06-06798 Distributed Systems

Lecture 3:
Networking

Overview

- Types of networks: how to choose
  - range, bandwith, latency
- Networking principles: how it works conceptually
  - transfer mode, switching schemes
  - protocol suites, routing, congestion control
- Sample protocols: how it works in detail
  - MobileIP, TCP/UDP, Wireless LAN

Types of Networks

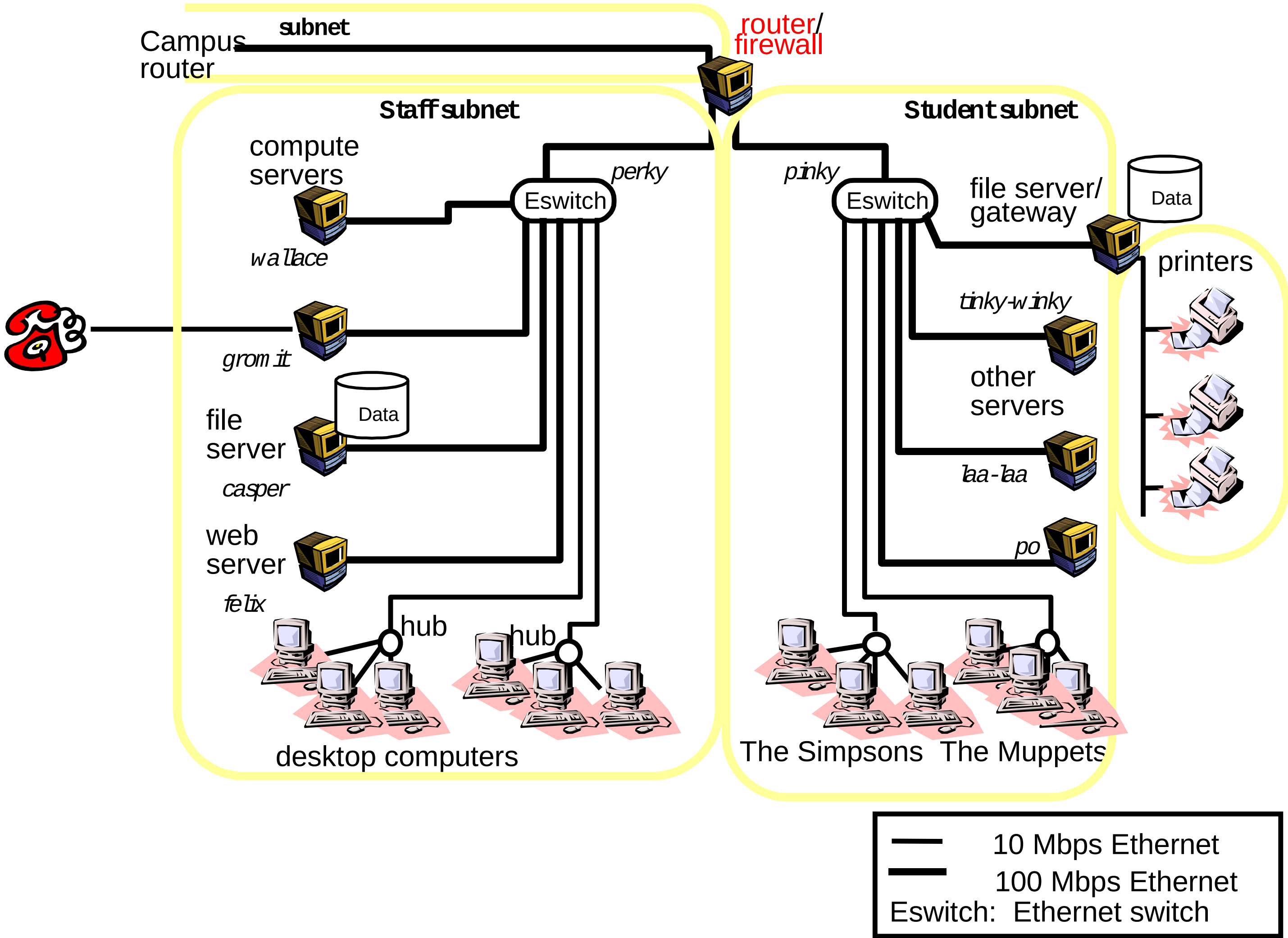
- LANs (Local Area Networks)
  - technology suitable for small area, usu. wire/fibre
- WANs (Wide Area Networks)
  - large distances, inter-city/country/continental
- MANs (Metropolitan Area Networks)
  - intra-city, cable based, multimedia
- Wireless networks
  - WLANs, WPANs

Distinguished by technology, not only distances.

LANs

- High bandwith
  (total amount of data per unit of time)
- Low latency
  (time taken for the first bit to reach destination)
- Technology
  - predominantly Ethernet, now 100/1000Mbps
  - earlier token ring
  - ATM better QoS, but more expensive

LAN example: the old SoCS



WANs

- Low bandwith, high latency
- Satellite/wire/cable
- Routers introduce delays

MANs

- Wire/cable
- Range of technologies (ATM, Ethernet)

Wireless networks

- WLANs (Wireless Local Area Networks)
  - to replace wired LANs
  - WaveLAN technology (IEEE 802.11)
- WPANs (Wireless Personal Area Networks)
  - variety of technologies
  - GSM, infra-red, BlueTooth low-power radio
  - WAP (Wireless Applications Protocol)

Network comparison

	Range	*Bandwidth (Mbps)*	*Latency (ms)*
LAN	1-2 kms	10-1000	1-10
WAN	worldwide	0.010-600	100-500
MAN	2-50 kms	1-150	10
Wireless LAN	0.15-1.5 km	2-11	5-20
Wireless WAN	worldwide	0.010-2	100-500
Internet	worldwide	0.010-2	100-500

Network principles

- Mode of transmission
- Switching schemes
- Protocol suites
- Routing
- Congestion control

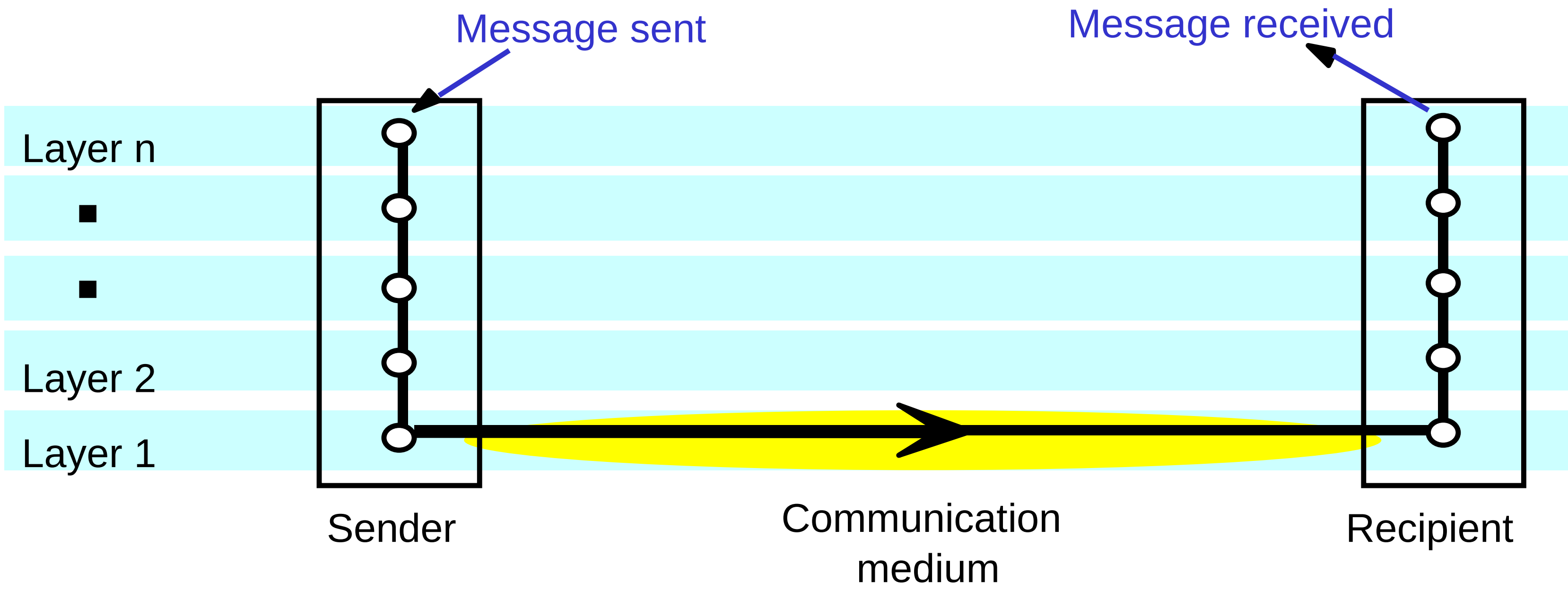
Mode of transmission

- Packets
  - messages divided into packets
  - packets queued in buffers before sent onto link
  - QoS not guaranteed
- Data streaming
  - links guarantee QoS (rate of delivery)
  - for multimedia traffic
  - higher bandwith

Switching schemes

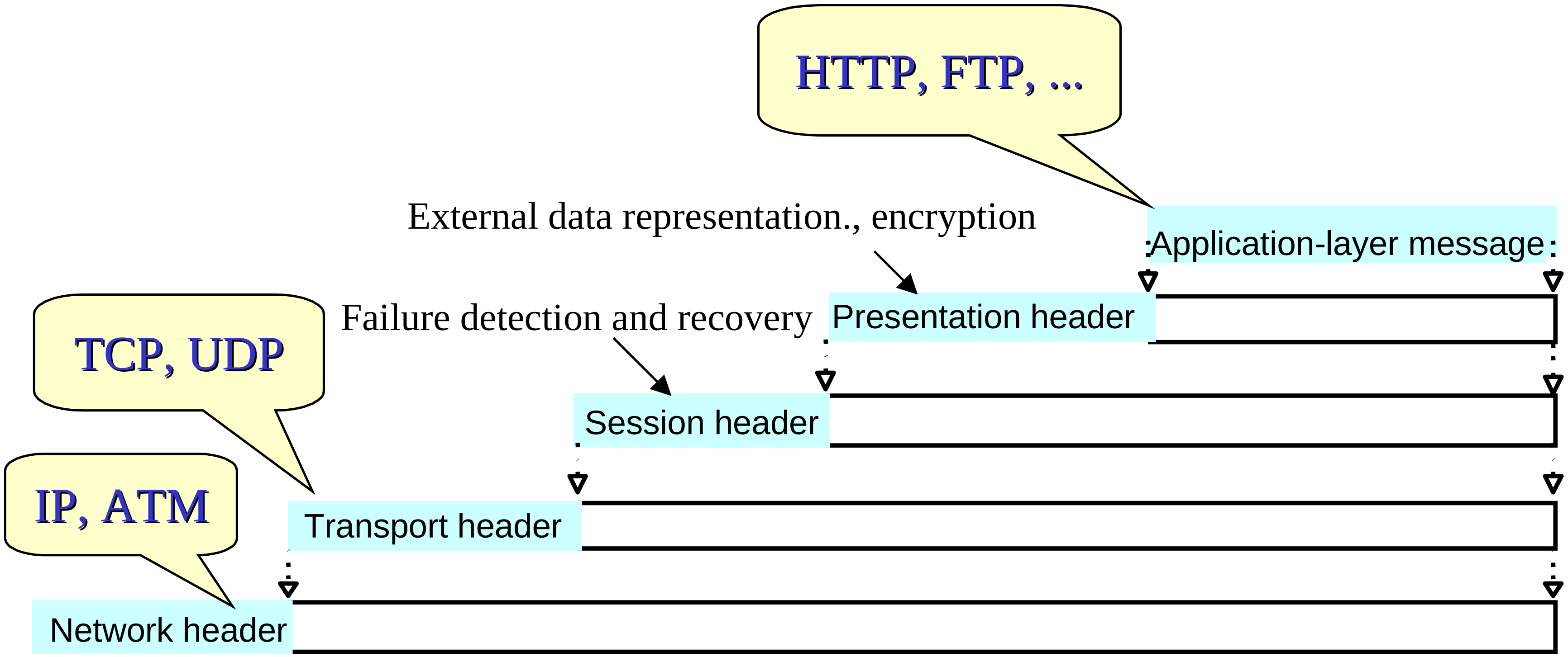
- Broadcasts (Ethernet, wireless)
  - send messages to all nodes
  - nodes listen for own messages (carrier sensing)
- Circuit switching (phone networks)
- Packet switching (TCP/IP)
  - store-and-forward
  - unpredictable delays
- Frame/cell relay (ATM)
  - bandwith & latency guaranteed (virtual path)
  - small, fixed size packets (padded if necessary)
  - avoids error checking at nodes (use reliable links)

Protocols (OSI view)



Definition: set of rules and formats for exchanging data, arranged into layers called protocol suite/stack.

Message encapsulation



Headers appended/unpacked by each layer.

OSI protocol summary

Layer	*Description*	*Example*
Application	Protocols for specific applications.	HTTP, FTP, SMTP
Presentation	Protocols for independent data representation and encryption if required.	Secure Sockets, CORBA CDR
Session	Protocols for failure detection and recovery.	
Transport	Message-level communication between ports attached to processes. Connection-oriented or connectionless.	TCP, UDP
Network	Packet-level transmission on a given network. Requires routing in WANs and Internet.	IP, ATM
Data link	Packet-level transmission between nodes connected by a physical link.	Ethernet MAC, ATM cell transfer

Routing

- Necessary in non-broadcast networks (cf Internet)
- Distance-vector algorithm: each node
  - stores table of state & cost info of links, cost infinity for faulty links
  - determines route taken by packet (the next hop)
  - periodically updates the table and sends to neighbours
  - may converge slowly [Bellman-Ford]
- RIP-1 for Internet similar except
  - use default routes, plus multicast and authentication
  - better convergence

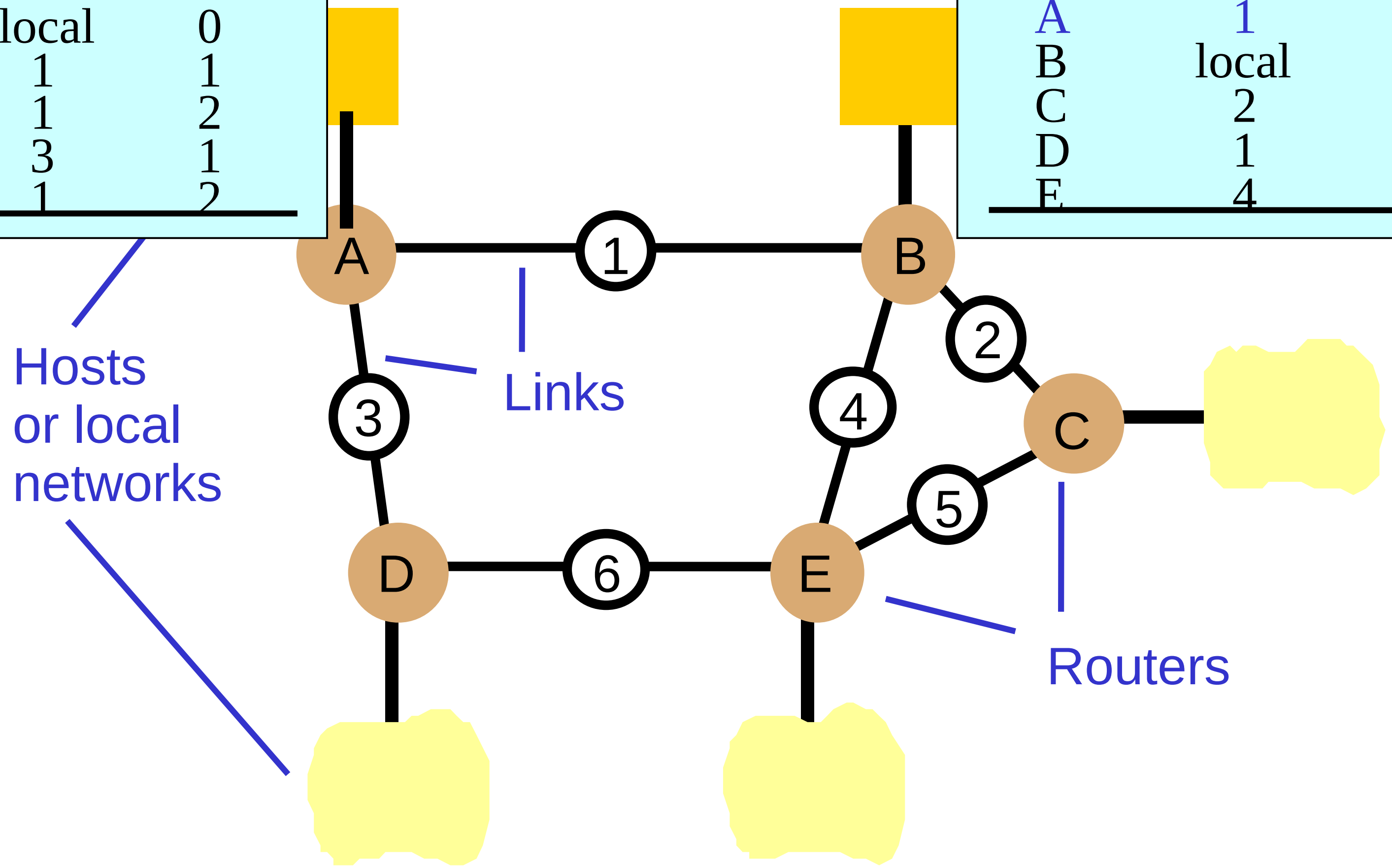
Routing example

Routings from A

To	*Link*	*Cost*
A	local	0
B	1	1
C	1	2
D	3	1
E	1	2

Routings from B

To	*Link*	*Cost*
A	1	1
B	local	0
C	2	1
D	1	2
E	4	1



Routing tables

Routings from A		
To	*Link*	*Cost*
A	local	0
B	1	1
C	1	2
D	3	1
E	1	2

Routings from B		
To	*Link*	*Cost*
A	1	1
B	local	0
C	2	1
D	1	2
E	4	1

Routings from C		
To	*Link*	*Cost*
A	2	2
B	2	1
C	local	0
D	5	2
E	5	1

Routings from D		
To	*Link*	*Cost*
A	3	1
B	3	2
C	6	2
D	local	0
E	6	1

Routings from E		
To	*Link*	*Cost*
A	4	2
B	4	1
C	5	1
D	6	1
E	local	0

RIP routing algorithm

Update**:** Each *30* seconds or when local table changes, send update on each non-faulty outgoing link.

Propagation:When router X finds that router Y has a shorter and faster path to router Z, then it will update its local table to indicate this fact. Any faster path is quickly propagated to neighbouring rotes through the ***Update*** process.

Shown to converge by mathematicians (Bertsekas).
See next slide for details.

RIP routing algorithm

Variables: *Tl* local table, *Tr* table received.

Send: Each *t* seconds or when *Tl* changes, send *Tl* on each non-faulty outgoing link.

Receive: Whenever a routing table *Tr* is received on link *n*:

```
for all rows Rr in Tr {
    if (Rr.link != n) {
        Rr.cost = Rr.cost + 1;
        Rr.link = n;
        if (Rr.destination is not in Tl) add Rr to Tl;
         // add new destination to Tl
        else for all rows Rl in Tl {
            if (Rr.destination = Rl.destination and
                    (Rr.cost < Rl.cost or Rl.link = n)) Rl = Rr;
            // Rr.cost < Rl.cost : remote node has better route
            // Rl.link = n : remote node is more authoritative
        }
    }
}
```

Sample routes

- Send from C to A:
  - to link 2, arrive at B
  - to link 1, arrive at A
- Send from C to A if B table modified to:
  - to link 5, arrive at E
  - to link 4, arrive at B
  - to link 1, arrive at A

  NB extra hop.

Routings from C

To	*Link*	*Cost*
B	2	1
C	local	0
E	5	1
default	5	-

Congestion control

- When load on network high (80% capacity)
  - packet queues long, links blocked
- Solutions
  - packet dropping
    - reliable of delivery at higher levels
  - reduce rate of transmission
    - nodes send choke packets (Ethernet)
    - transmission control (TCP)
  - transmit congestion information to each node
    - QoS guarantees (ATM)

Protocol examples

- MobileIP
  - connectivity for mobile devices, even in transit
  - device retains single IP address
  - re-routing by Home (HA) and Foreign Agents (FA)
  - transparent
- TCP and UDP
  - main transport level protocols used by IP
- Wireless LAN (IEEE 802.11)
  - radio or infra-red communications
  - CSMA/CA based

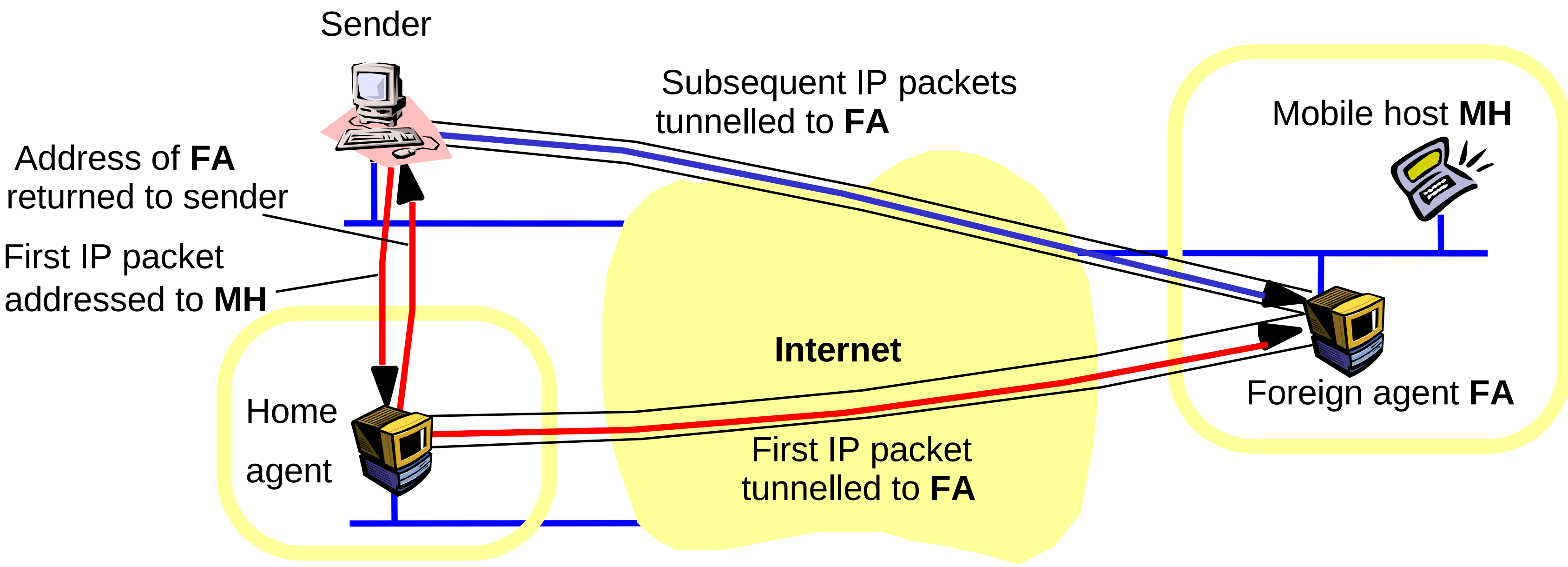
Transport level protocols

- UDP (basic, used for some IP functions)
  - uses IP address+port number
  - no guarantee of delivery, optional checksum
  - messages up to 64KB
- TCP (more sophisticated, most IP functions)
  - data stream abstraction, reliable delivery of all data
  - messages divided into segments, sequence numbers
  - sliding window, acknowledgement+retransmission
  - buffering (with timeout for interactive applications)
  - checksum (if no match segment dropped)

MobileIP

- At home normal, when elsewhere mobile host:
  - notifies HA before leaving
  - informs FA, who allocates temporary care-of IP address & tells HA
- Packets for mobile host:
  - first packet routed to HA, encapsulated in MobileIP packet and sent to FA (tunnelling)
  - FA unpacks MobileIP packet and sends to mobile host
  - sender notified of the care-of address for future communications which can be direct via FA
- Problems
  - efficiency low, need to notify HA

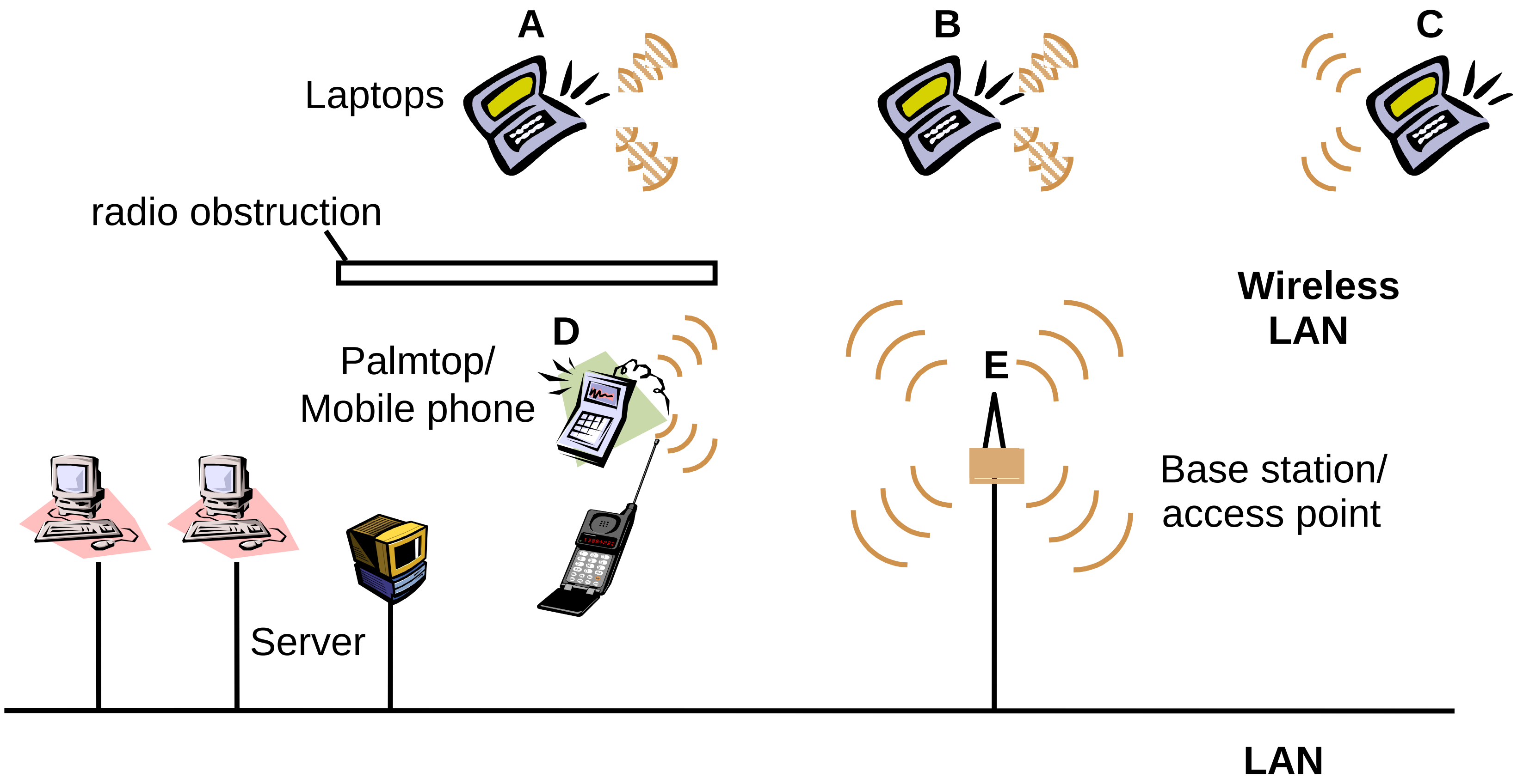
MobileIP routing



Wireless LAN (802.11)

- Radio broadcast (fading strength, obstruction)
- Collision avoidance by
  - slot reservation mechanism by Request to Send (RTS) and Clear to Send (CTS)
  - stations in range pick up RTS/CTS and avoid transmission at the reserved times
  - collisions less likely than Ethernet since RTS/CTS short
  - random back off period
- Problems
  - security (eavesdropping), use shared-key authentication

Wireless LAN configuration



Summary

- LANs
  - provide data transmission via layered protocol suites
  - delivery not always reliable (packet dropping)
  - congestion control needed to ensure QoS
  - security an issue for wireless (eavesdropping)
- WANs/Internet
  - require routers and routing mechanism
  - extra complexities in mobile context