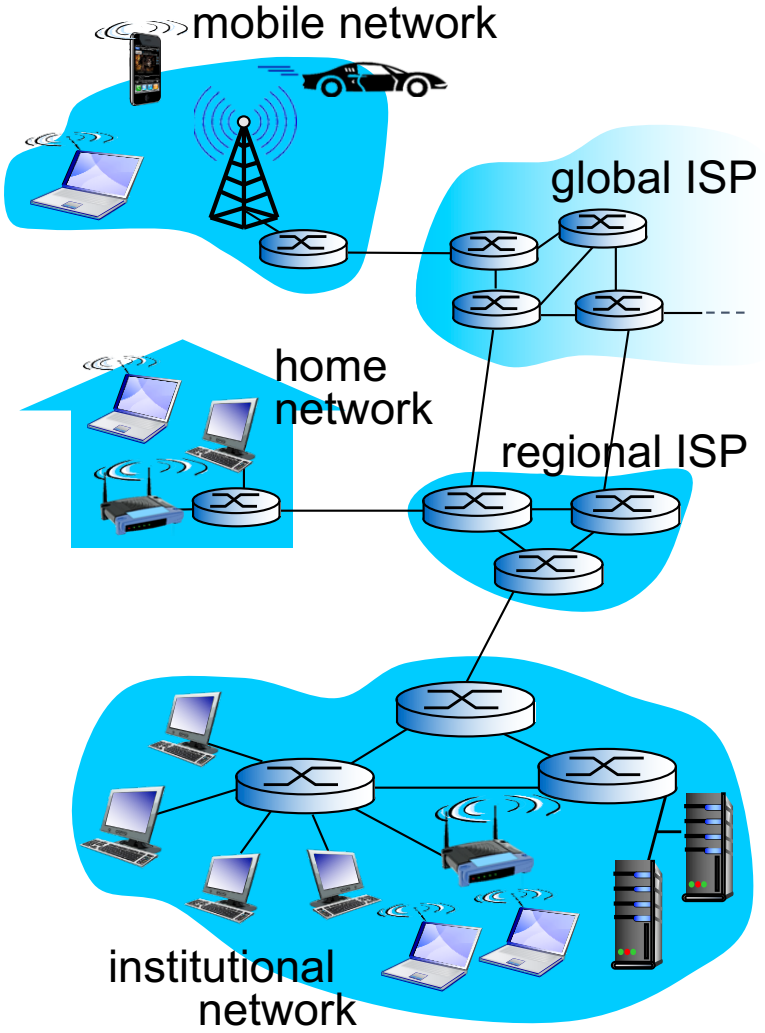
protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

Network Structure

Network structure

- *Network edge:*
  - *End system:*
    - hosts: clients and servers
    - Servers: often in data centers
  - *Access networks, physical media:* wired, wireless communication links

- *Network core:*
  - interconnected routers
  - network of networks



Network Edge

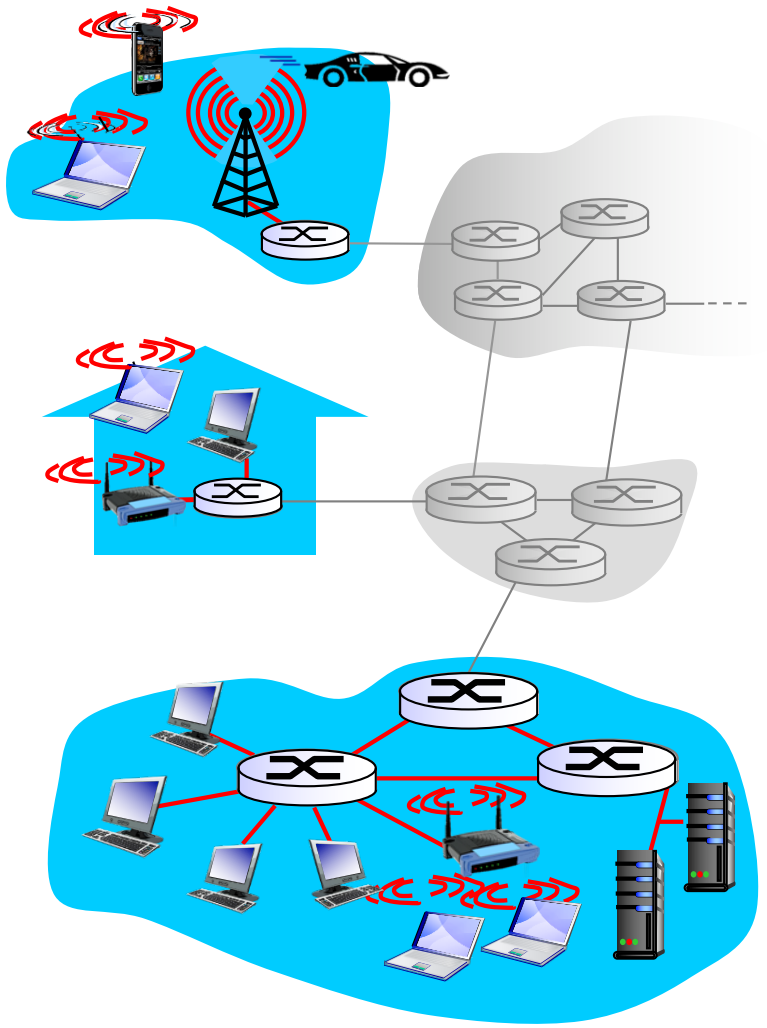
Access networks and physical media

Q: How to connect end systems to edge router?

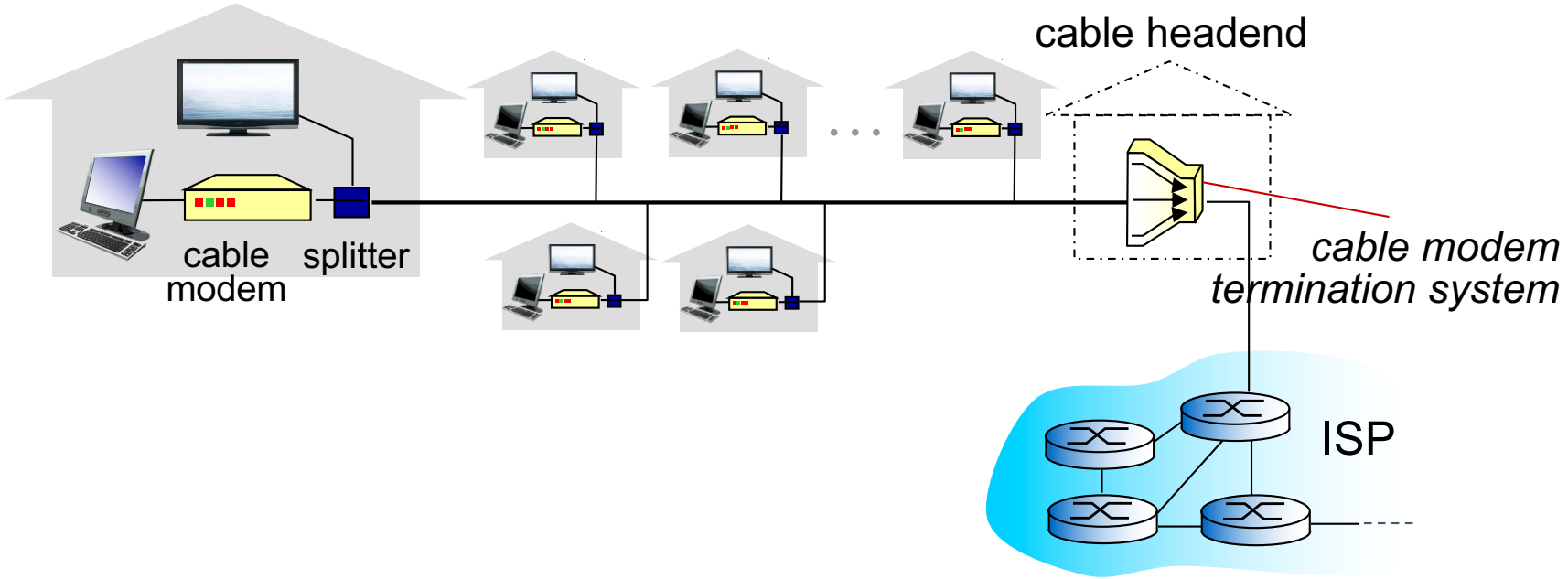
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (bits per second) of access network?
- shared or dedicated?



Access Net: Cable Networks

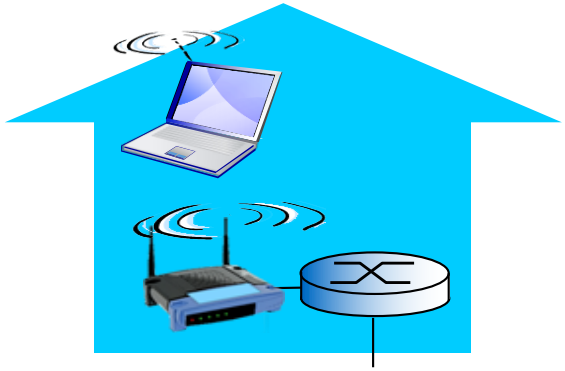


Wireless Access Networks

- shared *wireless* access network connects end system to router
  - via base station: “access point”

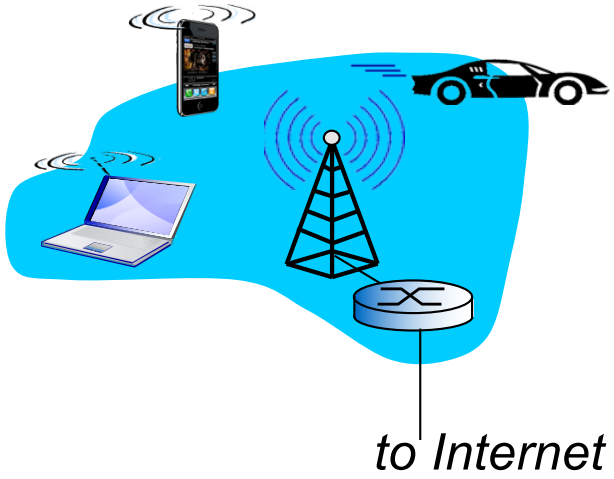
wireless LANs:

- within building (100 ft)
- 802.11b/g (WiFi): 11, 54 Mbps transmission rate

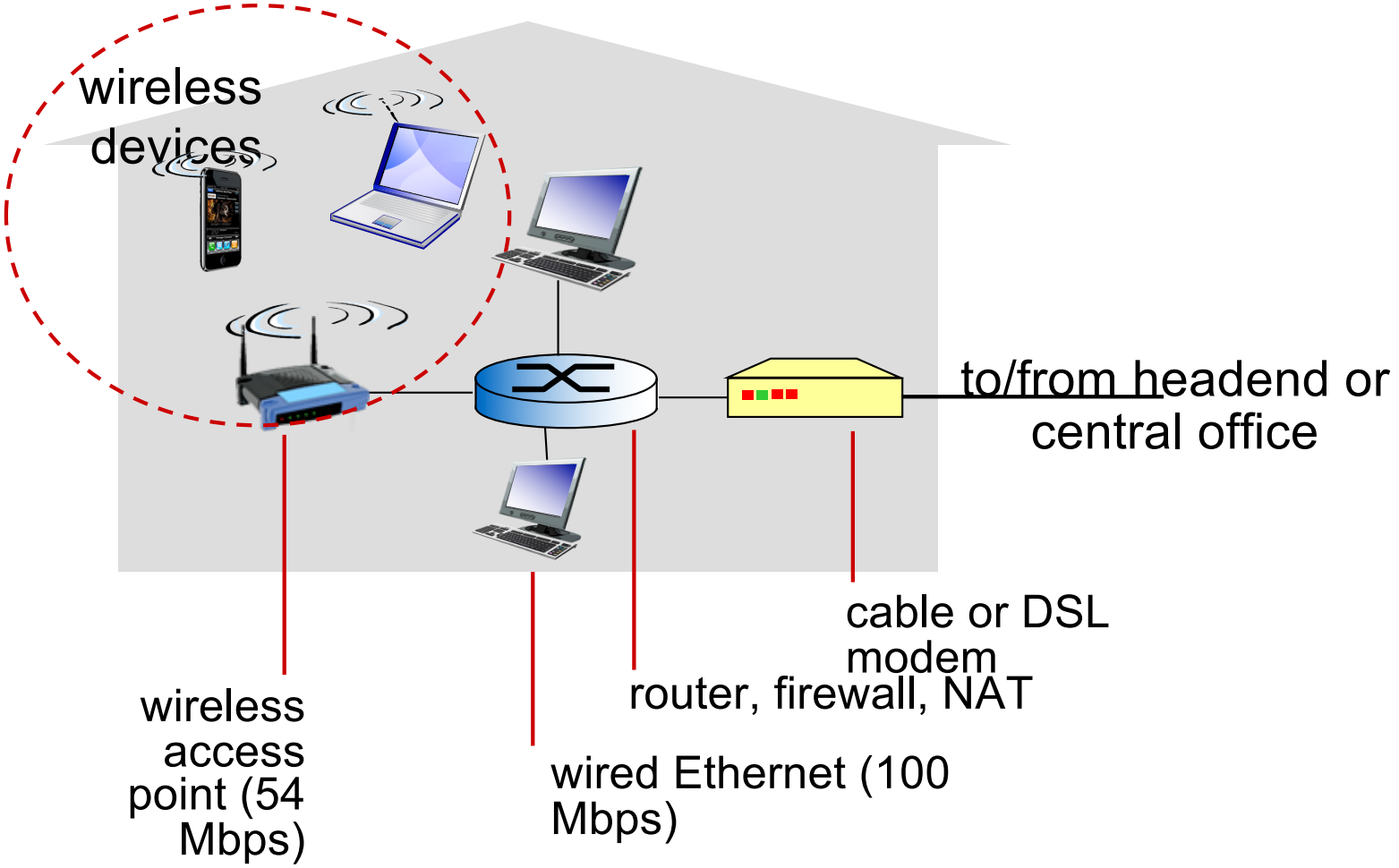


wide-area wireless access

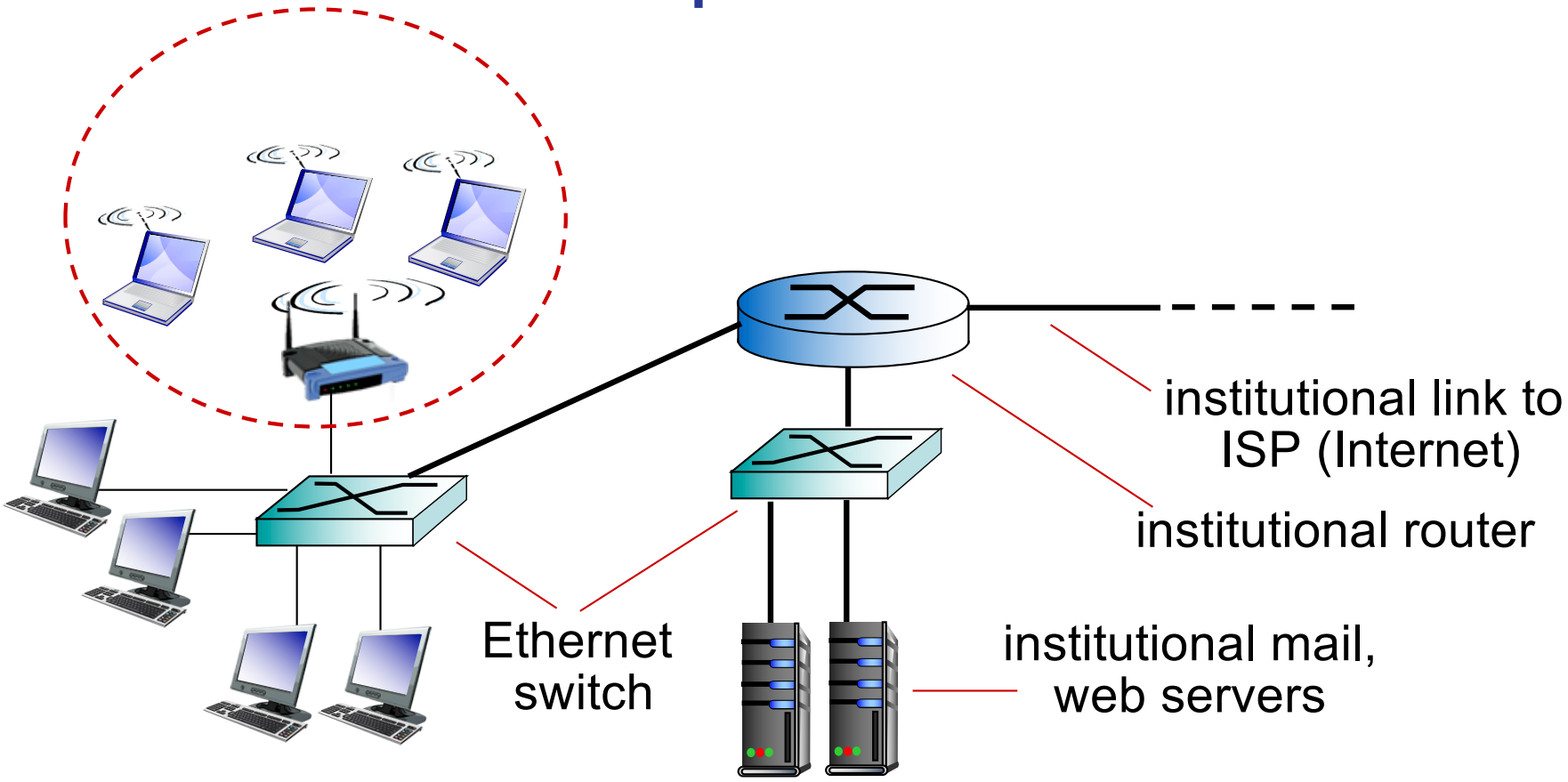
- provided by telco (cellular) operator, 10’s km
- between 1 and 10 Mbps
- 3G, 4G/LTE, 5G



Access Net: Home Networks

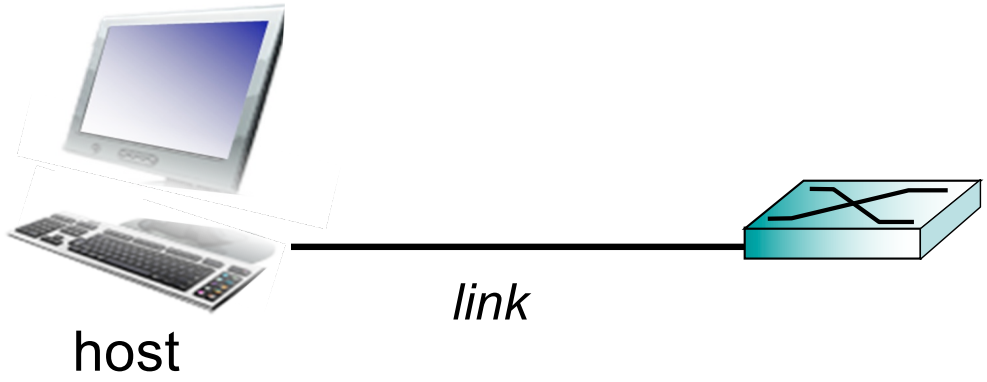


Access Net: Enterprise Access Networks



Physical media

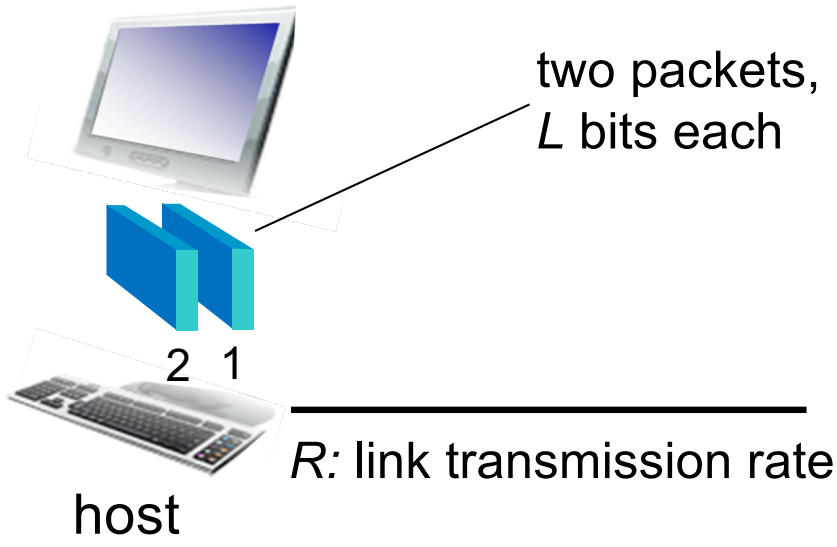
- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio



Transmission Link:

Host sends **packets** of data:

- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka link *capacity, aka link bandwidth*



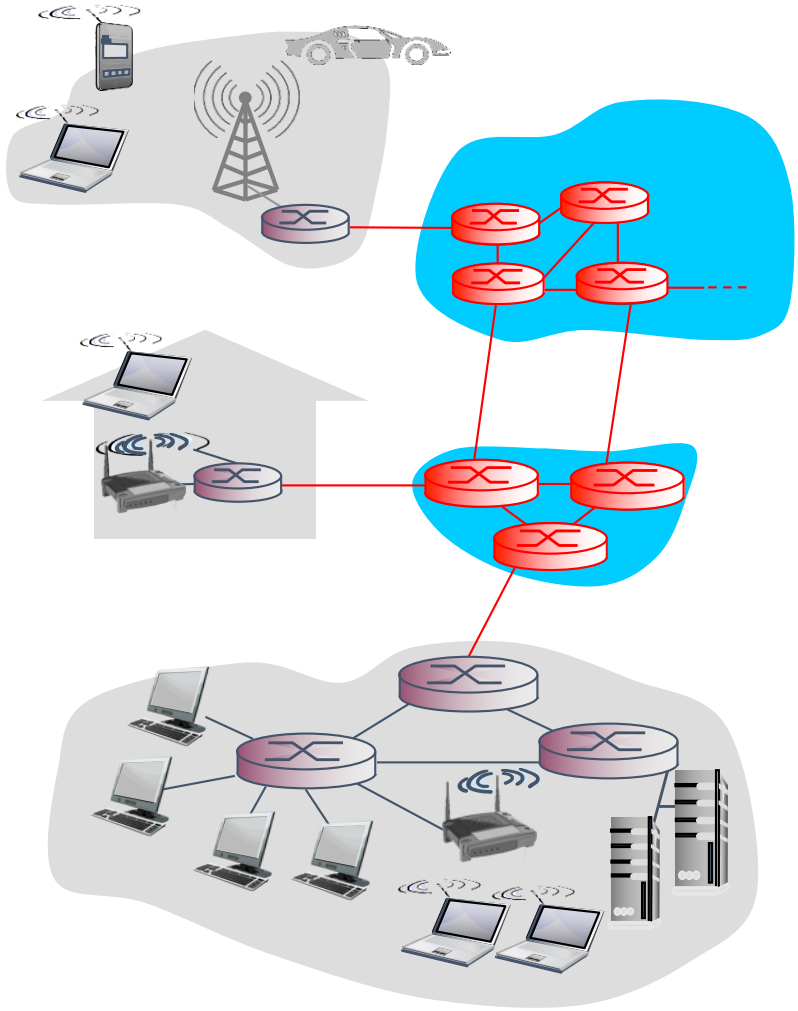
$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

Network core

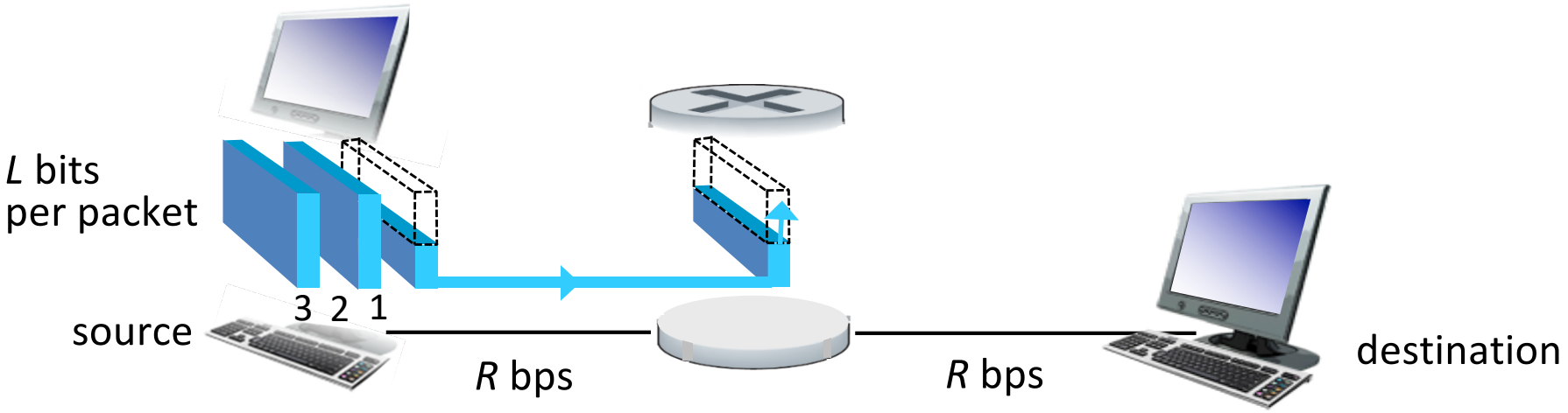
Network core

- mesh of interconnected routers

- How data is sent:
  - Packet-switching
  - Circuit switching

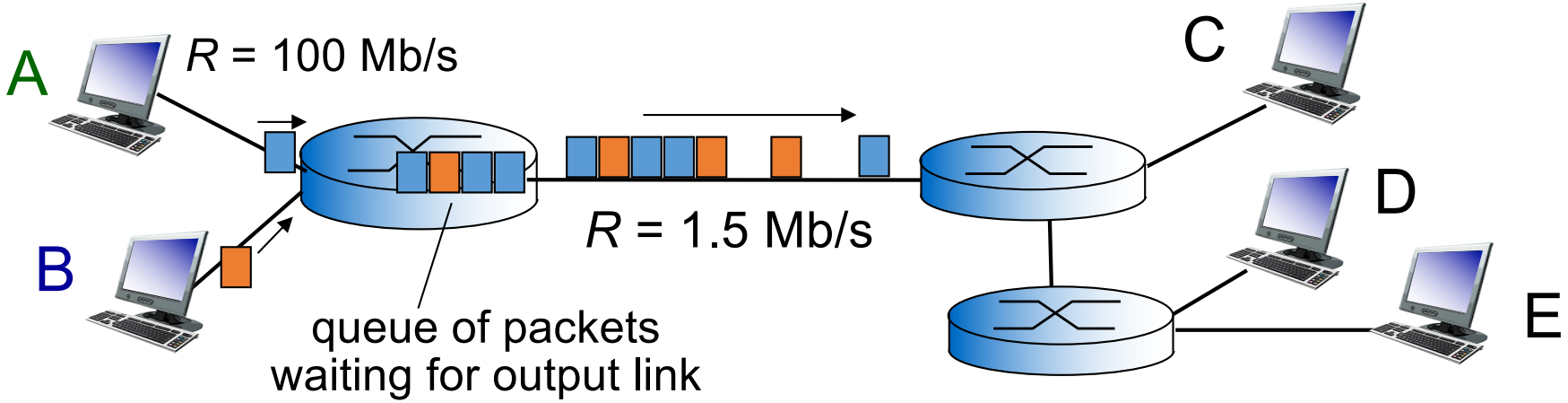


Packet Switching



- hosts break application-layer messages into *packets*
  - Store and forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity

Packet Switching: Queueing delay and loss

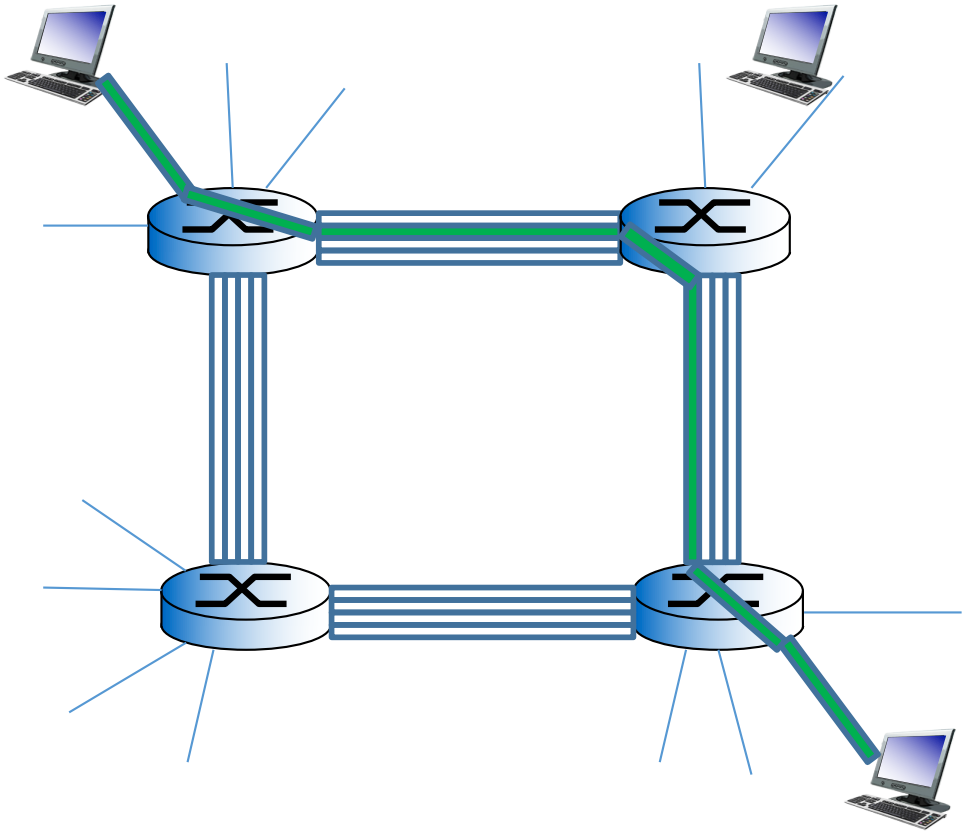


queuing and loss:

- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

Circuit switching

- end-end resources allocated to, reserved for "call" between source & dest

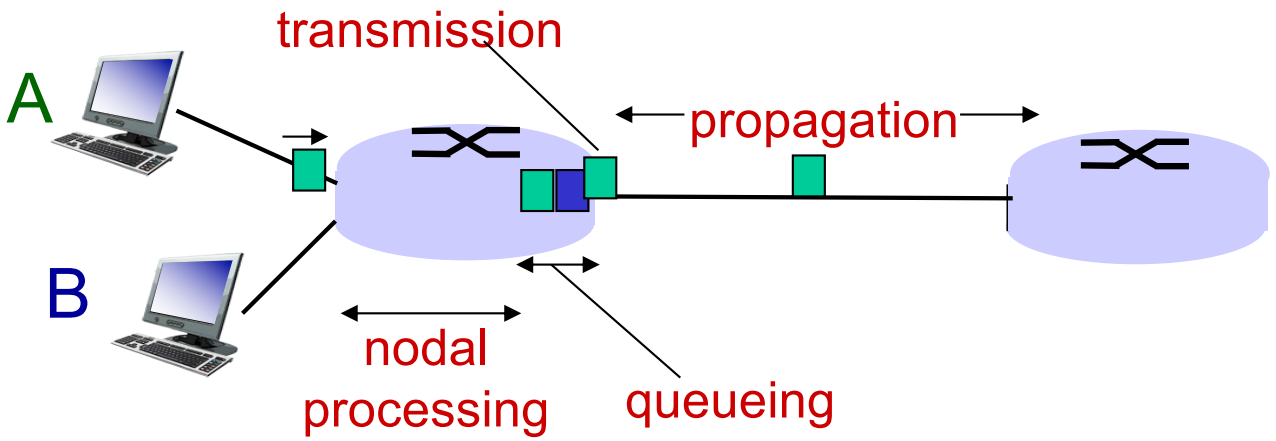


Network Performance

How do packet loss and delay occur?

Delay

- Sources of packet delay:



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{proc}: nodal processing

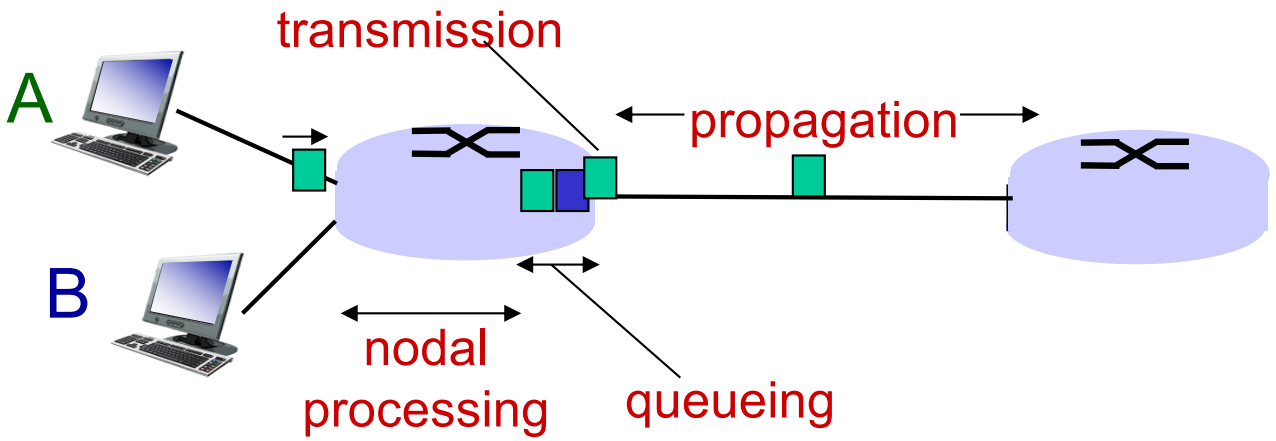
- check bit errors
- determine output link
- typically < msec

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

Delay

- Sources of packet delay:



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{trans}: transmission delay:

- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{prop}: propagation delay:

- d: length of physical link
- s: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$

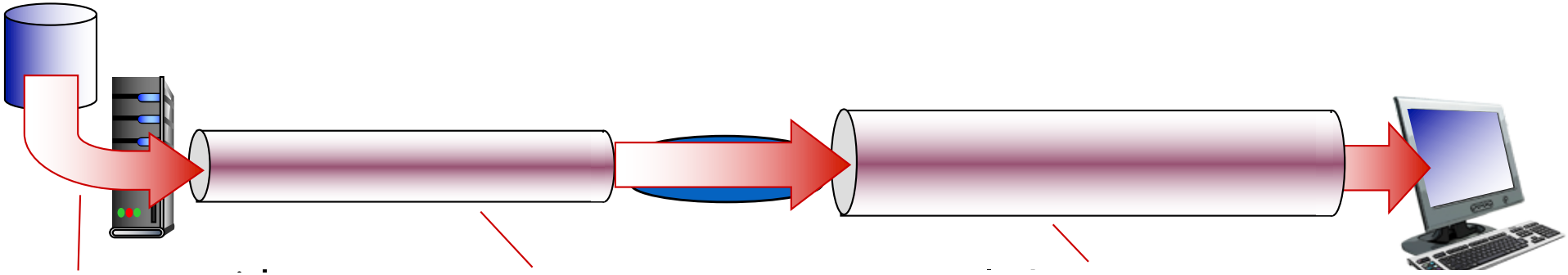
d_{trans} and d_{prop} *very* different

Packet Loss

- Full queue:
  - Queue (buffer) has finite capacity
  - Packets arriving to full queue are dropped (lost)
- Transmission loss:
  - Physical media: propagation loss
  - Transmission collision in wireless networks
  - Channel capacity

Throughput

- *throughput:* rate (bits/time unit) at which bits transferred between sender/receiver
  - *instantaneous:* rate at given point in time
  - *average:* rate over longer period of time
- Bottleneck link



Protocol layers and service models

Protocol layers

- “Pieces” of networks:

  ?

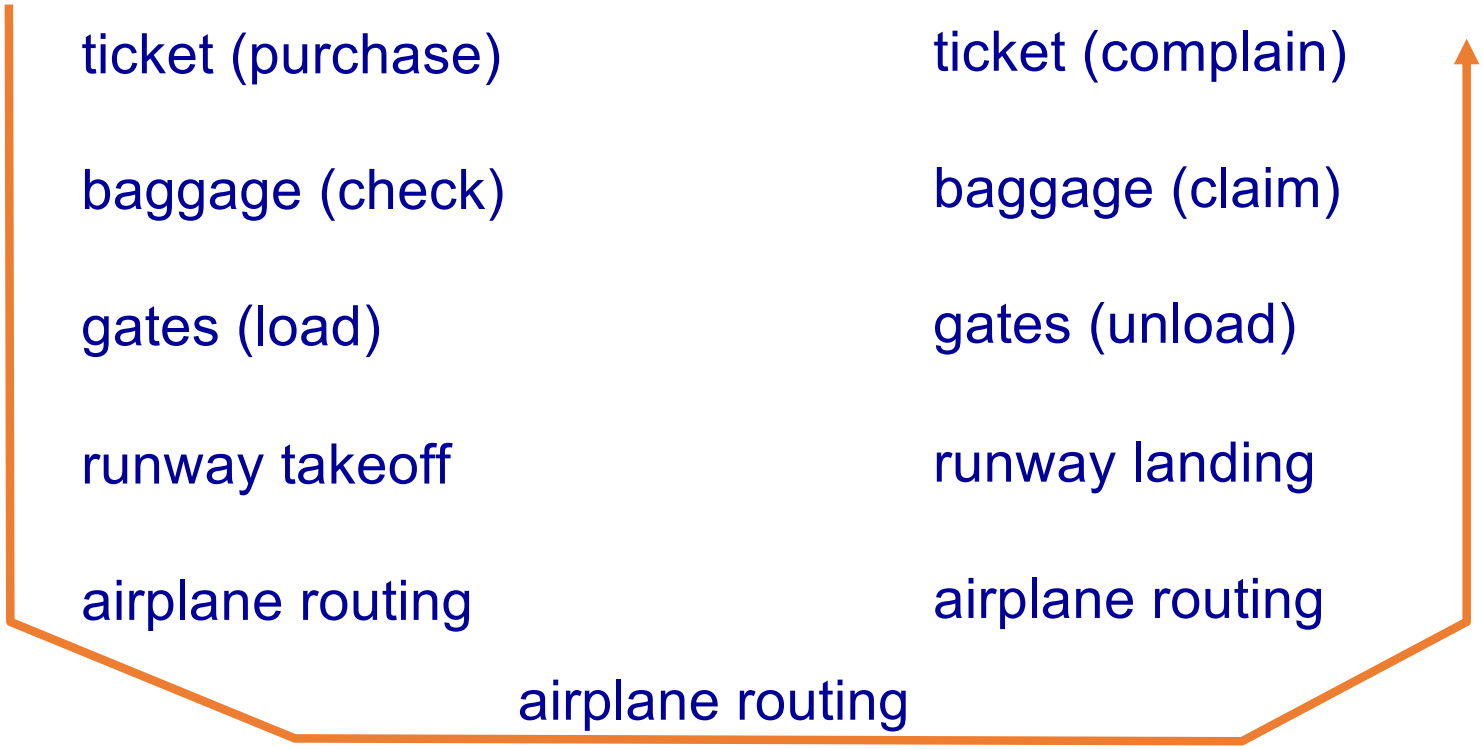
Protocol layers

- "Pieces" of networks:
  - Hosts
  - Routers
  - Links
  - Applications
  - Protocols
  - Hardware, software

Question:

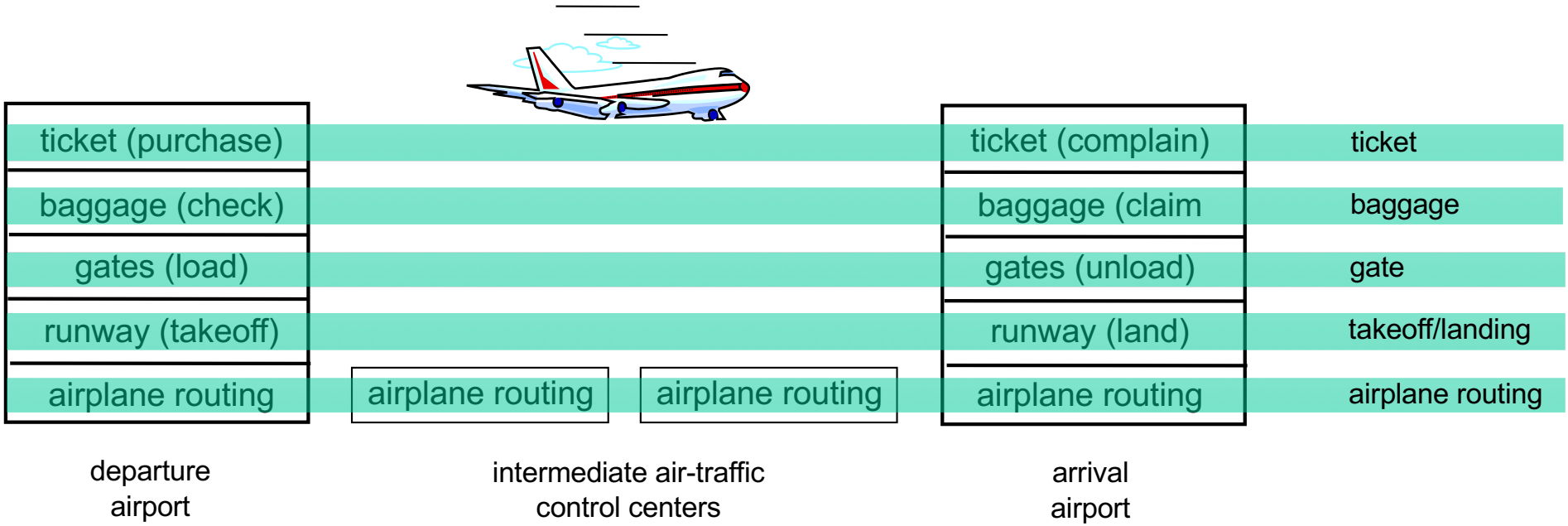
How to *organize* structure of network?

Organization of air travel



- a series of steps

Layering of airline functionality

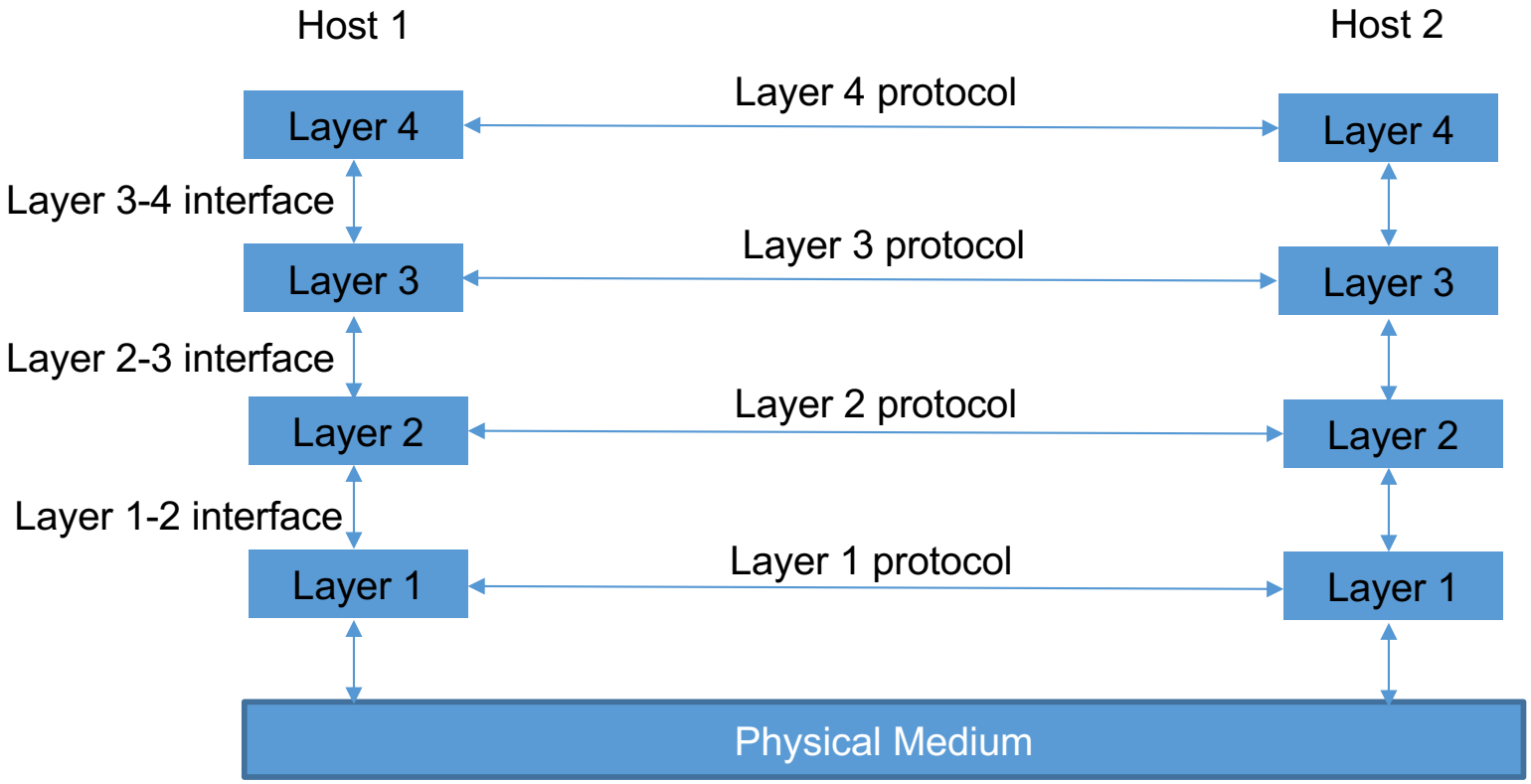


layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

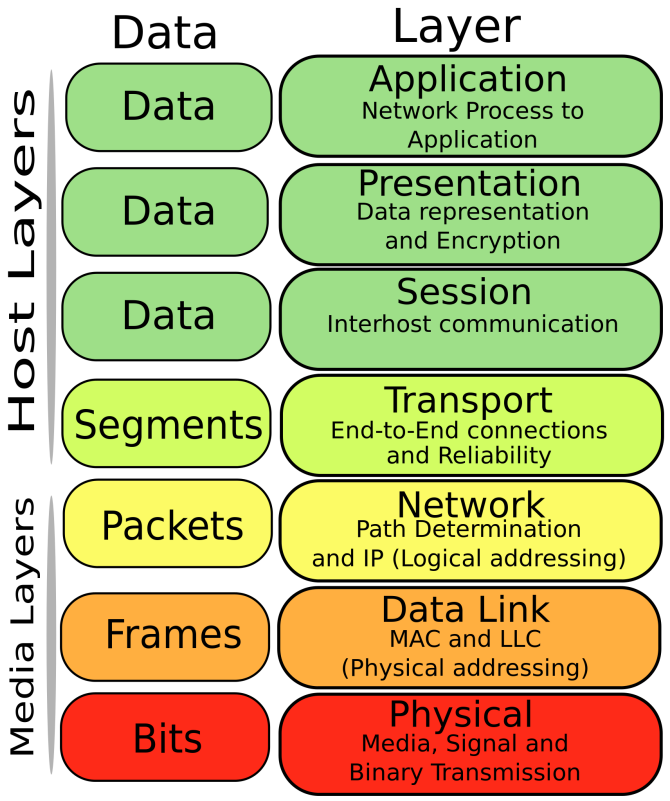
Layering of Network functionality

- Network layers



OSI reference model

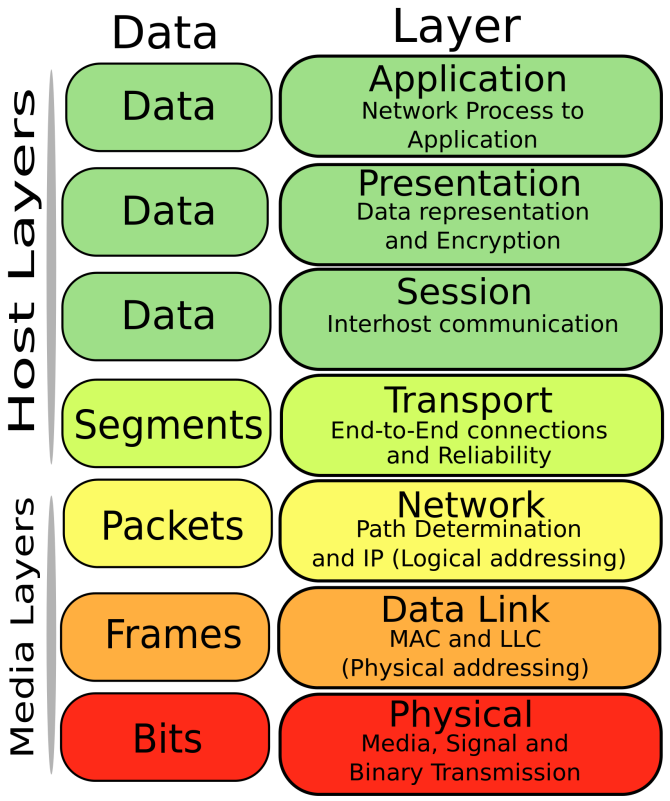
- *Application:* supporting network applications
  - FTP, SMTP, HTTP
- *Presentation*:* allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *Session*:* synchronization, checkpointing, recovery of data exchange
- *Transport:* process-process data transfer
  - TCP, UDP



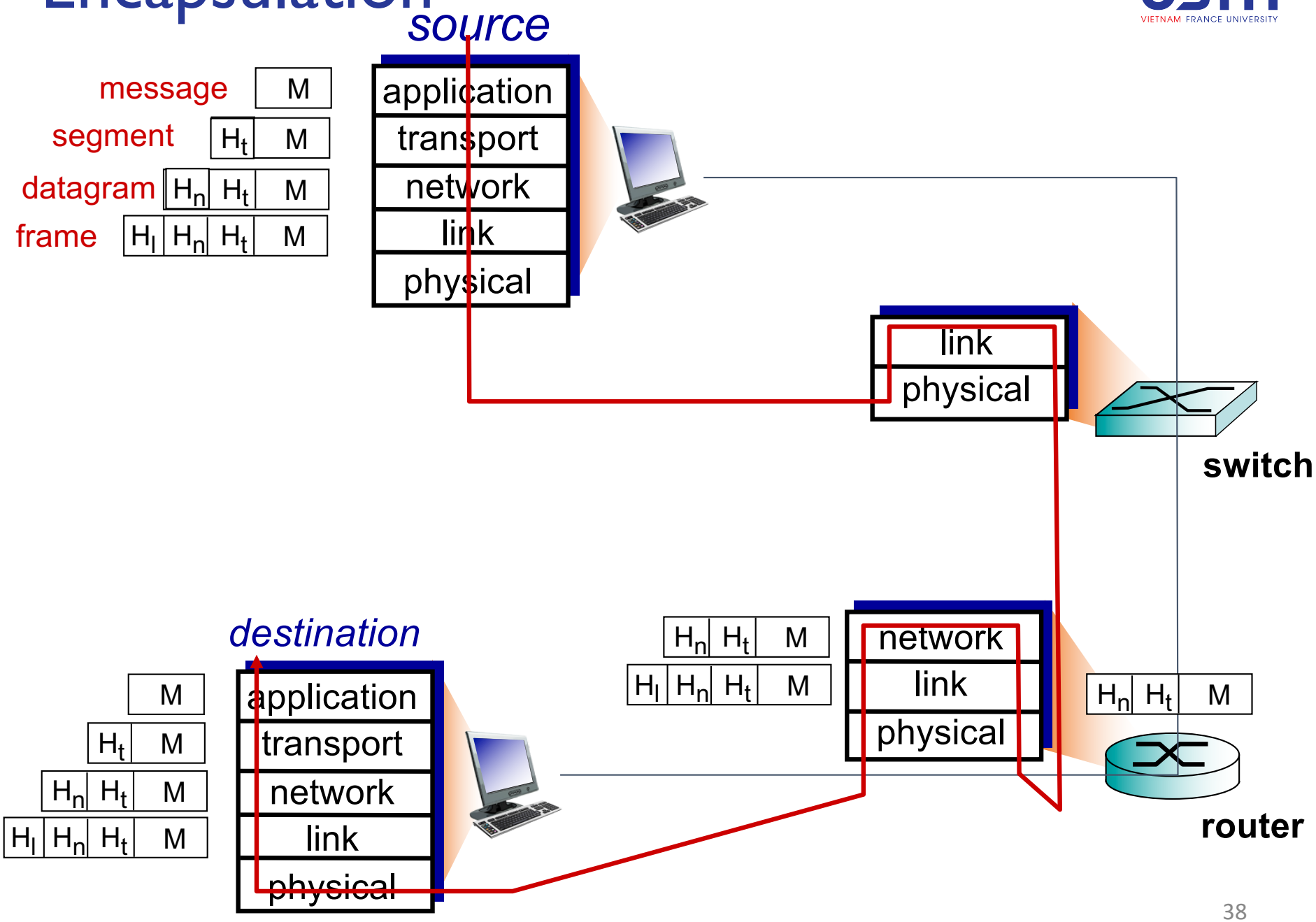
* Not included in Internet stack

OSI reference model

- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.111 (WiFi), PPP
- *physical:* bits "on the wire"



Encapsulation



Data Link layer

Data Link Layer

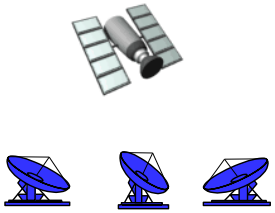
- Principles:
  - Error detection, correction
  - Multiple access:
    - Links
    - Protocols
  - Link layer addressing
  - Local area networks

Medium Access Control sublayer

- Multiple Access Links:
  - Point-to-point
  - Broadcast (shared wire or medium)

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)



shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

Medium Access Control sublayer

- Multiple Access Protocols:
  - Problem in broadcast channel:
    - *collision* if node receives two or more signals at the same time
  - Solution:
    - distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
    - communication about channel sharing must use channel itself!

Multiple Access Protocol

Medium Access Control sublayer

- Random Access Protocols
  - Carrier Sense Multiples Access (CSMA) Protocols
  - Wireless LAN Protocols

Random Access protocol

- when node has packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes
- two or more transmitting nodes ➜ "collision",
- random access MAC protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)
- examples of random access MAC protocols:
  - slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA

In a classroom

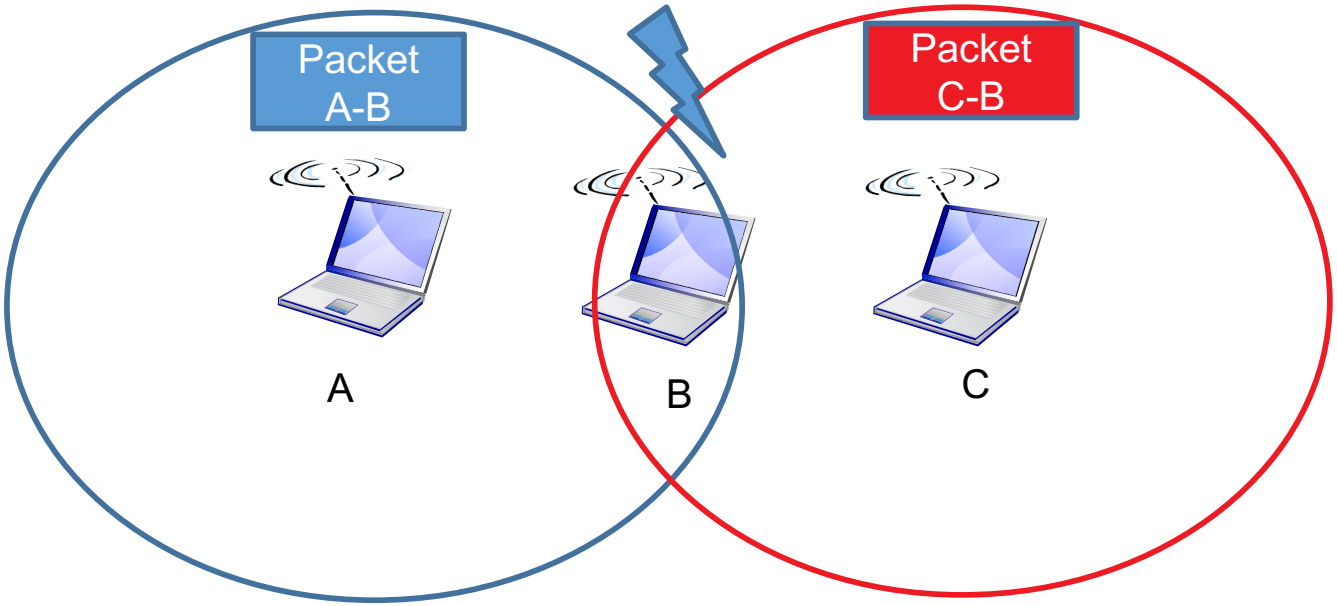
- Everyone has something to talk about
- Shared space, shared time
- How everyone has chance to talk?

CSMA (carrier sense multiple access)

- Listen before transmit
  - If channel is idle: transmit
  - If channel is busy: defer transmission

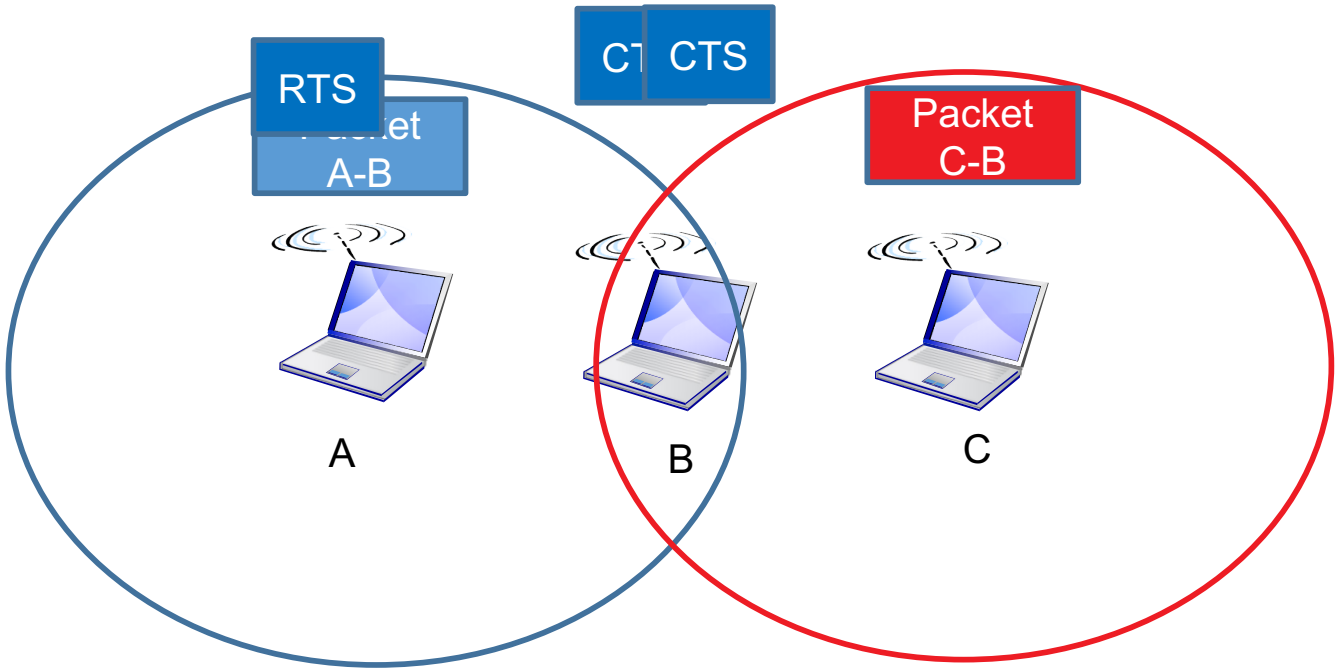
CSMA (cont)

- Collisions:
  - Still occur: how?
    - Propagation delay
    - Hidden terminal problem in wireless networks
  - Wasted time for no information

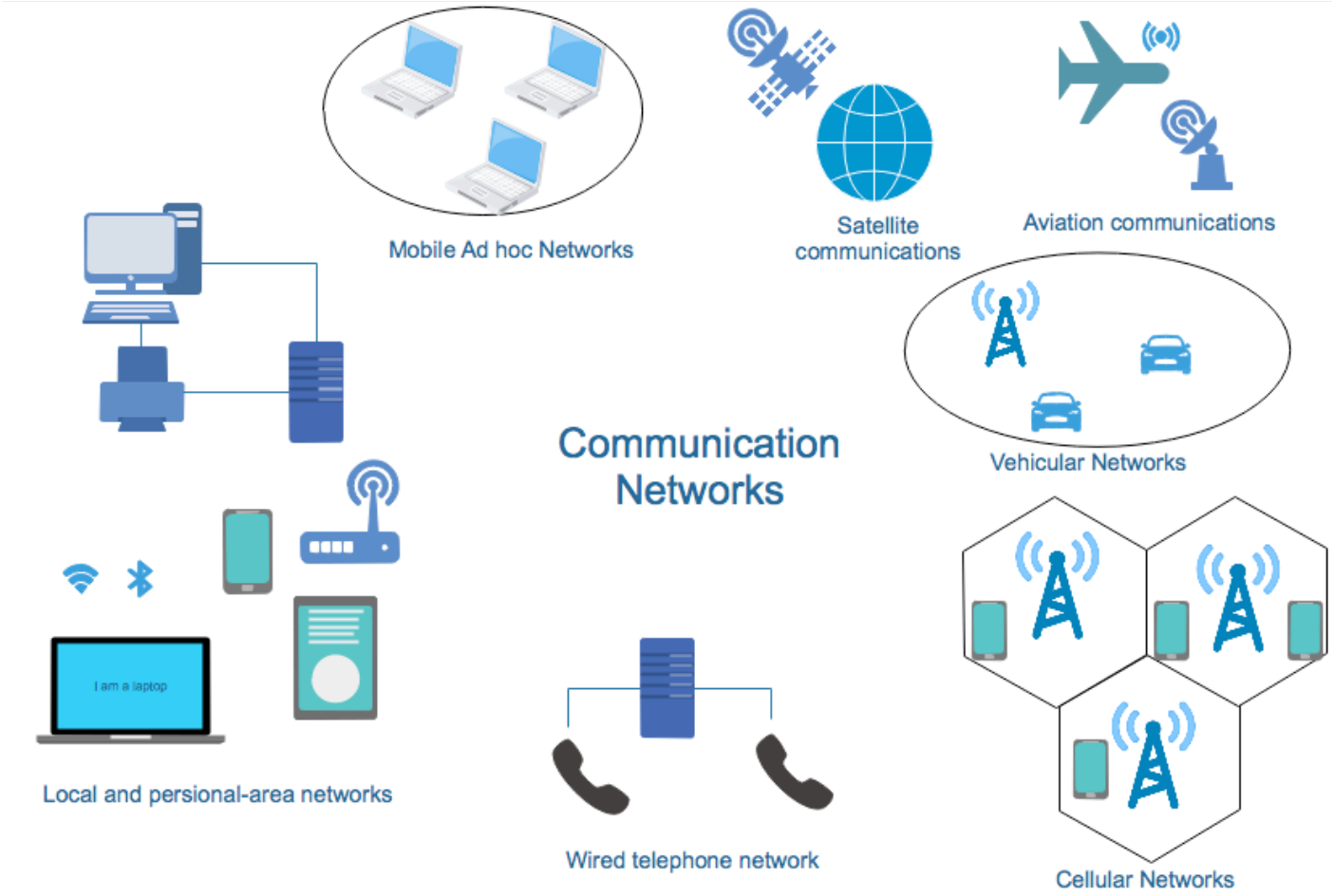


CSMA/CA (collision avoidance)

- Detect and avoid collision:
  - RTS (Request to Send)
  - CTS (Clear to Send)
  - ACK (Acknowledge)



Wireless (Access) Networks

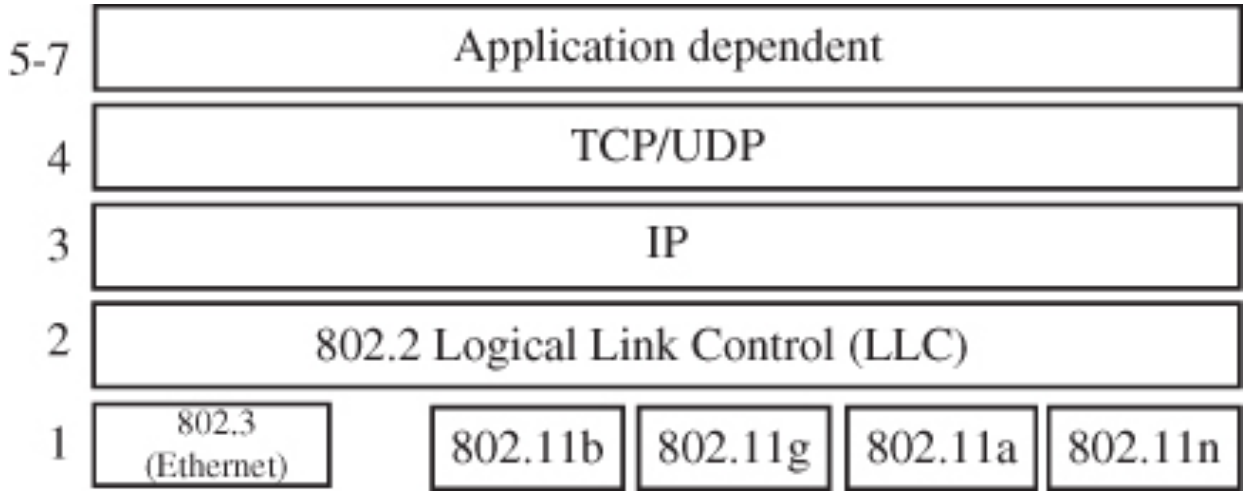


Wireless Networks

- Wireless LANs
- Vehicular Networks
- Mobile Wireless Networks

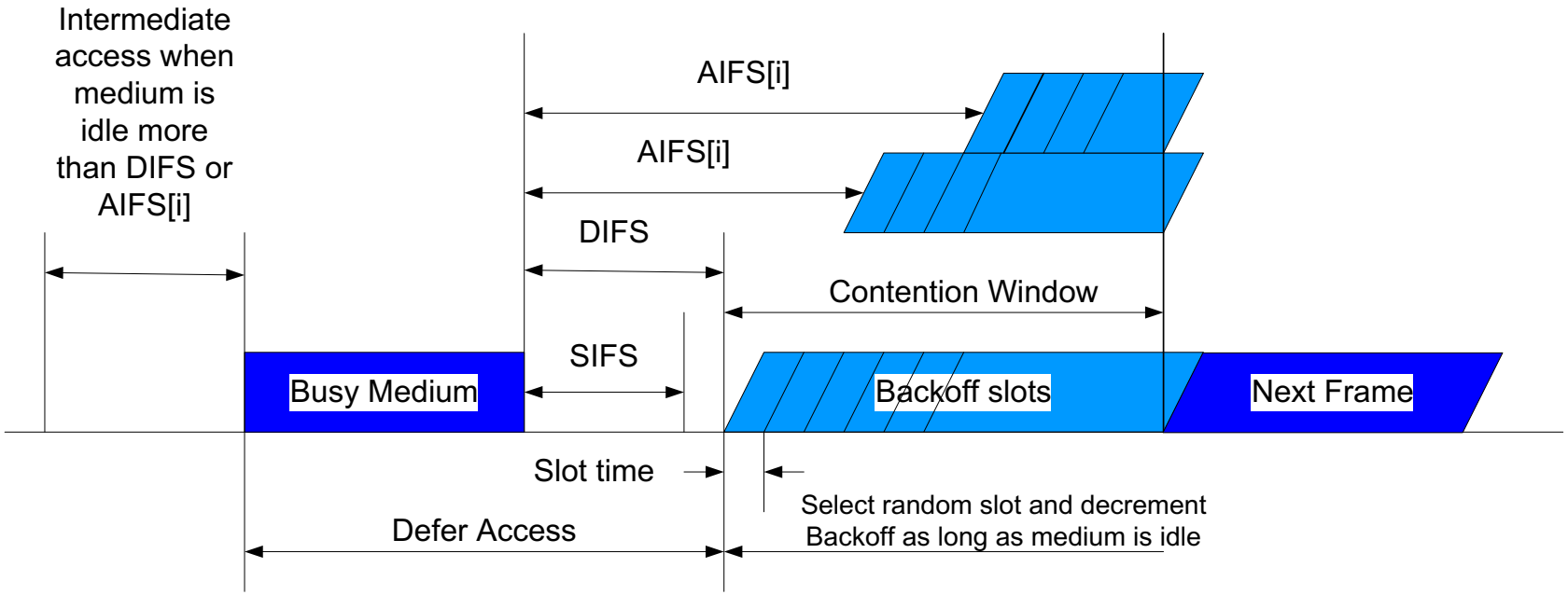
Wireless LANs

- Protocol stack:
  - Standard IEEE 802.11



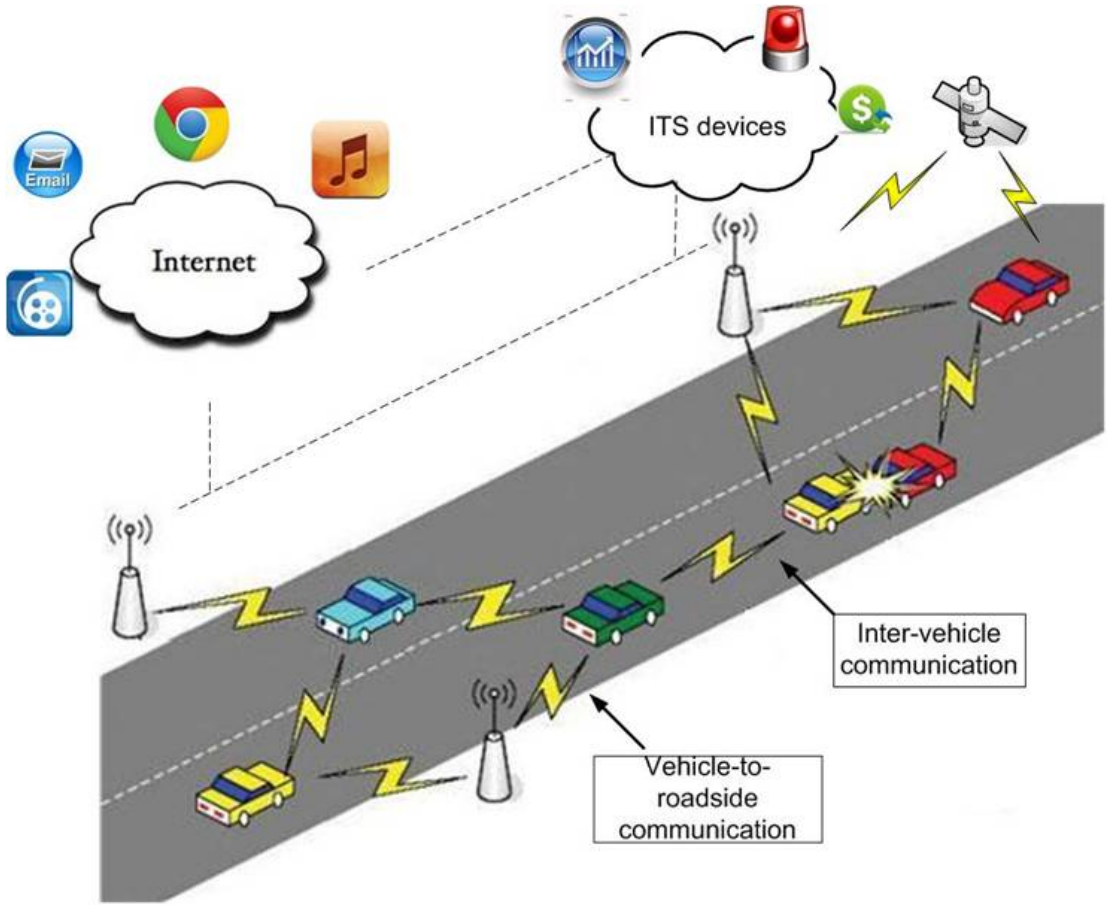
Wireless LANs

- CSMA/CA in IEEE 802.11

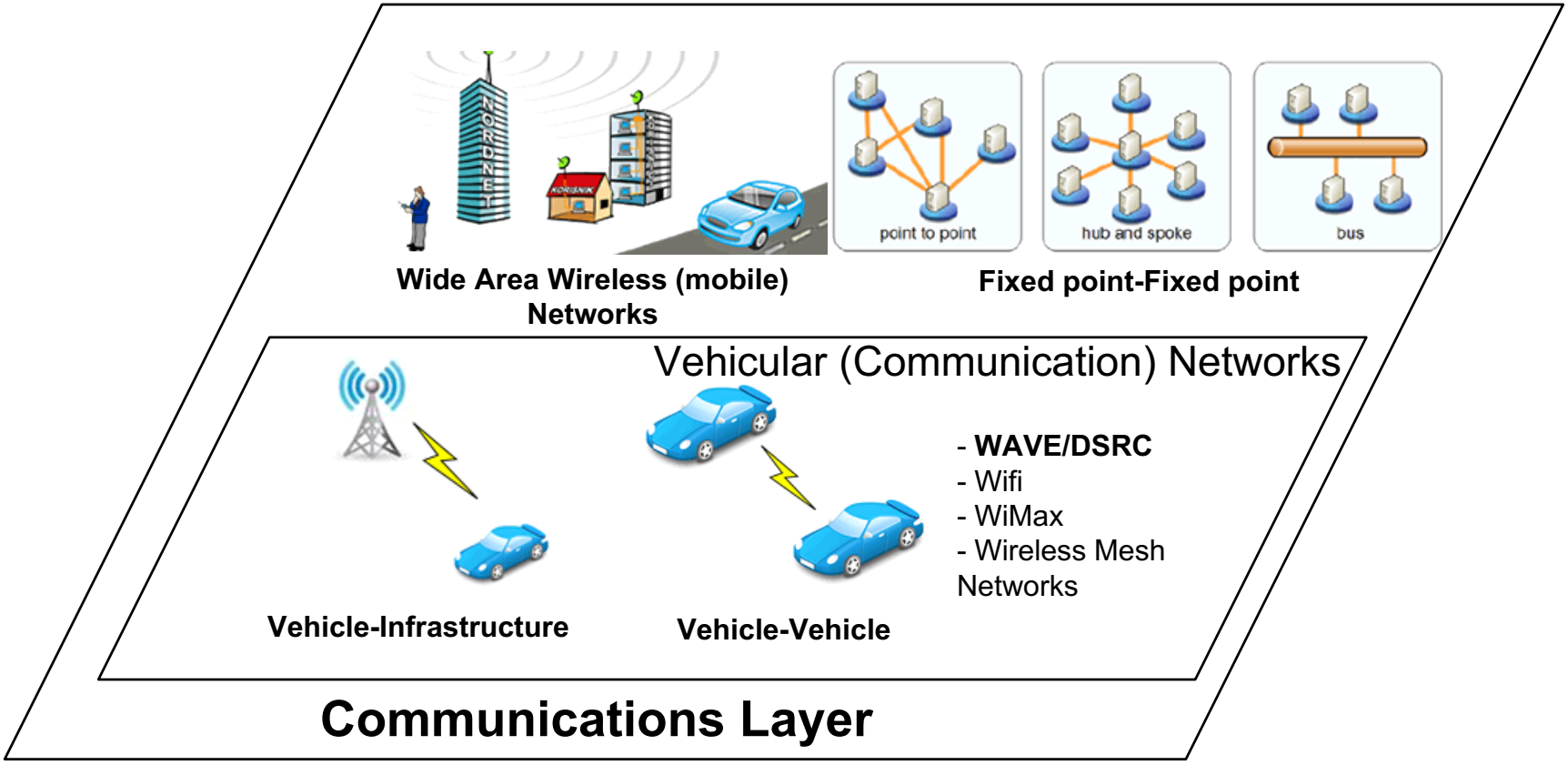


Vehicular Networks

- ITS architecture



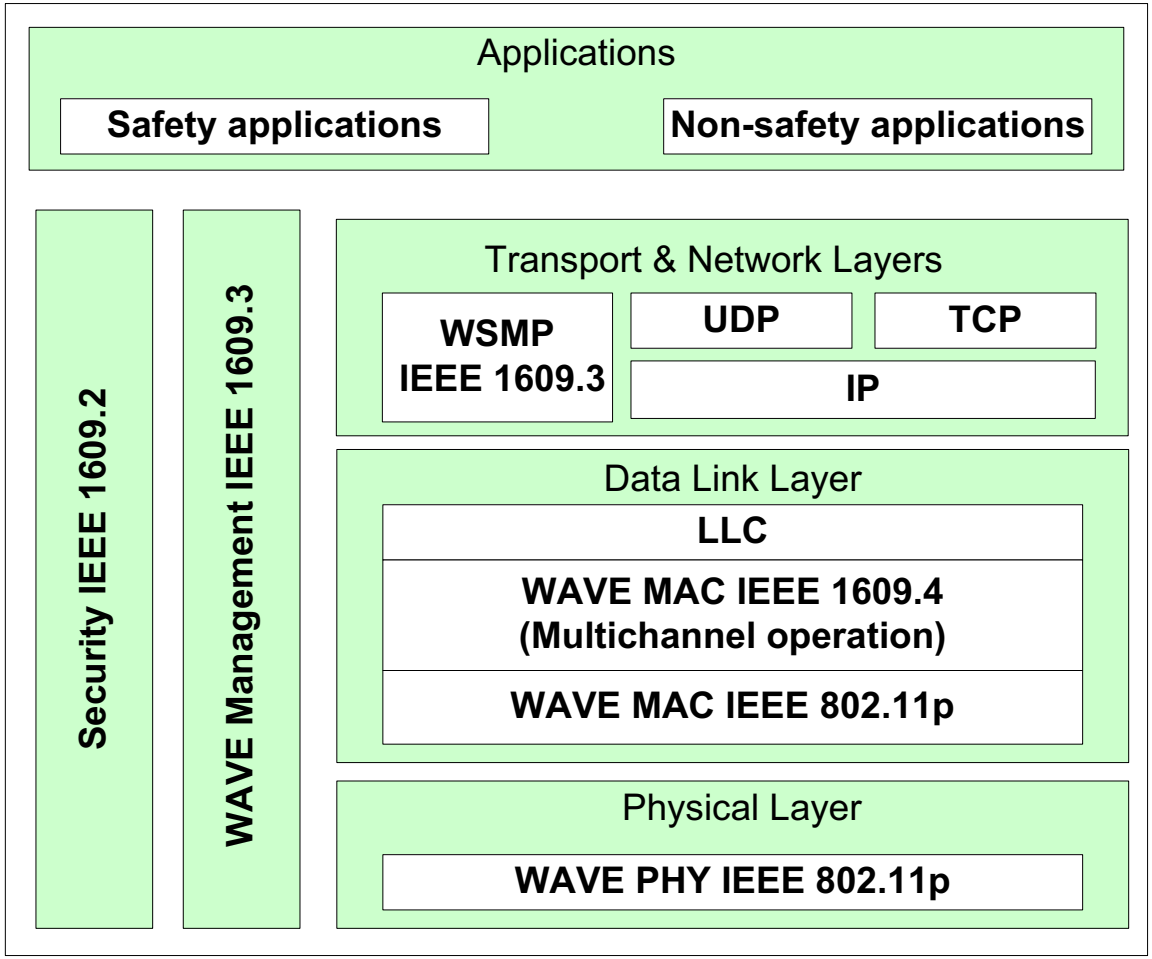
Vehicular Networks



Vehicular Networks

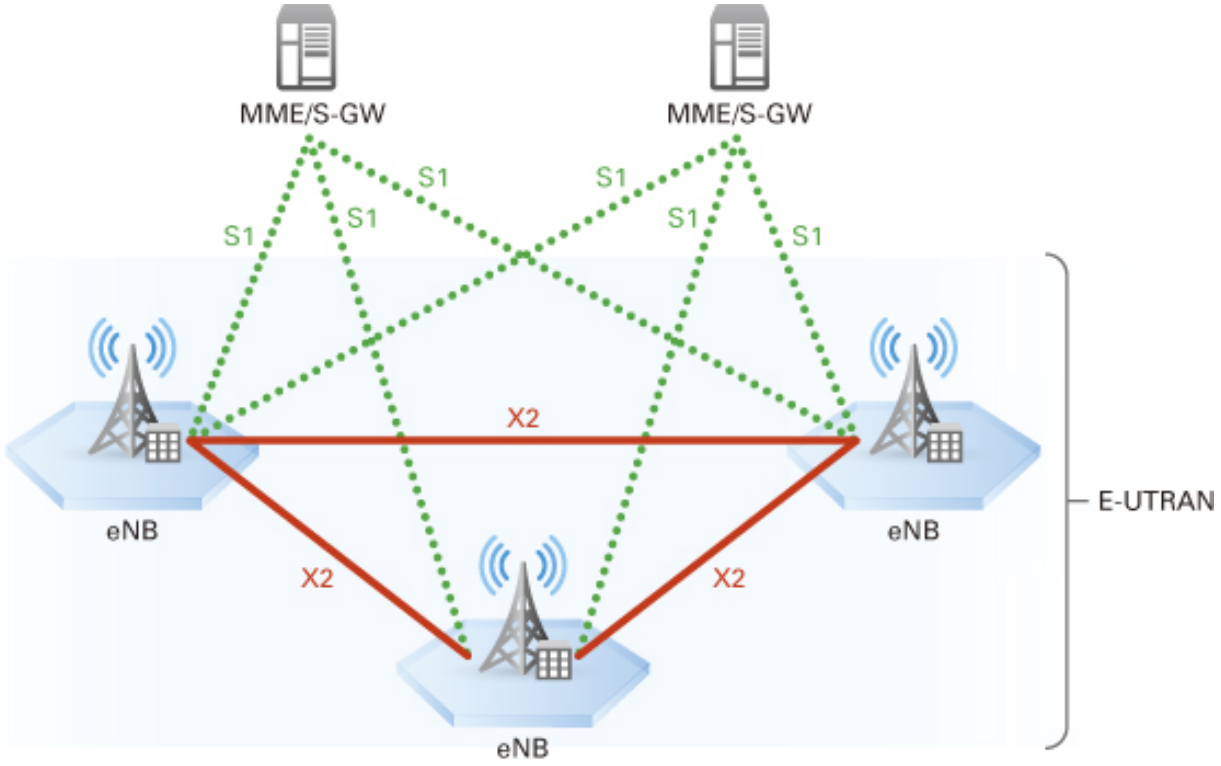
- Protocol Stack

WAVE protocols architecture



Mobile Wireless Networks

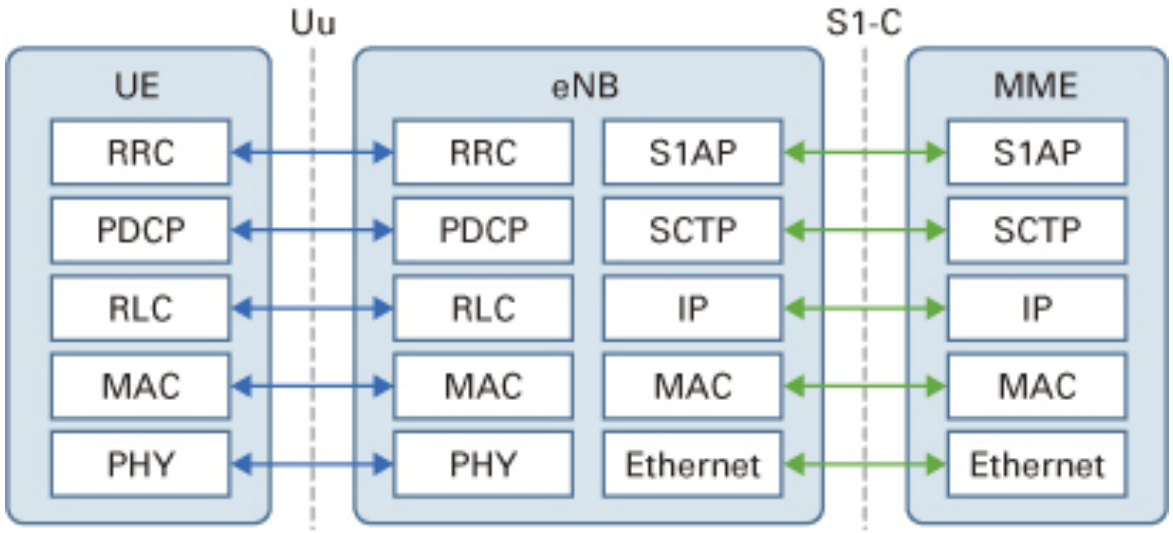
- Latest Technologies:
  - 4G/LTE
  - 5G



E-UTRAN Architecture- LTE

Mobile Wireless Networks

- LTE Protocol stack example:
  - C-plane Protocol Stack: Uu (UE/eNB) and S1-C (eNB/MME)…



Source: artizanetworks.com