Slides for Part B: Internetworking and Its Principles

Types of Networks (1)

- Local Area Networks (LAN)
  - floor/building-wide
  - single communication medium
  - no routing, broadcast
  - segments connected by switches or hubs
  - high bandwidth, low latency
  - Ethernet - 10Mbps, 100Mbps, 1Gbps
  - no latency guarantees (what could be the consequences?)
  - Personal area networks (PAN) [ad-hoc networks]: blue tooth, infra-red for PDAs, cell phones, …

Types of Networks (2)

- Metropolitan Area Networks (MAN)
  - city-wide, up to 50 km
  - Digital Subscriber Line (DSL): .25 - 8 Mbps, 5.5km from switch
    - BellSouth: .8 to 6 Mbps
  - Cable modem: 1.5 Mbps, longer range than DSL
    - Bright house w/ Road Runner: .5 to 10Mbps

Types of Networks (3)

- Wide Area Networks (WAN)
  - world-wide
  - Different organizations
  - Large distances
  - routed, latency .1 - .5 seconds
  - 1-10 Mbps (upto 600 Mbps)

Types of Networks (4)

- Wireless local area networks (WLAN)
  - IEEE 802.11 (WiFi)
  - 10-100 Mbps, 1.5km
    - 802.11 (1997): upto 2 Mbps, 2.4 GHz
    - 802.11a (1999): upto 54 Mbps, 5 GHz, ~75 feet outdoor
    - 802.11b (1999): upto 11 Mbps, 2.4 GHz, ~150 feet [most popular]
    - 802.11g (2003): upto 54 Mbps, 2.4 GHz, ~150 feet [backward compatible with 802.11b, becoming more popular]
- Wireless metropolitan area networks (WMAN)
  - IEEE 802.16 (WiMax)
  - 1.5-20 Mbps, 5-50km

Types of Networks (5)

- Wireless wide area networks (WWAN)
  - worldwide
  - GSM (Global System for Mobile communications)
  - 9.6 – 33 kbps
  - 3G (“third generation”): 128-384 kbps to 2Mbps

Types of Networks (6)

- Internetworks
  - connecting different kinds of networks
  - routers, gateways

Network performance

	Example	*Range*	*Bandwidth (Mbps)*	*Latency (ms)*
Wired:				
LAN	Ethernet	1-2 km	10-1000	1-10
MAN	ATM	250 km	1-150	10
WAN	IP routing	worldwide	.01-600	100-500
Internetwork	Internet	worldwide	0.5-600	100-500
Wireless:				
WPAN	Bluetooth (802.15.1)	10 - 30m	0.5-2	5-20
WLAN	WiFi (IEEE 802.11)	0.15-1.5 km	2-54	5-20
WMAN	WiMAX (802.16)	550 km	1.5-20	5-20
WWAN	GSM, 3G phone nets	worldwide	0.01-2	100-500

INTERNETWORKING

- **Internetworking is the process or technique of connecting different networks by using intermediary devices such as routers or gateway devices.**
- Internetworking ensures data communication among networks owned and operated by different entities using a common data communication and the Internet Routing Protocol. The Internet is the largest pool of networks geographically located throughout the world but these networks are interconnected using the same protocol stack, TCP/IP. Internetworking is only possible when the all the connected networks use the same protocol stack or communication methodologies.

Network principles (1)

- Packet transmission
  - message: logical unit of information
  - packet: transmission unit

Network principles (2)

- Data Streaming
  - audio/video
  - Need 120 Mbps (1.5 Mbps compressed)
  - Resource Reservation Protocol (RSVP), Real-time Transport Protocol (RTP)

Network principles (3)

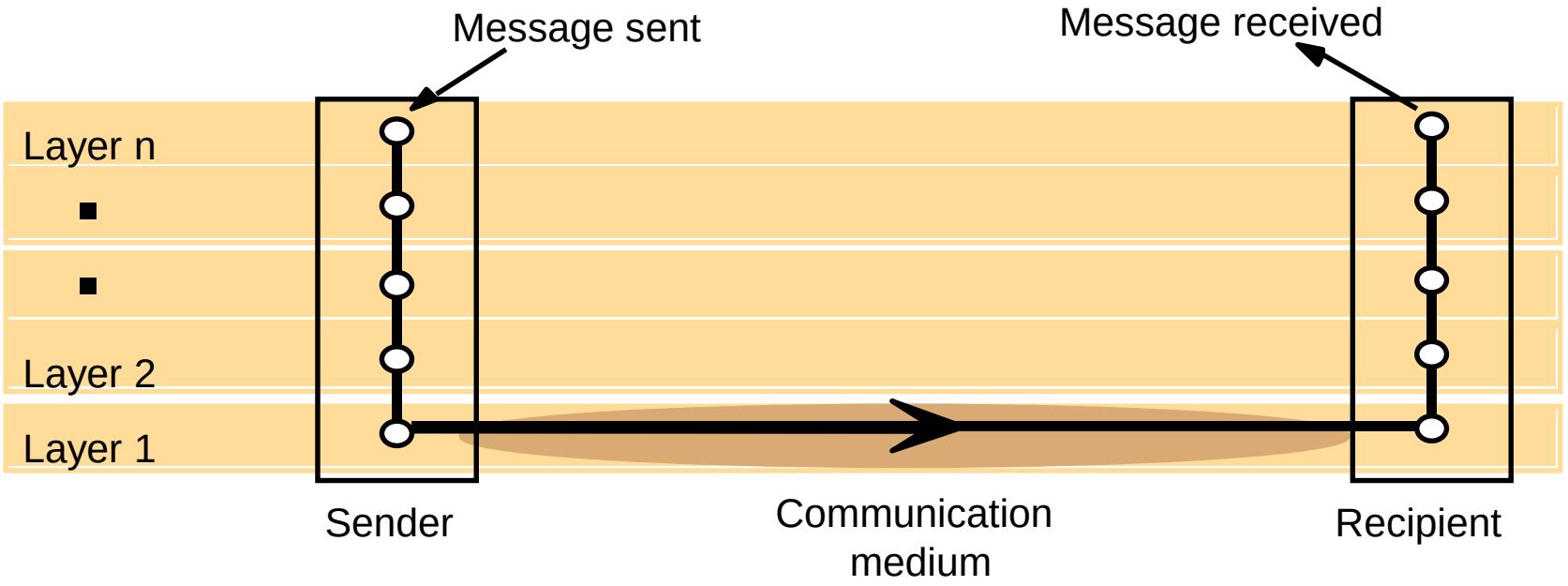
- Switching schemes (transmission between aribitrary nodes)
  - Broadcast: ethernet, token ring, wireless
  - Circuit switching: wires are connected
  - Packet switching:
    - store-and-forward
    - different routes
    - “store-and-forward” needs to buffer the entire packet before forwarding

Network principles (4)

- Protocols
  - Key components
    - Sequence of messages
    - Format of messages

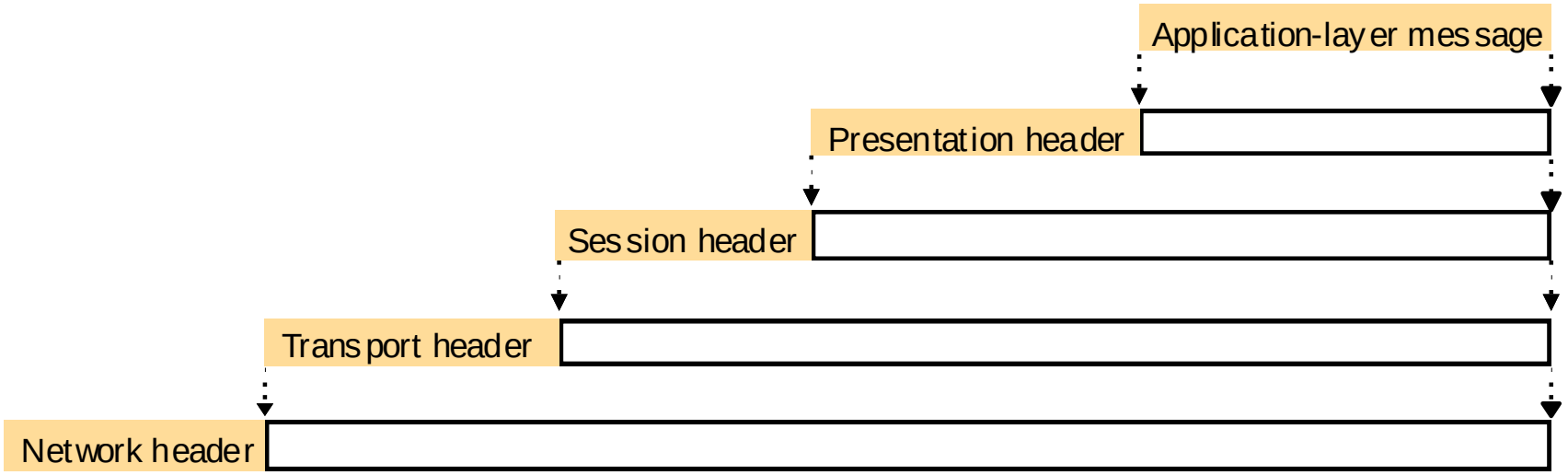
Network principles (5)

- Protocol layers, why?



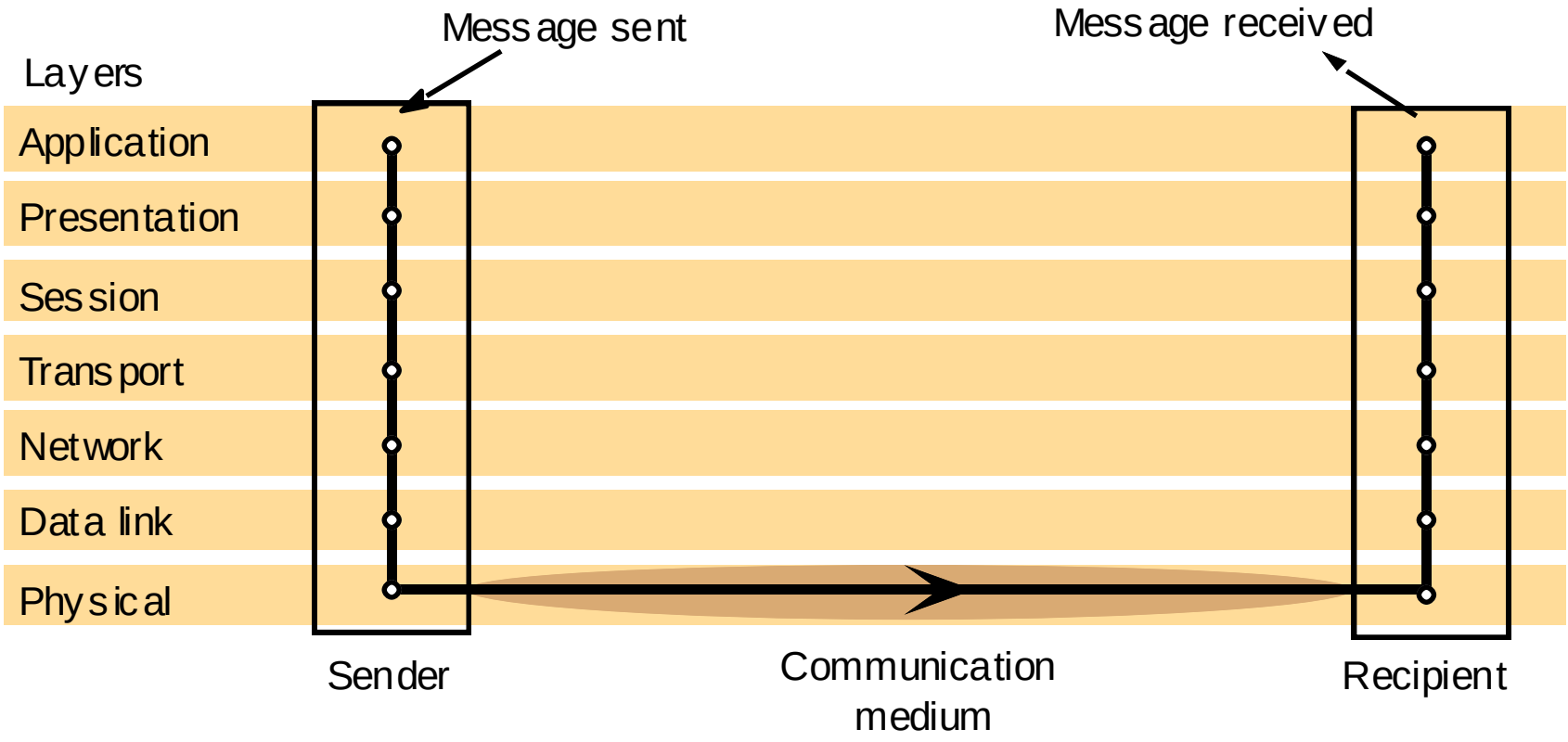
Network principles (6)

- Encapsulation in layered protocols



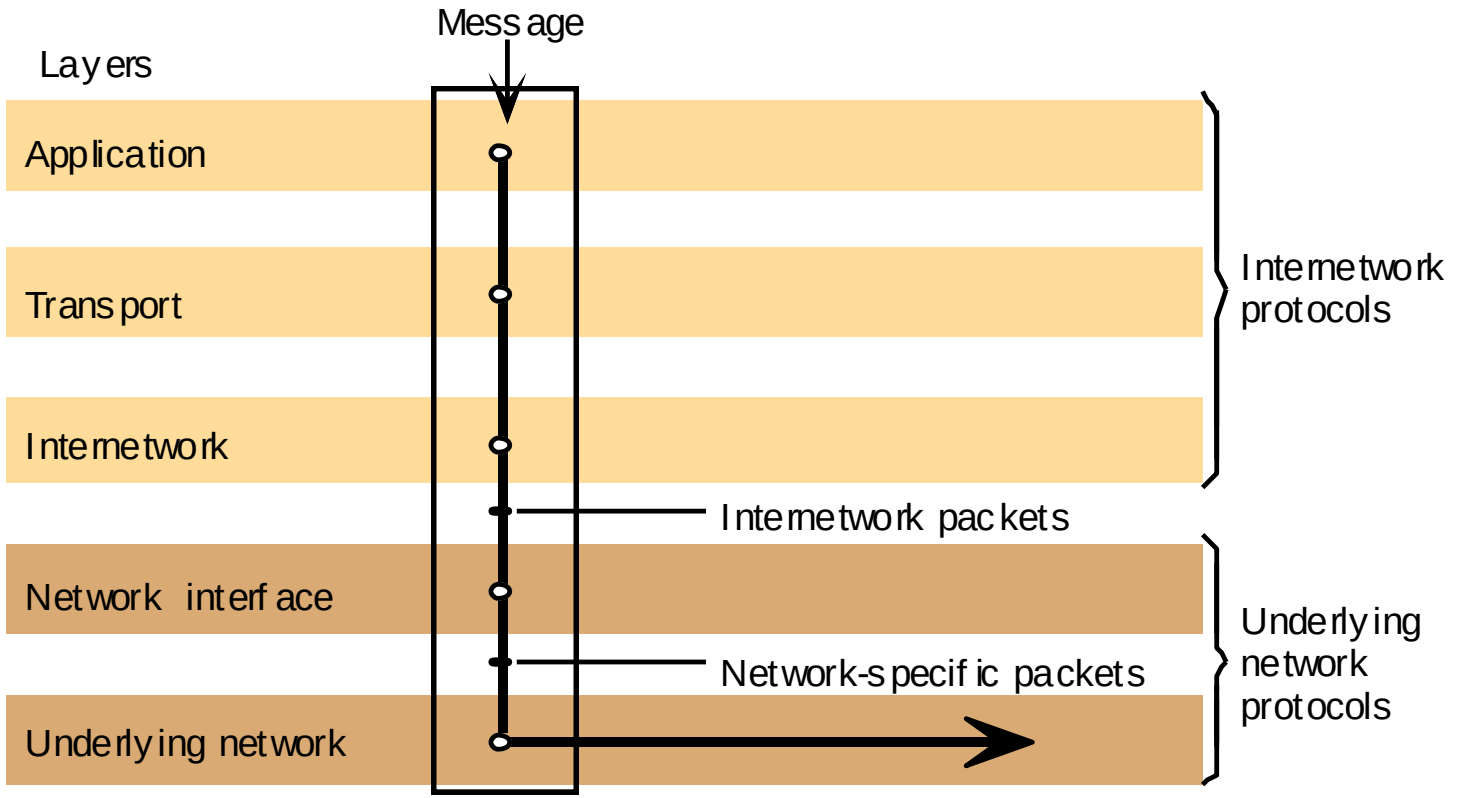
Network principles (7)

- ISO Open Systems Interconnection (OSI) model



Network principles (8)

- Internet layers
  - Application = application + presentation
  - Transport = transport + session



Network principles (9)

- Packet assembly
  - header and data
  - maximum transfer unit (MTU): 1500 for Ethernet
  - 64K for IP (8K is common because of node storage)
- ports: destination abstraction (application/service protocol)
- addressing: transport address = network address + port
  - Well-known ports (below 1023)
  - Registered ports (1024 - 49151)
  - Private (up to 65535)

Network principles (10)

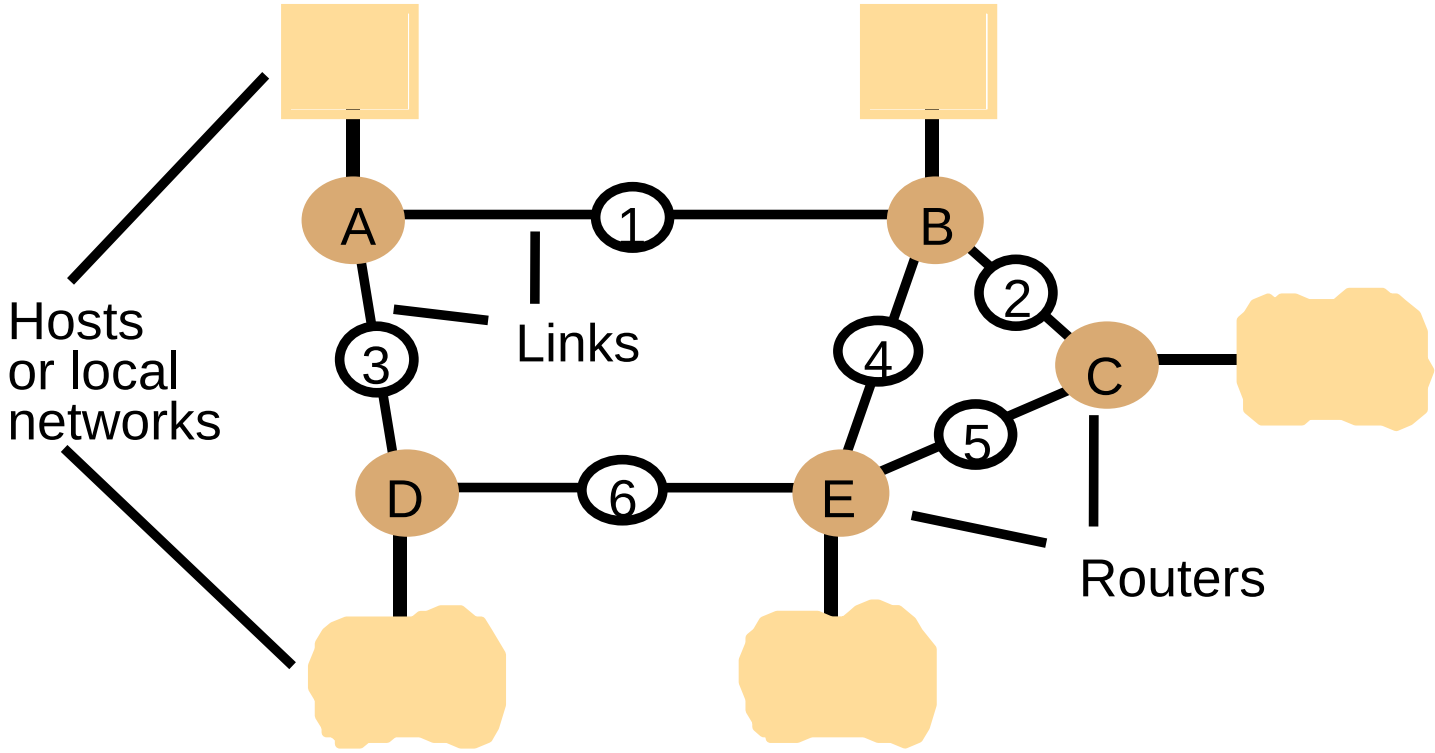
- Packet delivery (at the network layer)
  - Datagram packet
    - one-shot, no initial set up
    - different routes, out of order
    - Ethernet, IP
  - Virtual circuit packet
    - initial set up for resources
    - virtual circuit # for addressing
    - ATM
- Similar but different pairs of protocols at the transport layer (connection-oriented and connectionless)

Network principles (11)

- Routing
  - Routing Algorithm
    - decide which out-going link to forward the packet
      - for circuit switching, the route is determined during the circuit setup time
      - for packet switching, each packet is routed independently
    - update state of the out-going links
  - Routing Table
    - a record for each destination
    - fields: outgoing link, cost (e.g. hop count)

Network principles (12)

- Router example



Network principles (13)

- Congestion control
  - high traffic load, packets dropped due to limited resources
  - reducing transmission rate: "choke packets" from sender to receiver

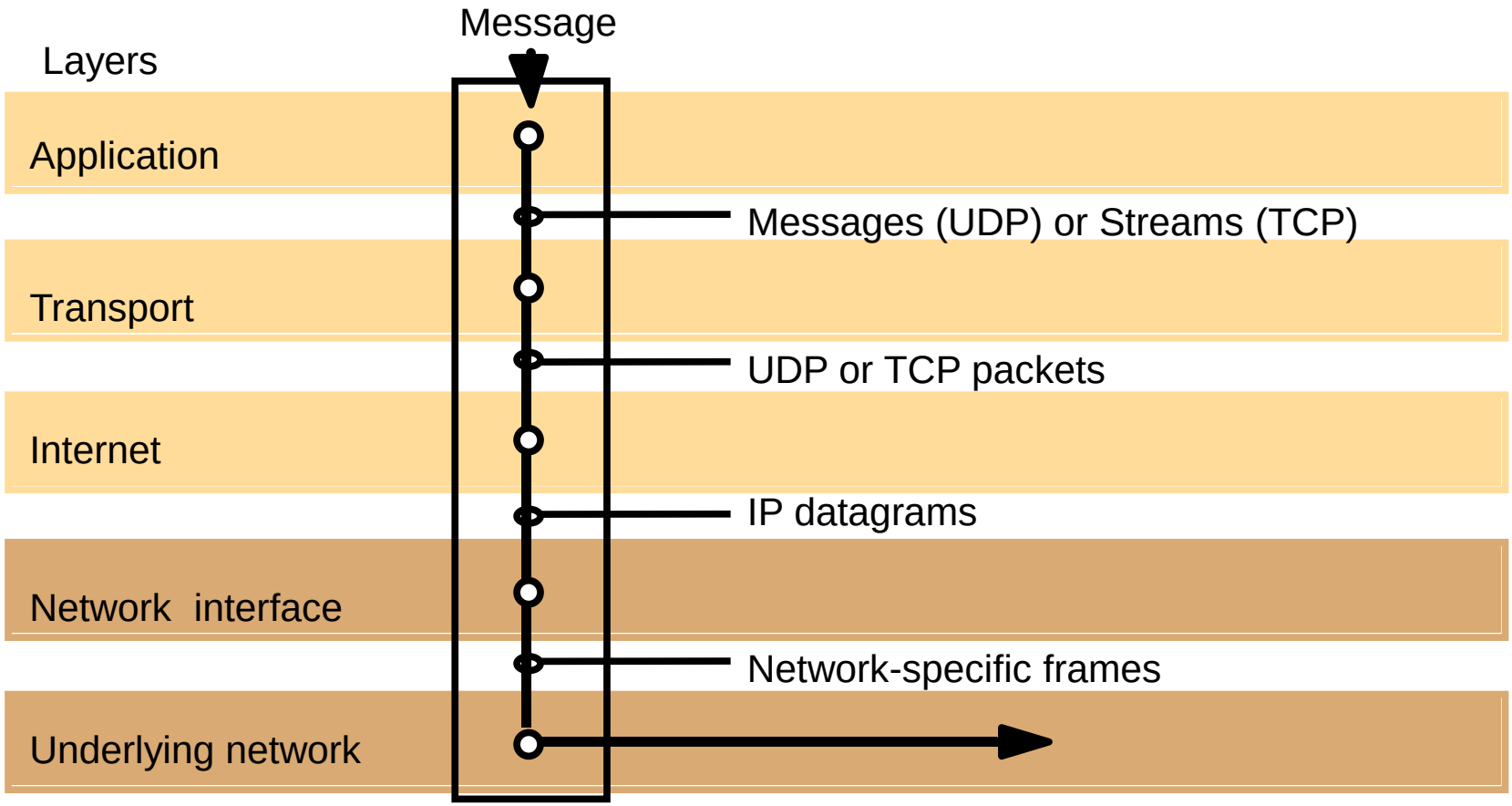
Networking principles (14)

- Network connecting devices
  - Hubs: extending a segment of LAN (broadcast)
  - Switches: switching traffic at data-link level (different segments of a LAN), making temporary hardware connections between two ports (or store and forward) [switches do not exchange info with each other]
  - Routers: routing traffic at IP level
  - Bridges: linking networks of different types, could be routers as well

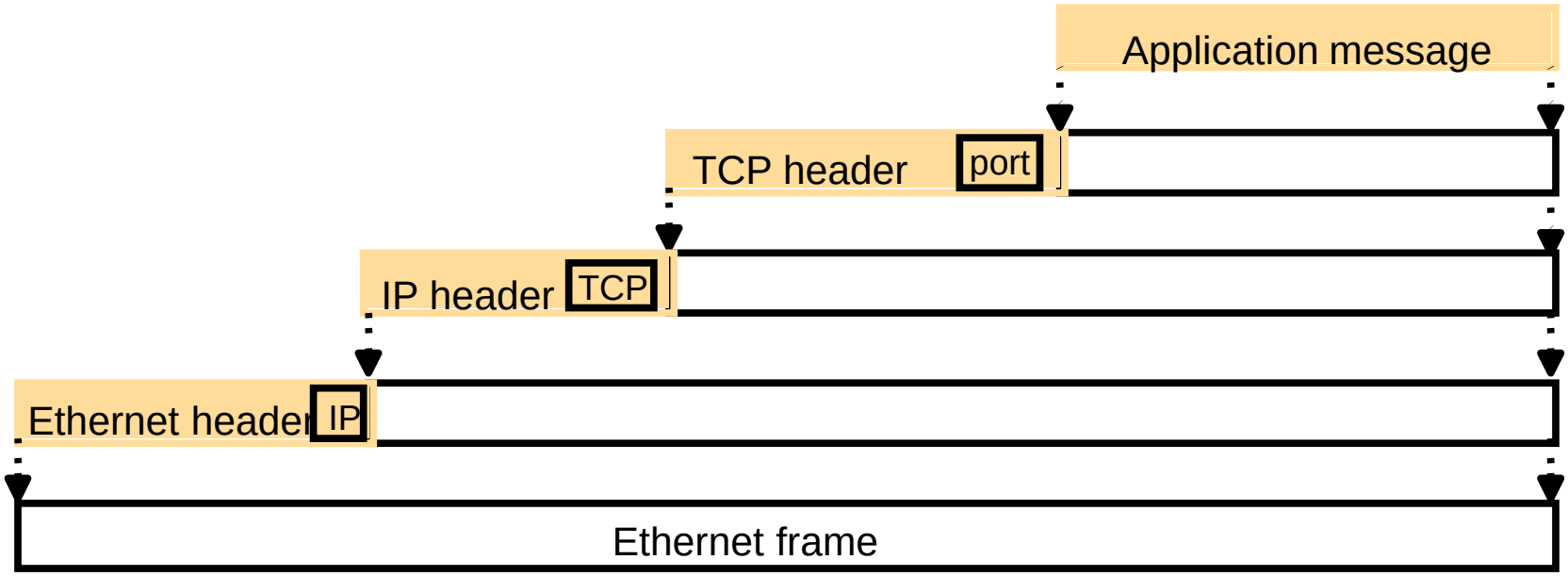
Internet protocols (1)

- IP (Internet Protocol)
  - "network" layer protocol
  - IP addresses
- TCP (Transmission Control Protocol)
  - transport layer
  - connection-oriented
- UDP (User Datagram Protocol)
  - transport layer
  - connection-less

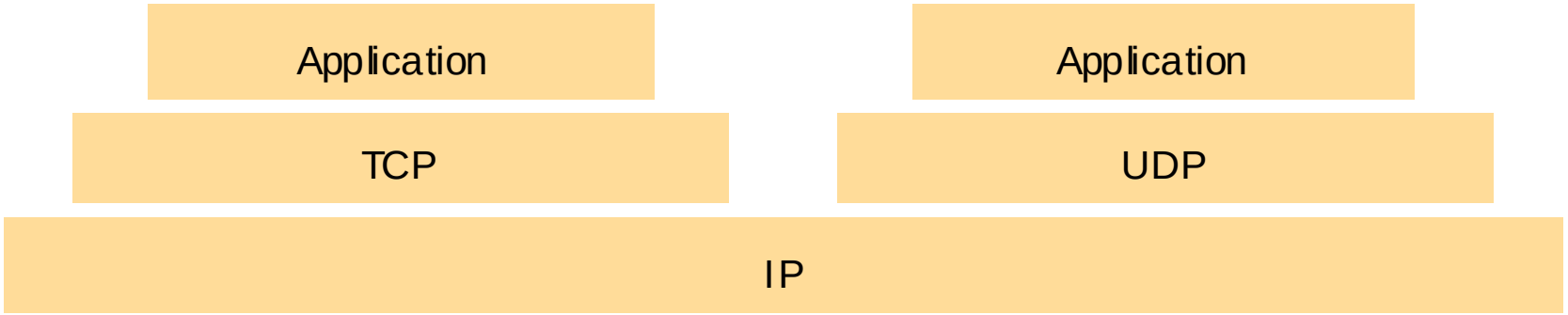
Internet protocols (2): TCP/IP layers



Internet protocols (3): layer encapsulation



Internet protocols (4): Programmer's view



Internet Protocols (15): IPv6

- IP addresses:128 bits (16 bytes)
  - 3 x 10^{38} addresses (7 x 10^{23} addresses per square meter!)
- routing speed
  - no data checksum as before
  - no fragmentation – need to know the smallest MTU in data-link layer
- real-time and special services
  - traffic class: priority, time-dependent (expired data are useless)
  - flow label: timing requirements for streams (reserving resources in advance)
- “next” header field
  - extension header types for IPv6
  - routing information, authentication, encryption ...
- Anycast: at least one nodes gets it
- security
  - currently handled above the IP layer
  - extension header types
- Migration from IPv4
  - backward compatibility: IPv6 addresses include IPv4 addresses
  - Islands of IPv6 networks, traffic tunnels though other IPv4 networks

Internet protocols (16):