Computer Networks

Networking Standards

Lecture Objectives

- Overview of OSI networking standards
- explore the functionalities of different layers
- Explore and analyse conceptual models (e.g. OSI model, TCP/IP model), standards (e.g. IEEE 802.x).
- Gain knowledge on 7-layer OSI reference model.

Network Architecture

Problem

- Networks are complex (heterogeneity, distributed, delay, losses, reordering, …)
- How do we organize a network implementation?

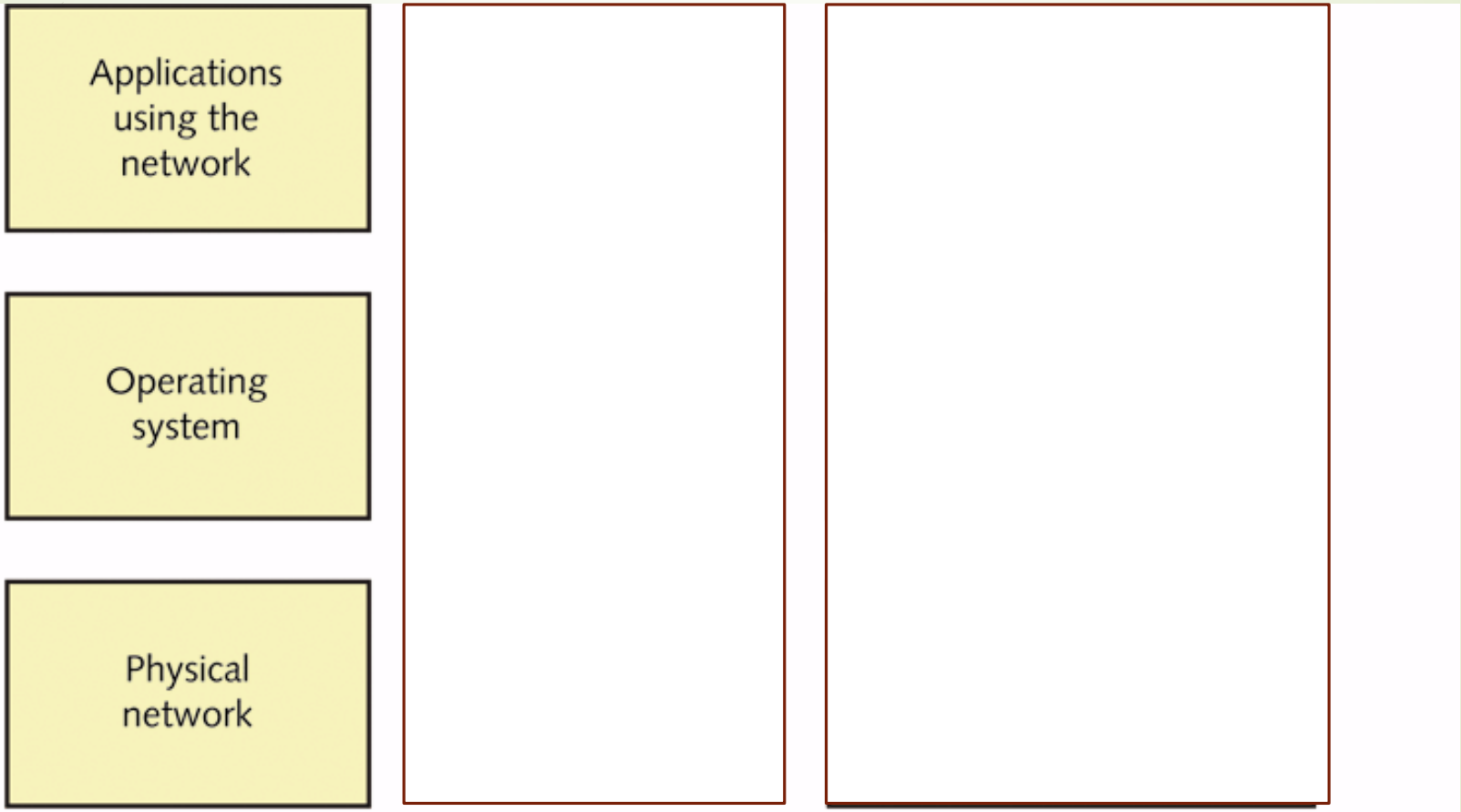
Solution

- To deal with complexity → use layering

Layering

- The system is broken into a vertical hierarchy of logically distinct entities (layers)
- The service provided by one layer is based solely on the service provided by layer below

Simple layering for a Network



An operating system can use more than one method to address a computer on the network, but at the network level, a MAC address is always used to address a device on the network

TCP/IP Network Layers

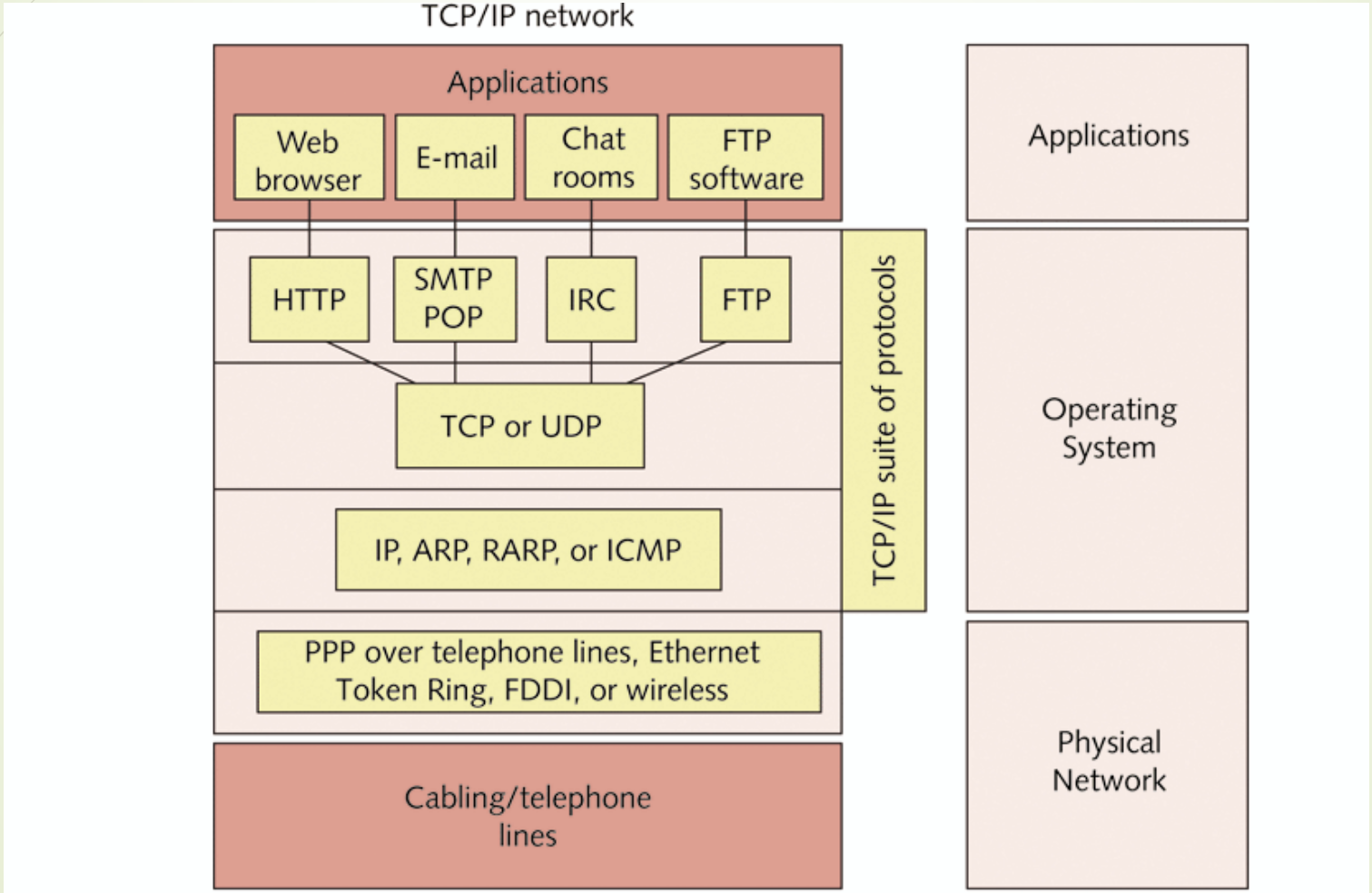
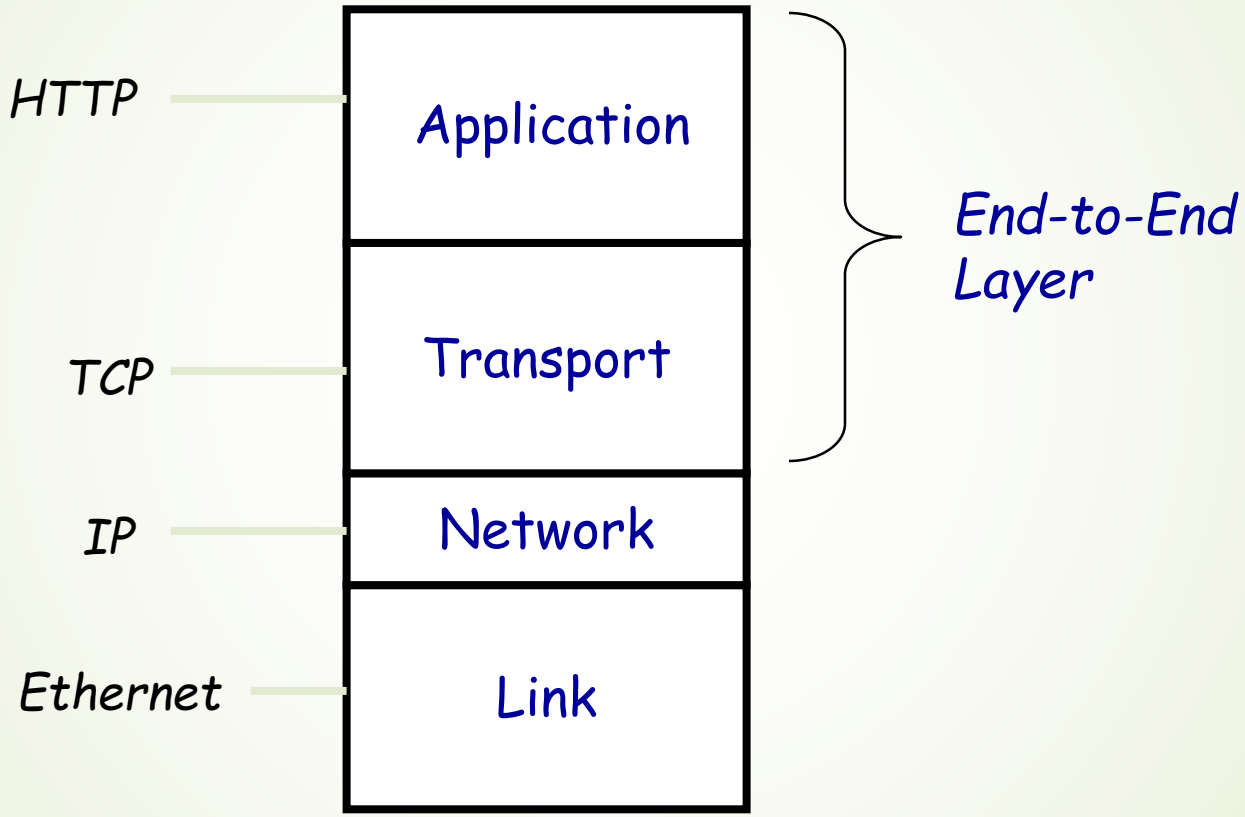


Figure 19-3 How software, protocols, and technology on a TCP/IP network relate to each other

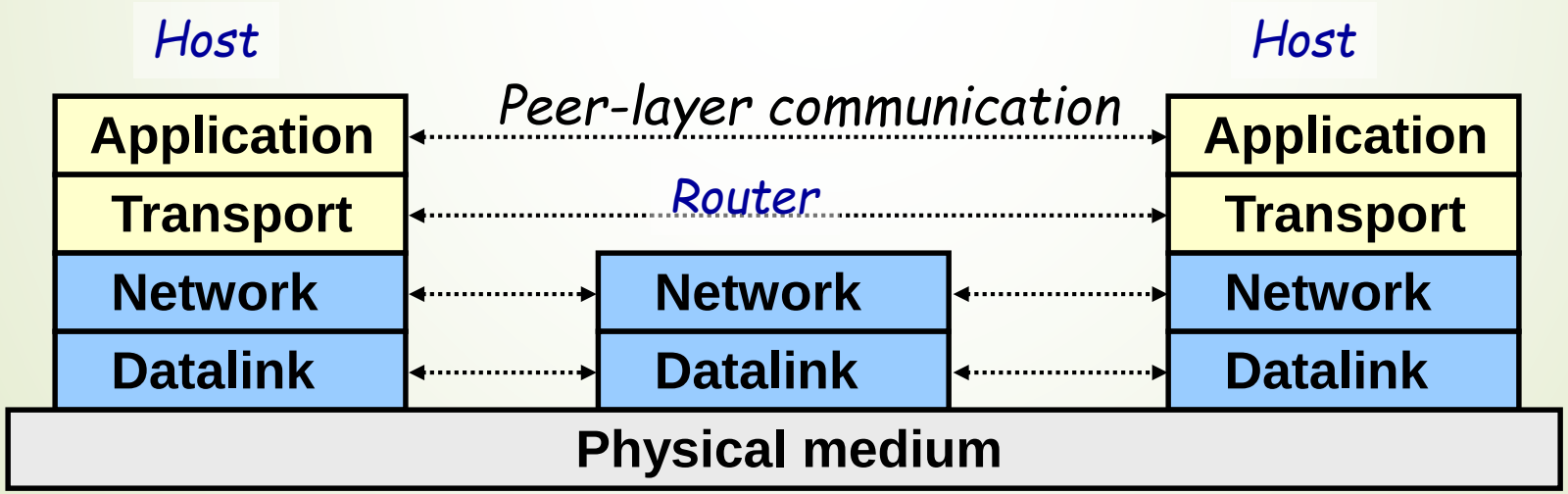
Layering: Our HTTP Example



The 4-layer Internet model

Where are these layers?

- Link and network layers are implemented everywhere
- The end-to-end layer (i.e., transport and application) is implemented only at hosts



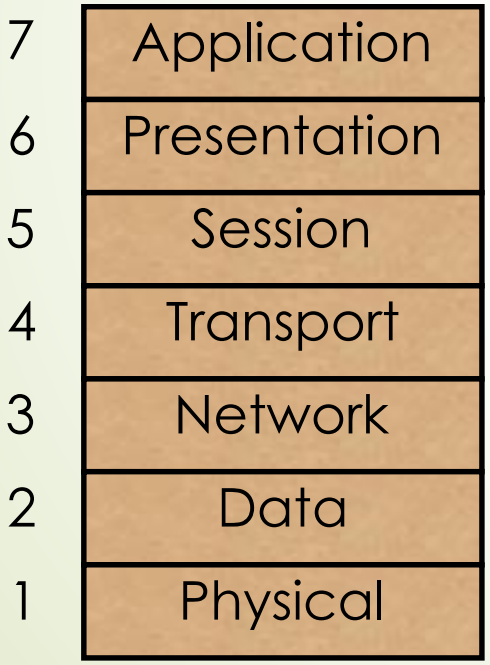
THE OSI REFERENCE MODEL

- The model was developed by the **International Organisation for Standardisation (ISO) in 1984**. It is now considered the primary Architectural model for inter-computer communications.
- The **Open Systems Interconnection** (OSI) reference model is a descriptive network scheme. It ensures greater compatibility and interoperability between various types of network technologies.
- The OSI model describes **how information or data makes its way** from application programmes (such as web browser) through a network medium (such as wire) to another application programme located on another network.
- The OSI reference model divides the problem of moving information between computers over a network medium into **SEVEN smaller and more manageable** problems .
- This separation into smaller more manageable functions is **known as layering.**

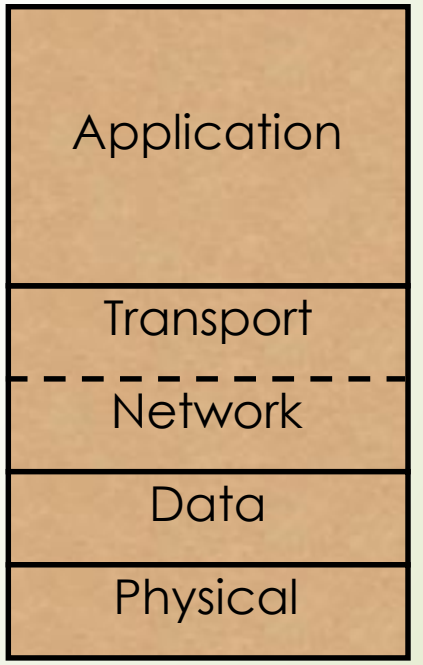
Computer Networking Models

- Models, also called protocol stacks, represented in layers, help to understand where things go right or wrong.

OSI 7-layer model



Simplified 4/5-layer model



Protocol Concepts

- Protocols are sets of rules.
- What do you want to do? (Application)
- Where are you going? (Addressing)
- How do you get there? (Media types)
- Did you get there? (Acknowledgments, Error checking)

Layered Communication

Number	Name	Function
Layer 1	Physical layer	Consists of the networking media (wiring and interconnections) and the components necessary to transmit a signal from one end to the other
Layer 2	Data Link layer	Packages the data so that it can be transmitted over the Physical layer
Layer 3	Network layer	Separates the data into frames and determines the route the data will take to its destination
Layer 4	Transport layer	Makes sure data packets are sequenced properly and do not contain any errors

Layers in the OSI Model

Layered Communication

Number	Name	Function
Layer 5	Session layer	Maintains a connected link, called a session, between the two communicating ends
Layer 6	Presentation layer	Determines the format used for communication and compresses, encrypts, or converts the data as necessary for the protocol in use
Layer 7	Application layer	Completes or initiates the actions being communicated

Layers in the OSI Model

LAYER 1: PHYSICAL

- The physical layer deals with the **physical characteristics of the transmission medium**.
- It defines the electrical, mechanical, procedural, and functional specifications for activating, maintaining, and deactivating the physical link between end systems.
- **Such characteristics** as voltage levels, timing of voltage changes, physical data rates, maximum transmission distances, physical connectors, and other similar attributes **are defined by physical layer specifications**.

Physical Layer (Layer 1)

- Nowadays: Pretty much just Cat 5 (or Cat 5e or Cat6) twisted pair copper wire and microwave (wireless).
- Other: Fiber (multi-mode or single-mode) coaxial copper (thick- and thin-net), Cable Modem, plain phone (DSL), microwaves (wireless ethernet), etc.

Physical: Wireless

- Terms: 802.11b, 802.11a, 802.11g
- Uses microwave radio waves in the 2.4Ghz (802.11b and g) and 5.4Ghz (802.11a and n) bands to transmit data. These are unregulated frequencies, so other things (cordless phones, etc.) can use the same frequencies, but hopefully one or the other is smart enough to hop frequencies to stay clear of the other. 802.11b and g devices can use the same access points easily. 802.11a requires separate (or dual) antennae.
- For the most part, completely and utterly insecure. Very easy to capture someone else's data. Make sure your application is secure (SSL, SSH, etc.)
- 802.11b at 11Mbps; both 802.11a and g at 54Mbps

LAYER 2: DATA LINK

- The data link layer provides **access to the networking media** and physical transmission across the media and this enables the data to locate its intended **destination** on a network.
- Concerned with network topology, network access, error notification, ordered delivery of frames, and flow control.
- Examples :- **Ethernet**, Frame Relay, FDDI.

Data Layer (Layer 2)

- The data layer takes the 1's and 0's handed it by the Network layer and turns them into some kind of signal that can go over the physical layer (electrical current, light pulses, microwaves, etc.) It also takes this signal and turns it back into 1's and 0's to pass up the stack on the receiving end.
- If there might be more than 2 devices on the connection, some form of addressing scheme is required to get the packet to the right destination.
- Some data layers: Token Ring, FDDI, LocalTalk, and the overwhelmingly most common data layer protocol: Ethernet.

Data Layer: Ethernet

- **CSMA/CD**: Carrier Sense, Multiple Access, Collision Detect. Simple!
- Since Ethernet was designed to be on **shared media**, with 2 or more users, and the "more" part can be very big (that's the "Multiple Access" part) you have to listen to see if anyone else is talking before you talk (**Carrier Sense**) and if you and someone else start talking at the same time, notice it **(Collision Detect)**, say "excuse me" stop and try again later.
- Ethernet is **10Mbit** (10 million bits per second) only.
  - **Fast ethernet**, which has nearly the same rules, is **100Mbit** only.
  - **Gigabit ethernet** is **1000Mbit** only.
  - Some Network Interface Cards (NIC's) can speak at 10 or 100 (and sometimes 10 or 100 or 1000) but each end has to be using the same speed or there's no connection. 10Mbit at one end and 100Mbit at the other end won't work.

Ethernet: Addressing

- Since there can be many users on an ethernet network, everyone has to have their own **unique address**.
- This is called the Media Access Control (or **MAC) address**, or sometimes ethernet address, physical address, adaptor address, hardware address, etc.
- It's a **12-digit (48 bit)** hexadecimal address that is unique to that ethernet adaptor and no other in the world. It can be written as **00:30:65:83:fc:0a** or 0030.6583.fc0a or 003065:83fc0a or 00-30-65-83-fc-0a but they all mean the same thing.
- The first 6 digits are the Vendor code, (003065 belongs to Apple), the last 6 are the individual interface's own.

Ethernet addresses: now what?

- To send someone a message, start with a broadcast (FFFF.FFFF.FFFF) asking "where's Bob?" Everyone's supposed to look at broadcasts.
- "Bob" replies, in his reply, he includes his ethernet address. Since every ethernet packet has the destination and sender address listed, "Bob" knows your address (from your broadcast packet) so doesn't have to start with a broadcast.
- For the rest of the conversation, you'll put each other's address as the destination (and yours as the sender), so the conversation can pass along the ethernet media between you.
- Who's "Bob" and how did he get that name? That's a layer 3 (Network) problem, layer 2 (Data) doesn't care.

LAYER 3: NETWORK

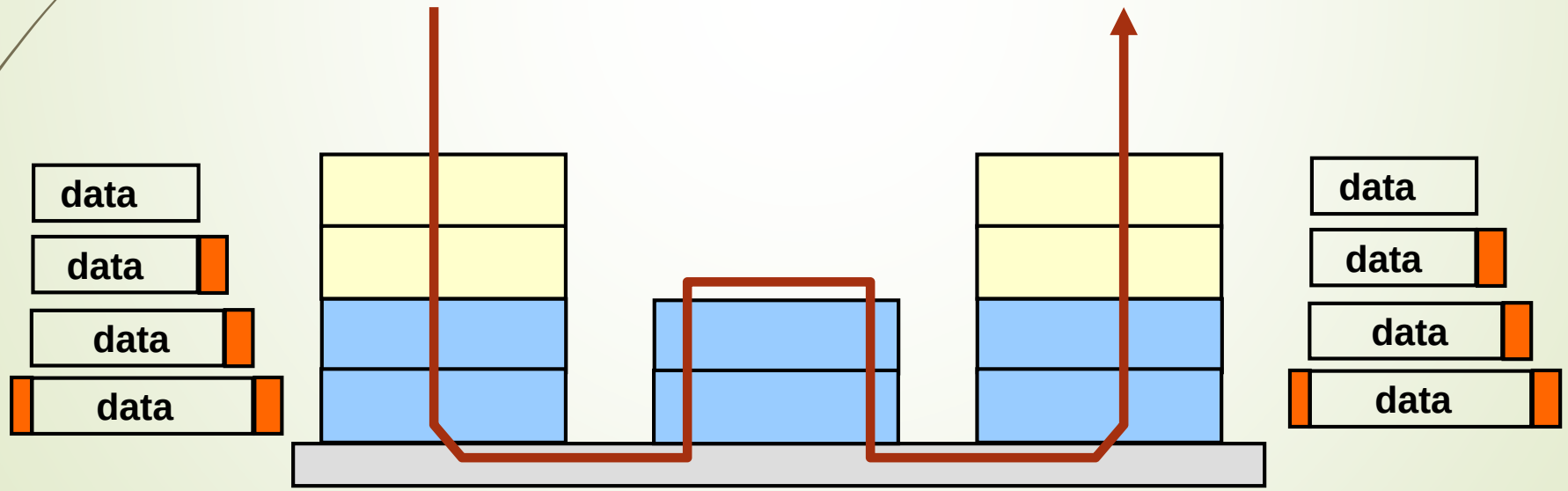
- Defines end-to-end delivery of packets.
- Defines logical addressing so that any endpoint can be identified.
- Defines how routing works and how routes are learned so that the packets can be delivered.
- The network layer also defines how to fragment a packet into smaller packets to accommodate different media.
- Routers operate at Layer 3.
- Examples :- IP, IPX, AppleTalk.

Network Layer (Layer 3)

- Data layer packets can't be routed, they're local only. Your computer can only get data layer packets on its data layer interface,
- Network packets can be routed. This means they can be passed from one local network to another.
- so network layer packets have to be stuffed inside the data layer packets.
- This is called "**encapsulation**" and is why a layered model is so handy.

Encapsulation

- A layer can use only the service provided by the layer immediate below it
- Each layer may change and add a header to data packet



Network Layer (Layer 3)

- When you link computers up, via layers 1 (Physical) and 2 (Data) you get a network. When you link networks up, you get an internetwork. You need the Network layer (3) to get data between all the little networks (often called subnets) of your internetwork.
- Network Layer Protocols: Internet Protocol (IP) and some others that aren't used any more (AppleTalk, Netware, etc.)

Network Layer: IP

- The **Internet Protocol (IP)** is the Network layer protocol used on the Internet! It's so handy that most everyone uses it on all their networks big and small.
- Designed for huge, ever-expanding networks of networks. Works pretty well with unreliable links, routes can be re-built when links go down.
- **ARP**: **Address Resolution Protocol.** Turns an IP number into an ethernet number, very important. Instead of asking "Who's Bob?" you ask "Who's 172.19.4.15" and if you get a reply, associate the ethernet address with the IP address in your arp table, and now you can keep sending your data to the intended recipient via the correct ethernet address.
- Remember: the only packet you can actually send on ethernet is an ethernet packet, everything else has to be stuffed inside it.

LAYER 4: TRANSPORT

- The transport layer **regulates information flow** to ensure end-to-end connectivity between host applications reliably and accurately.
- The transport layer **segments** data from the sending host's system and **reassembles** the data into a data stream on the receiving host's system.
- Layer 4 protocols include **TCP** (Transmission Control Protocol) and **UDP** (User Datagram Protocol).

UDP v/s TCP

Characteristics/ Description	UDP	TCP
General Description	Simple High speed low functionality "wrapper" that interface applications to the network layer and does little else	Full-featured protocol that allows applications to send data reliably without worrying about network layer issues.
Protocol connection Setup	Connection less data is sent without setup	Connection-oriented; Connection must be Established prior to transmission.
Data interface to application	Message base-based is sent in discrete packages by the application.	Stream-based; data is sent by the application with no particular structure
Reliability and Acknowledgements	Unreliable best-effort delivery without acknowledgements	Reliable delivery of message all data is acknowledged.
Retransmissions	Not performed. Application must detect lost data and retransmit if needed.	Delivery of all data is managed, and lost data is retransmitted automatically.
Features Provided to Manage flow of Data	None	Flow control using sliding windows; window size adjustment heuristics; congestion avoidance algorithms
Overhead	Very Low	Low, but higher than UDP
Transmission speed	Very High	High but not as high as UDP
Data Quantity Suitability	Small to moderate amounts of data.	Small to very large amounts of data.

LAYER 5: SESSION

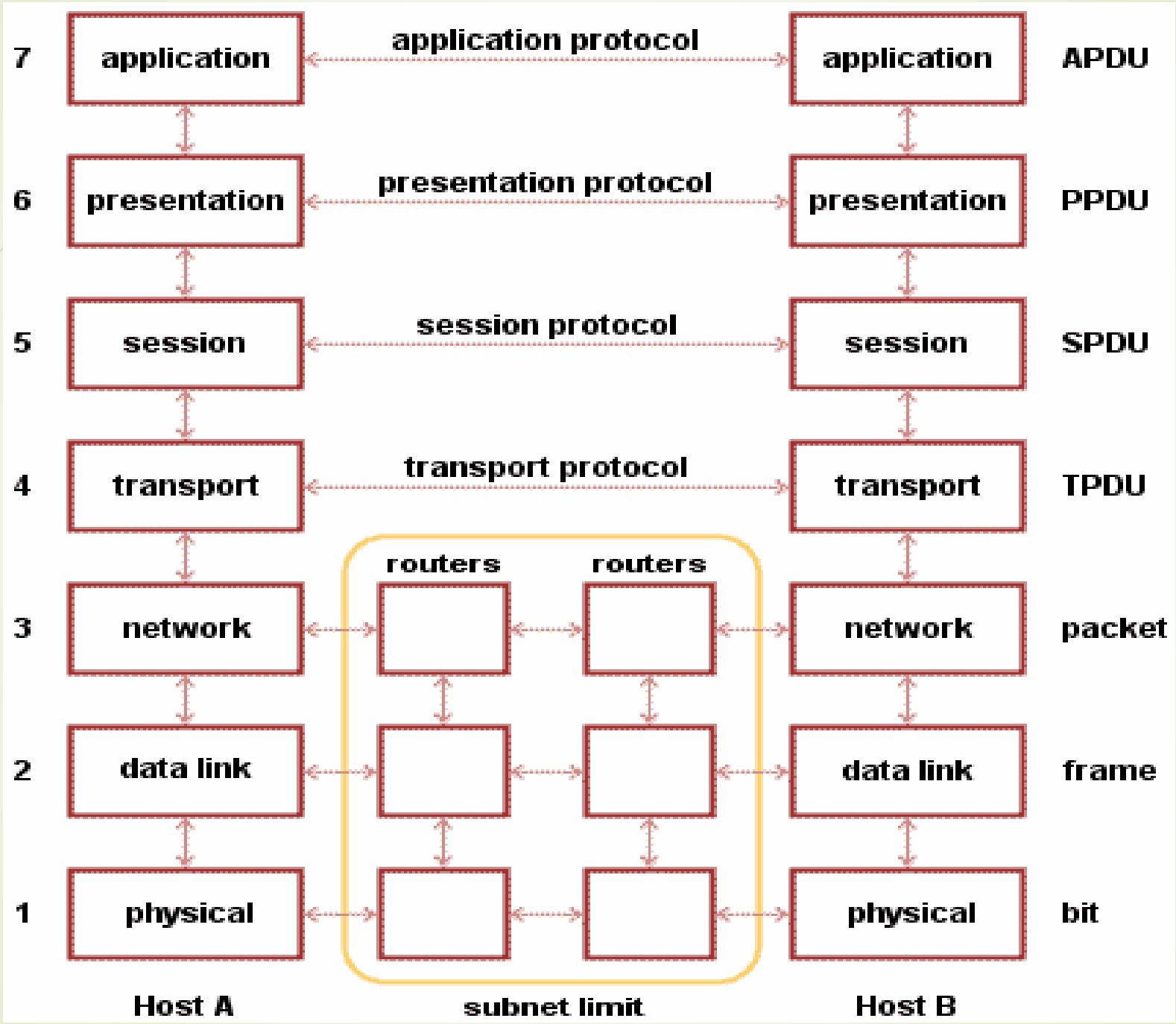
- The session layer defines how to start, control and end conversations (called sessions) between applications.
- This includes the control and management of multiple bi-directional messages using dialogue control.
- It also synchronizes dialogue between two hosts' presentation layers and manages their data exchange.
- The session layer offers provisions for efficient data transfer.
- Examples :- SQL, ASP(AppleTalk Session Protocol).

LAYER 6: PRESENTATION

- The presentation layer ensures that the information that the application layer of one system sends out is readable by the application layer of another system.
- If necessary, the presentation layer translates between multiple data formats by using a common format.
- Provides encryption and compression of data.
- Examples :- JPEG, MPEG, ASCII, EBCDIC, HTML.

LAYER 7: APPLICATION

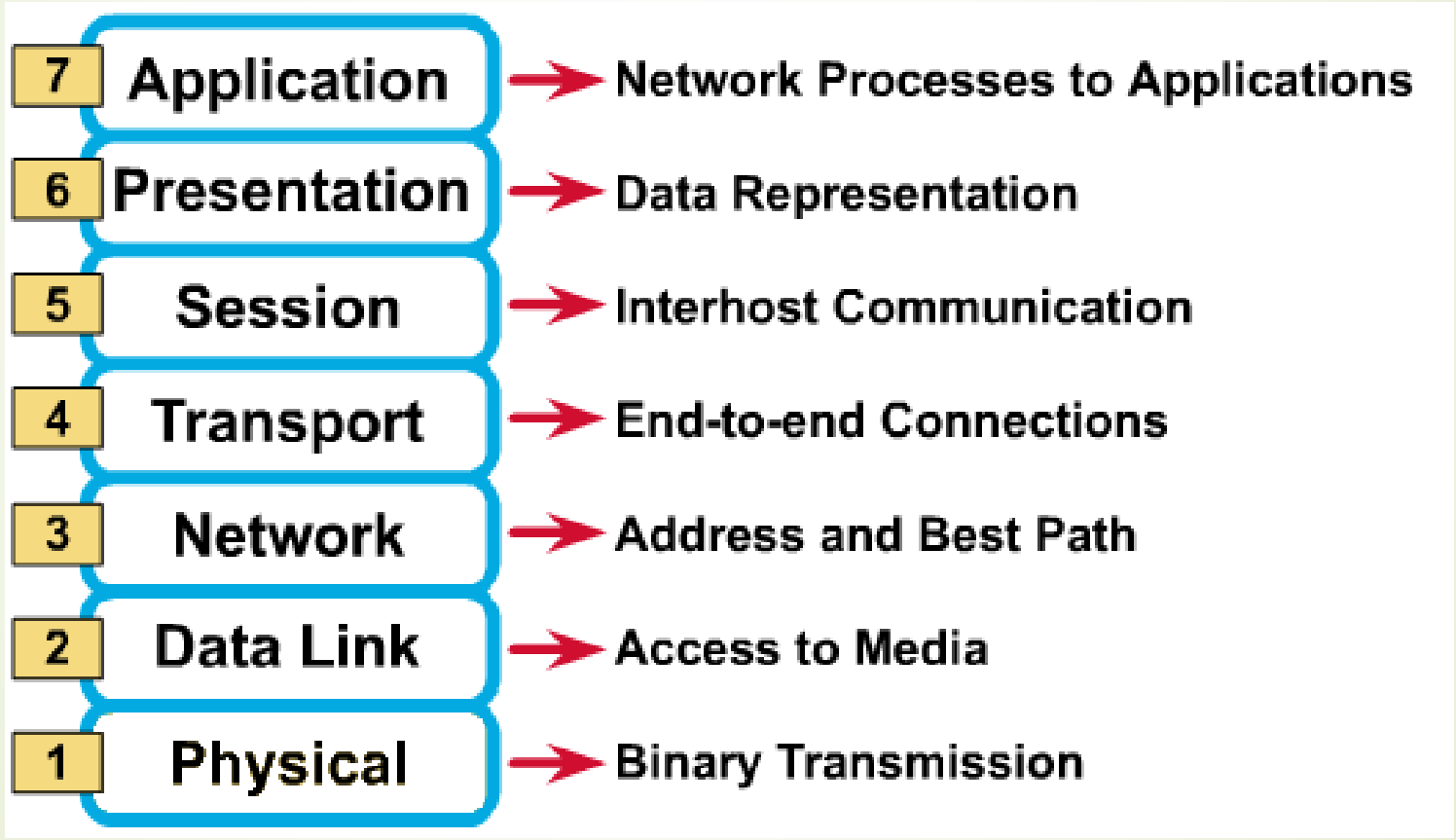
- The application layer is the OSI layer that is closest to the user.
- It provides network services to the user's applications.
- It differs from the other layers in that it does not provide services to any other OSI layer, but rather, only to applications outside the OSI model.
- Examples of such applications are spreadsheet programs, word processing programs, and bank terminal programs.
- The application layer establishes the availability of intended communication partners, synchronizes and establishes agreement on procedures for error recovery and control of data integrity.


7
application
application protocol
application
APDU
6
presentation
presentation protocol
presentation
PPDU
5
session
session protocol
session
SPDU
4
transport
transport protocol
transport
TPDU
routers
routers
3
network
network
packet
2
data link
data link
frame
1
physical
physical
bit
Host A
subnet limit
Host B

A LAYERED NETWORK MODEL

- The process of breaking up the functions or tasks of networking into layers **reduces complexity**.
- Each layer provides a **service to the layer above** it in the protocol specification.
- Each layer software or hardware on other computers. **communicates with the same layer's**
- The lower 4 layers (transport, network, data link and physical —Layers 4, 3, 2, and 1) are concerned with the flow of data from end to end through the network.
- The upper four layers of the OSI model (application, presentation and session—Layers 7, 6 and 5) are orientated more toward services to the applications.
- Data is Encapsulated with the necessary protocol information as it moves down the layers before network transit.

THE SEVEN **OSI** REFERENCE MODEL LAYERS



IEEE 802 standard

- A family of IEEE standards dealing with local area networks and metropolitan area networks.
- Map to the lower two layers (Data Link and Physical) of the seven-layer OSI networking reference model
- IEEE 802 splits the OSI Data Link Layer into two sub-layers named logical link control (LLC) and media access control (MAC).

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)
802.13	Unlucky number. Nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth)
802.16 *	Broadband wireless
802.17	Resilient packet ring

Questions?