Computer Networks

-Network architecture-

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W1 recap

- Much information on the Internet is accessed using a client-server model
- In peer-to-peer communication, individuals forming a loose group are communicating with others in the group
- IoT is about connecting our electronic devices to the Internet
- Broadband access is delivered to homes through copper, coaxial, or optical
- There are fixed-wireless and mobile wireless networks
- LAN is a private network that operates within and nearby a single building
  - the IEEE 802.11 standard is called WiFi
  - the Ethernet (IEEE 802.3) is the most common wired LAN
  - a switch has multiple ports, each of which connect to one other device
- A WAN spans a large geographical area with hosts connected by the subnet
- There are policy, legal, and social issues involving computer networks

The ARPANET

- There are many different types of networks, in different sizes, for different goals
- At the late 50s, military communications still used the public telephone network that was vulnerable
- The **ARPANET** (Advanced Research Projects Agency Network) is an early network where the subnet consists of minicomputers connected by transmission lines
  - made to be reliable and redundant
  - later **NSFNET** (National Science Foundation Network) that allowed universities, research labs to have access to supercomputers and communicate

The Internet

- The **Internet** is a collection of different networks that use common protocols and provide common services
  - not controlled by any single organization
  - it exploded in size with the emergence of the **WWW** (World Wide Web)
- The way we use the Internet has changed radically
  - initially it was mainly for email, newsgroups, remote login, and file transfer
  - nowadays mainly real-time media distribution, social media with the dominant form of traffic being video streaming

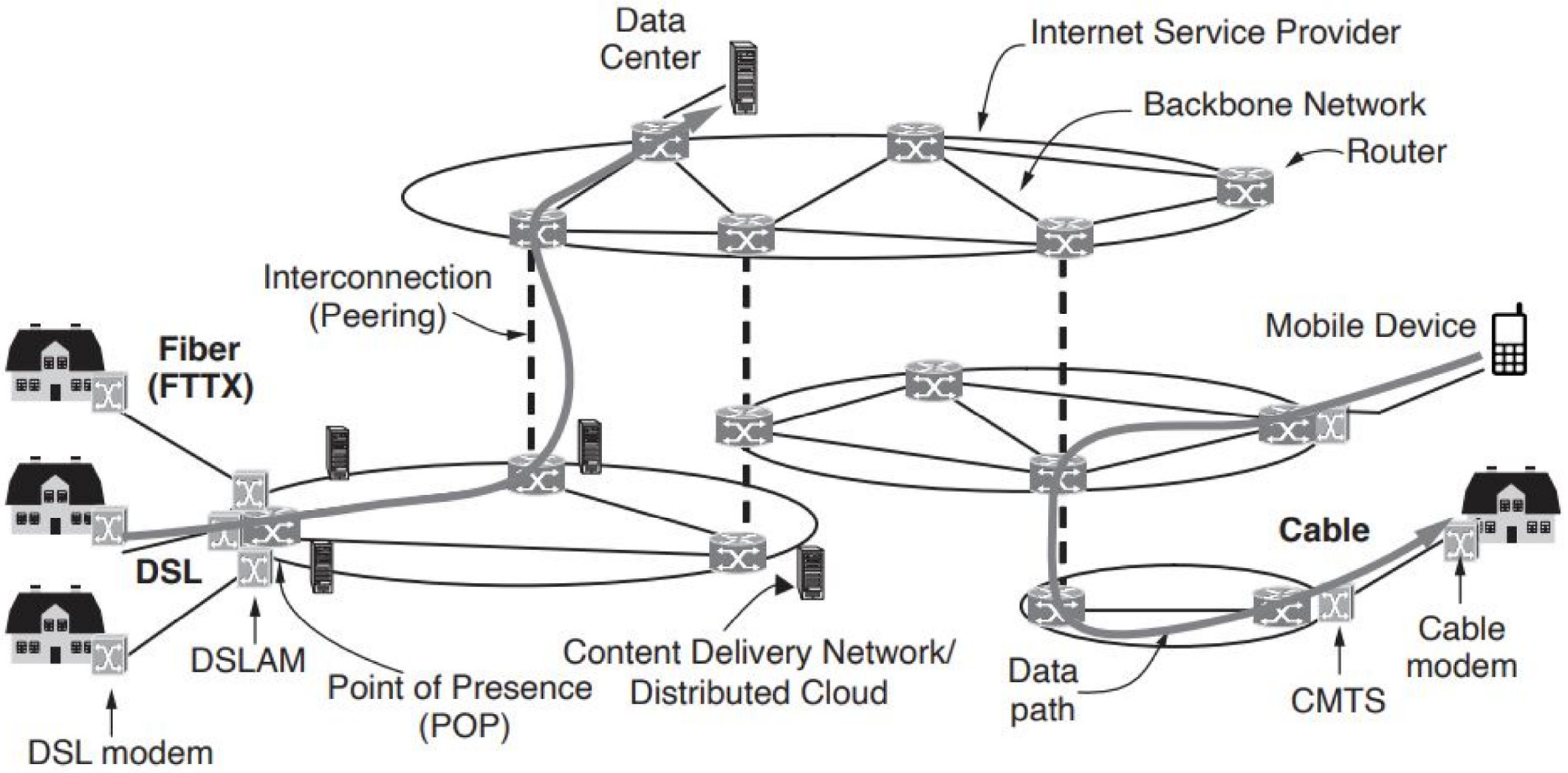
Connect to the network

- To join the Internet, the computer is connected to an ISP
  - lets the computer exchange packets (data divided into segments) with all other hosts
  - many kinds of Internet access (bandwidth, costs, connectivity)
- A common way to connect is the cable network, or **HFC** (Hybrid Fiber-Coaxial) network
  - transmit a variety of other data services, like TV channels, voice
  - uses a packet-based transport called **DOCSIS** (Data Over Cable Service Interface Specification)
- The device at the home end is the **cable modem** and the one at the cable headend is the **CMTS** (Cable Modem Termination System)
  - a modem is any device that converts between digital bits and analog signals
- Another option to connect is the high-speed **FTTH** (Fiber to the Home)

The ISP's side

- The location where customer packets enter the ISP network for service the ISP's **POP** (Point of Presence)
  - if a packet is destined for a host served directly by the ISP, the packet is routed over the **backbone** of the ISP (and delivered to the host), otherwise handed over to another ISP
- ISPs connect their networks to exchange traffic at **IXPs** (Internet eXchange Points)
  - the connected ISPs are said to *peer* with each other
  - small ISPs are often paying for *transit* to larger ISPs
- Companies that provide lots of content locate their servers in **data centers**

Internet architecture overview



Shared goals

- Network protocols often share a common set of design goals
- *Reliability* is the issue of making a network that operates correctly even though it is somehow compromised
- *Resource allocation* to make designs that are scalable
- *Evolvability*, since networks grow larger and new designs emerge that need to be connected to the existing network
- *Security* to defend against different kind of threats

Reliability and Resource allocation

- Make a network operate correctly even though it is comprised of a collection of components that are themselves unreliable
  - error detection finds errors in received information
  - error correction corrects a message by recovering the possibly incorrect bits
- Find a working path through a network using routing
  - routing allows network to automatically make the decision
- Allocate resources so scalable designs continue to work well when network gets large
  - keeping a fast sender from swamping a slow receiver with data
- Congestion problem
  - occurs when too many computers want to send too much traffic, and the network cannot deliver it all

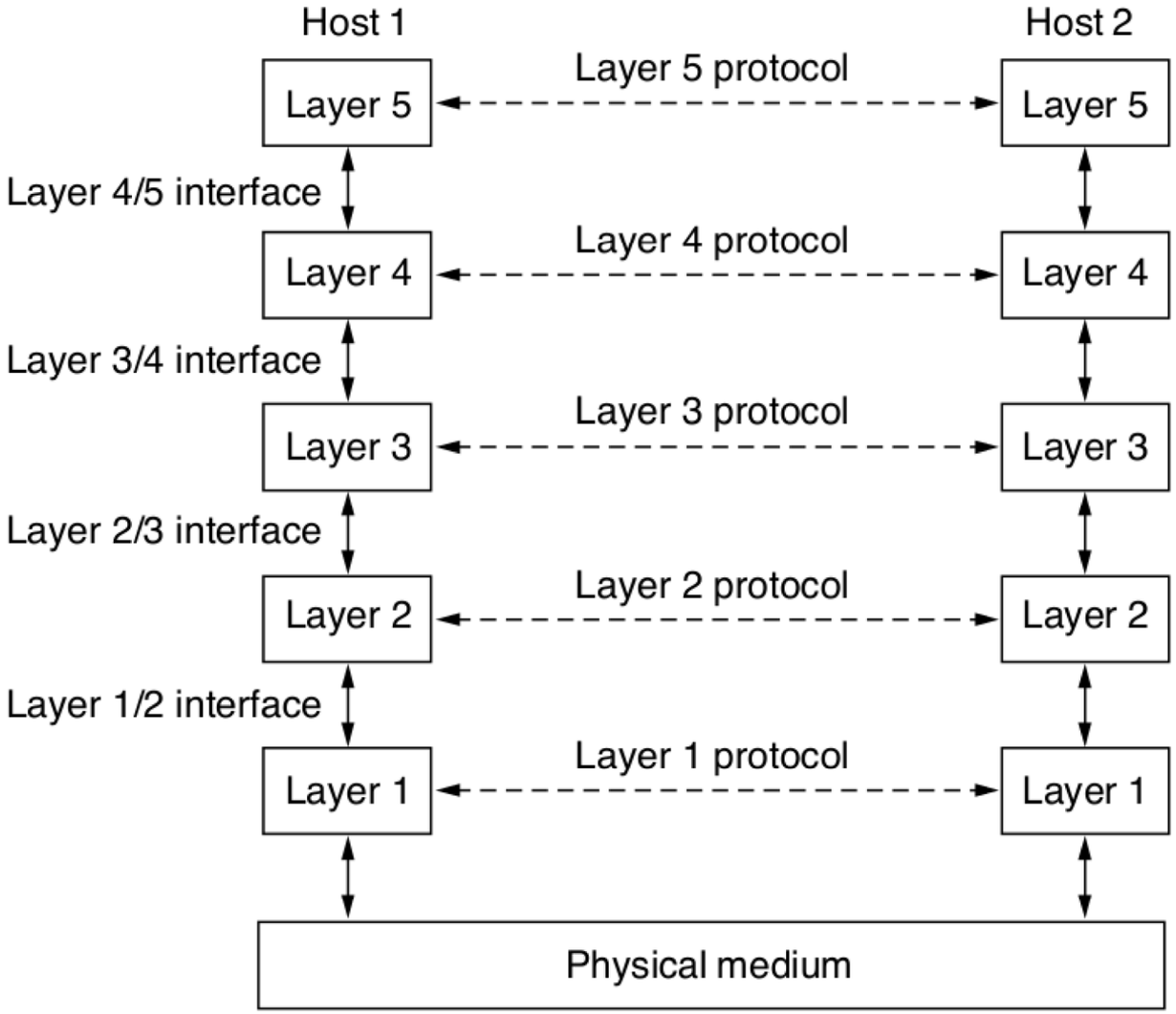
Evolvability and Security

- Design issue concerns the evolution of the network
- Over time, networks grow larger and new designs emerge that need to be connected to the existing network
- Use addressing or naming mechanism to identify the senders and receivers involved in a particular message
- Different network technologies often have different limitations
- Confidentiality mechanisms defend against eavesdropping on communications
- Authentication mechanisms prevent someone from impersonating someone else
- Integrity mechanisms prevent surreptitious changes to messages

Protocol layering (1)

- To reduce the design complexity, most networks are organized as a stack of **layers** or **levels**
  - the purpose of each layer is to offer services to the higher layers
- When layer *n* on a machine communicates with layer *n* on another machine, the rules of communications are called layer *n* protocol
  - essentially, a **protocol** is an agreement between the parties on how the communication is to proceed
- A set of layers and protocols is a **network architecture**, where a list of protocols used one per layer, is a **protocol stack**

Protocol layering (2)



Connections (1)

- Layers offer two types of service to the layers above them: connection-oriented and connectionless
- A **connection-oriented** service is modeled after the telephone system
- **Circuit switching** is a method of implementing a telecommunications network in which two network nodes establish a dedicated communications channel (circuit) through the network before the nodes may communicate
  - the circuit functions as if the nodes were physically connected as with an electrical circuit
- By setting up a connection in advance, the subnet can reserve link bandwidth, switch buffer space and CPU time

Connections (2)

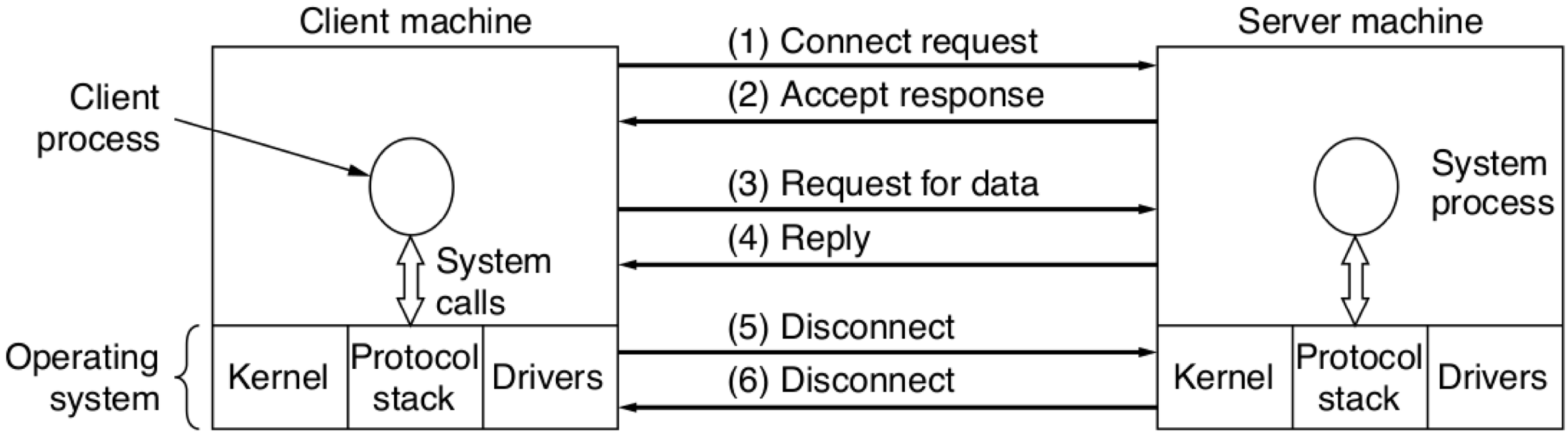
- The **connectionless** service is modeled after the postal system
- **Packet switching** is a method of grouping data which is transmitted over a digital network into **packets** which are made of a *header* and a *payload*
  - the primary basis for data communications in computer networks worldwide
- Every packet is routed independently of every other packet
  - fault tolerant if some routers go down during a session

Service primitives (1)

- A service is formally specified by a set of **primitives** (operations) available to user processes to access the service
  - the primitives tell the service to perform some action
  - the set of primitives available depends on the service being provided
- A simple connection-oriented service:

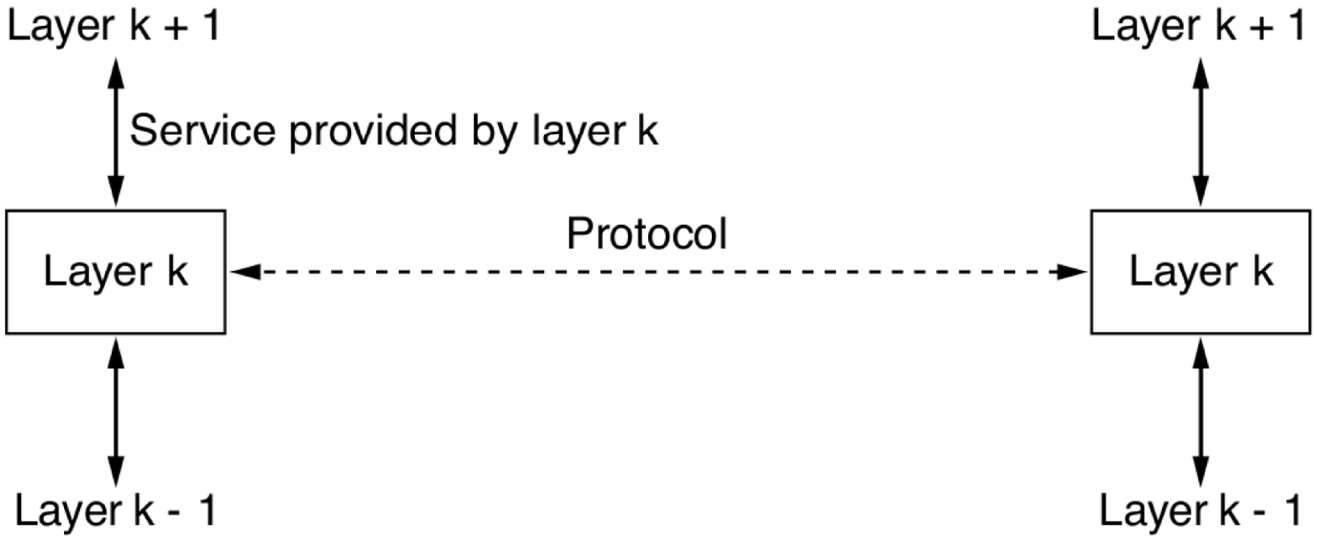
Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
ACCEPT	Accept an incoming connection from a peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Service primitives (2)



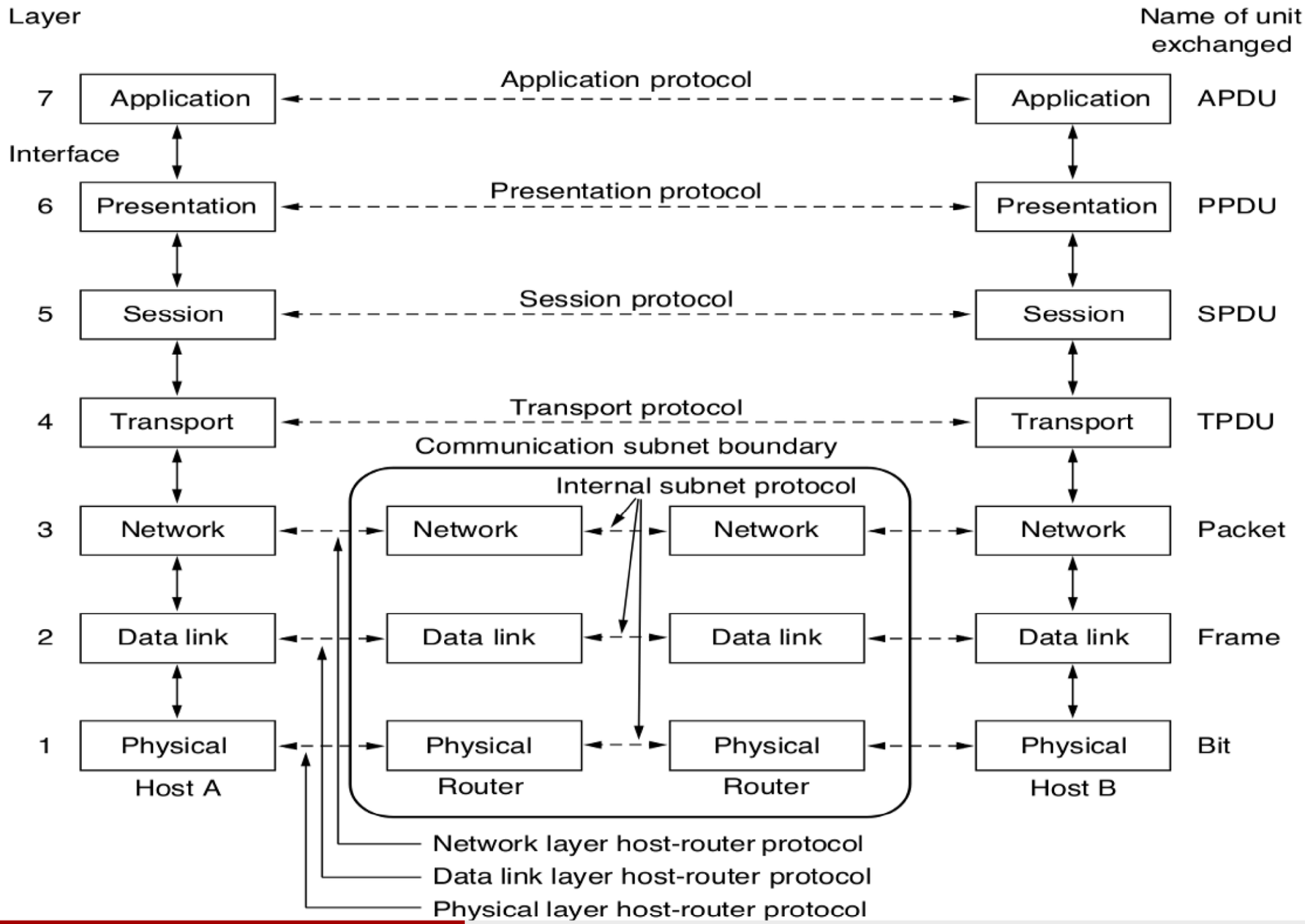
Distinction between services protocols

- A service is a set of primitives that a layer provides to the layer above it
  - it is not about how the operations are implemented
- A protocol is a set of rules governing the format and meaning of the packets exchanged by the peer entities within a layer on different machines
  - entities use protocols to implement their service definitions



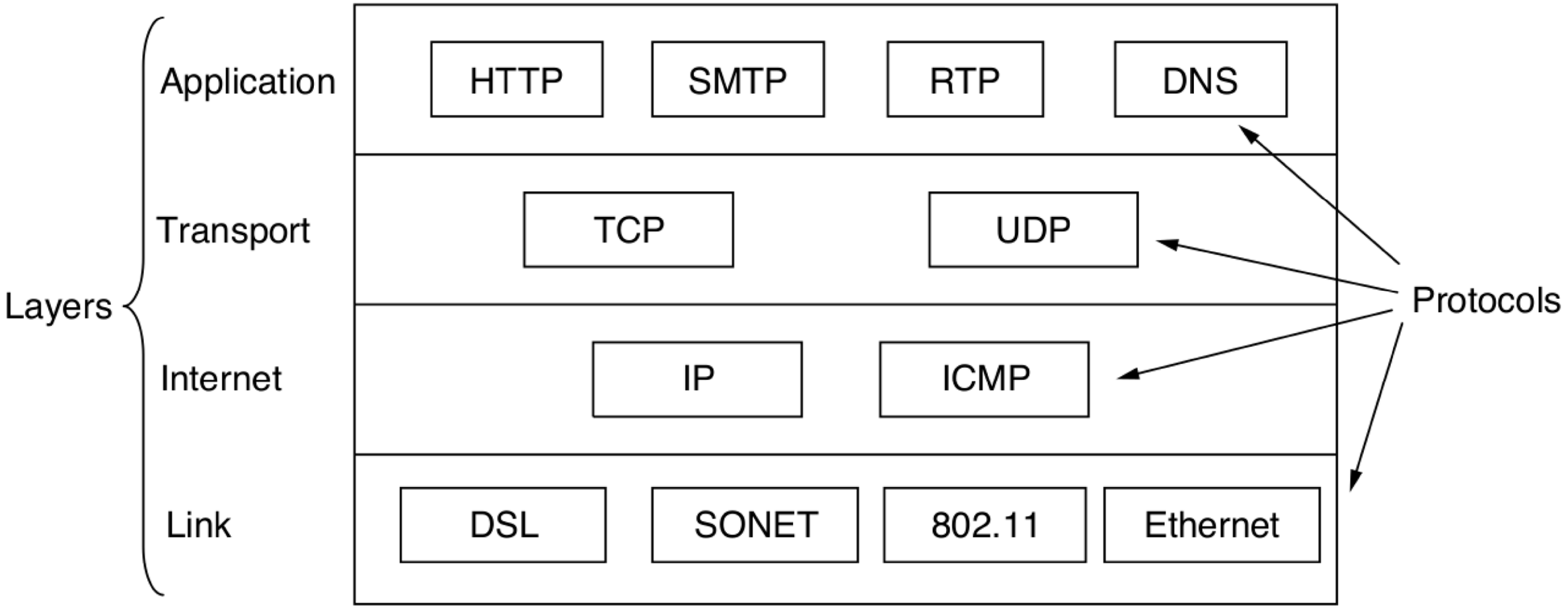
The OSI reference model

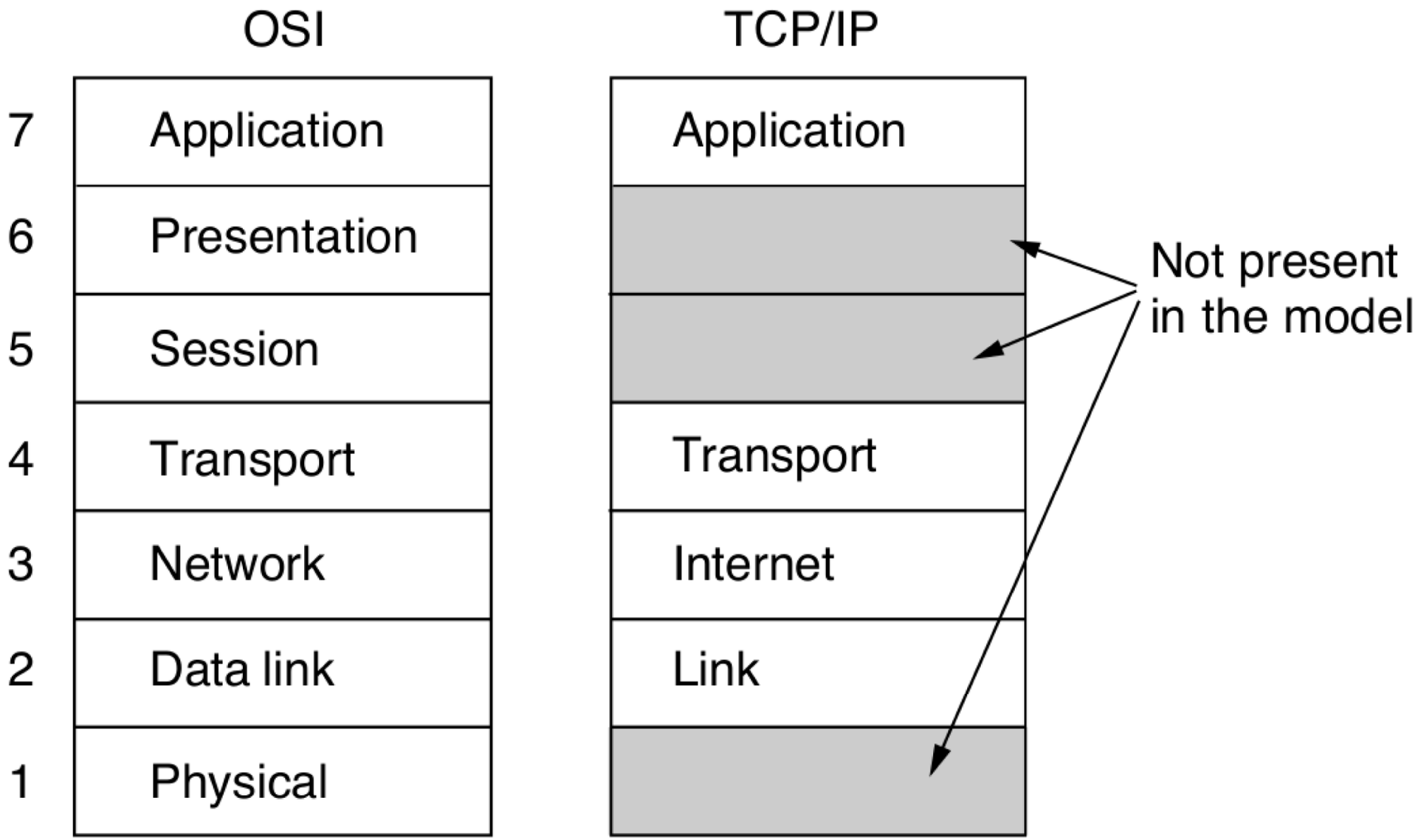
- The **OSI** (Open Systems Interconnection) model was developed by the **ISO** (International Standards Organization) towards the international standardization of the protocols used in the layers
  - deals with connecting systems that are open for communication with other systems
- Seven layers in total; Physical, Data link, Network, Transport, Session, Presentation, and Application
- Three main concepts: services, interfaces, protocols


Layer
Name of unit exchanged
7
Application
Application protocol
Application
APDU
Interface
6
Presentation
Presentation protocol
Presentation
PPDU
5
Session
Session protocol
Session
SPDU
4
Transport
Transport protocol
Transport
TPDU
Communication subnet boundary
Internal subnet protocol
3
Network
Network
Network
Network
Packet
2
Data link
Data link
Data link
Data link
Frame
1
Physical
Physical
Physical
Physical
Bit
Host A
Router
Router
Host B
Network layer host-router protocol
Data link layer host-router protocol
Physical layer host-router protocol

The TCP/IP reference model

- Lowest layer is the **link layer**, describing what links such as serial lines and Ethernet must do to meet the needs of the connectionless **internet layer**
- The internet layer defines a packet format and main protocol **IP** (Internet Protocol) to ensure the packets are delivered where they are supposed to go
- The **transport layer** is designed to allow peer entities on the source and destination hosts to carry on a conversation
- The **application layer** contains all higher-level protocols, without additional session or presentation layers from the OSI model


Layers
Application
Transport
Internet
Link
HTTP
SMTP
RTP
DNS
TCP
UDP
IP
ICMP
DSL
SONET
802.11
Ethernet
Protocols


OSI
TCP/IP
7
Application
6
Presentation
5
Session
4
Transport
3
Network
2
Data link
1
Physical
Application
Transport
Internet
Link
Not present
in the model

OSI vs. TCP/IP

- Neither of them or their protocols are perfect, both received plenty of criticism
- The the OSI reference model has proven to be useful to understand how computer networks work
  - minus the presentation and session layers
- The TCP/IP reference model is useful for understanding protocols
  - protocols which are widely used for many years
- Five layer model: 1. Physical, 2. (Data) Link, 3. Network, 4. Transport, 5. Application

The five layer model

- The **physical layer** specifies how to transmit bits across different kinds of media as electrical signals
- The (data) **link layer** is about how to send messages between directly connected computers with specified levels of reliability
- The **network layer** deals with how to combine multiple links into networks, and networks of networks
- The **transport layer** strengthens the delivery guarantees of the network layer, and provide delivery abstractions that match the needs of different applications
- The **application layer** contains programs that make use of the network

W2 summary (1)

- There are many different types of networks, in different sizes, for different goals
- The Internet is a collection of different networks that use common protocols and provide common services
- To join the Internet, the computer is connected to an ISP with a cable network, HFC, FTTH
  - device at the home end is the cable modem and the one at the cable headend is the CMTS
- The location where customer packets enter the ISP network for service the ISP's POP
  - the packet is routed over the backbone of the ISP, or handed over to another ISP, connected by an IXP

W2 summary (2)

- Network protocols often share a common set of design goals: reliability, resource allocation, evolvability, and security
- Most networks are organized as a stack of layers
- A service is a set of primitives that a layer provides to the above layer
- A protocol is a set of rules governing the format and meaning of the packets exchanged within a layer
- A set of layers and protocols is a network architecture, where a list of protocols used one per layer, is a protocol stack
- The OSI reference model is useful as a model of computer networks
- The TCP/IP reference model is useful for the representation of protocols
- Five layer model to discuss computer networks: Physical, (Data) Link, Network, Transport, Application

W3 topic

- The Application layer
  - Domain Name System (DNS), Electronic mail (e-mail), World Wide Web (WWW)