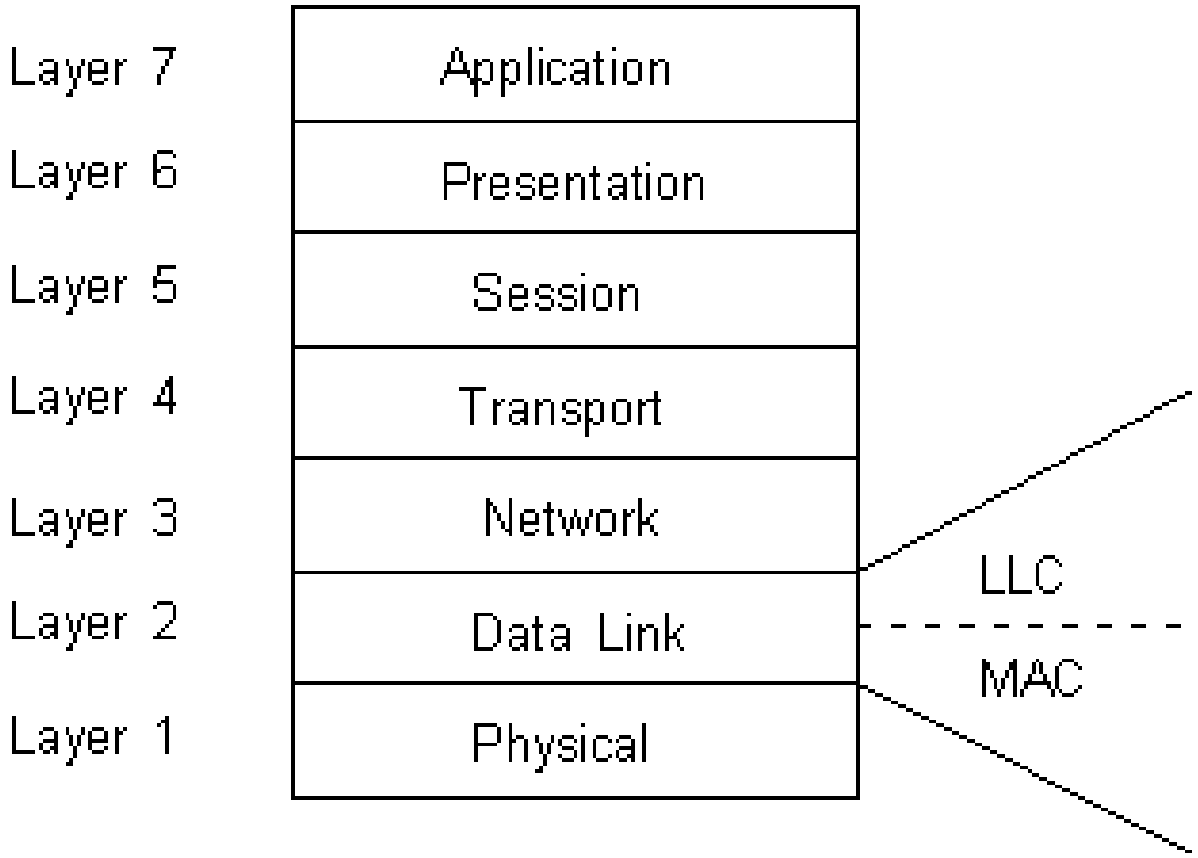
OSI Model

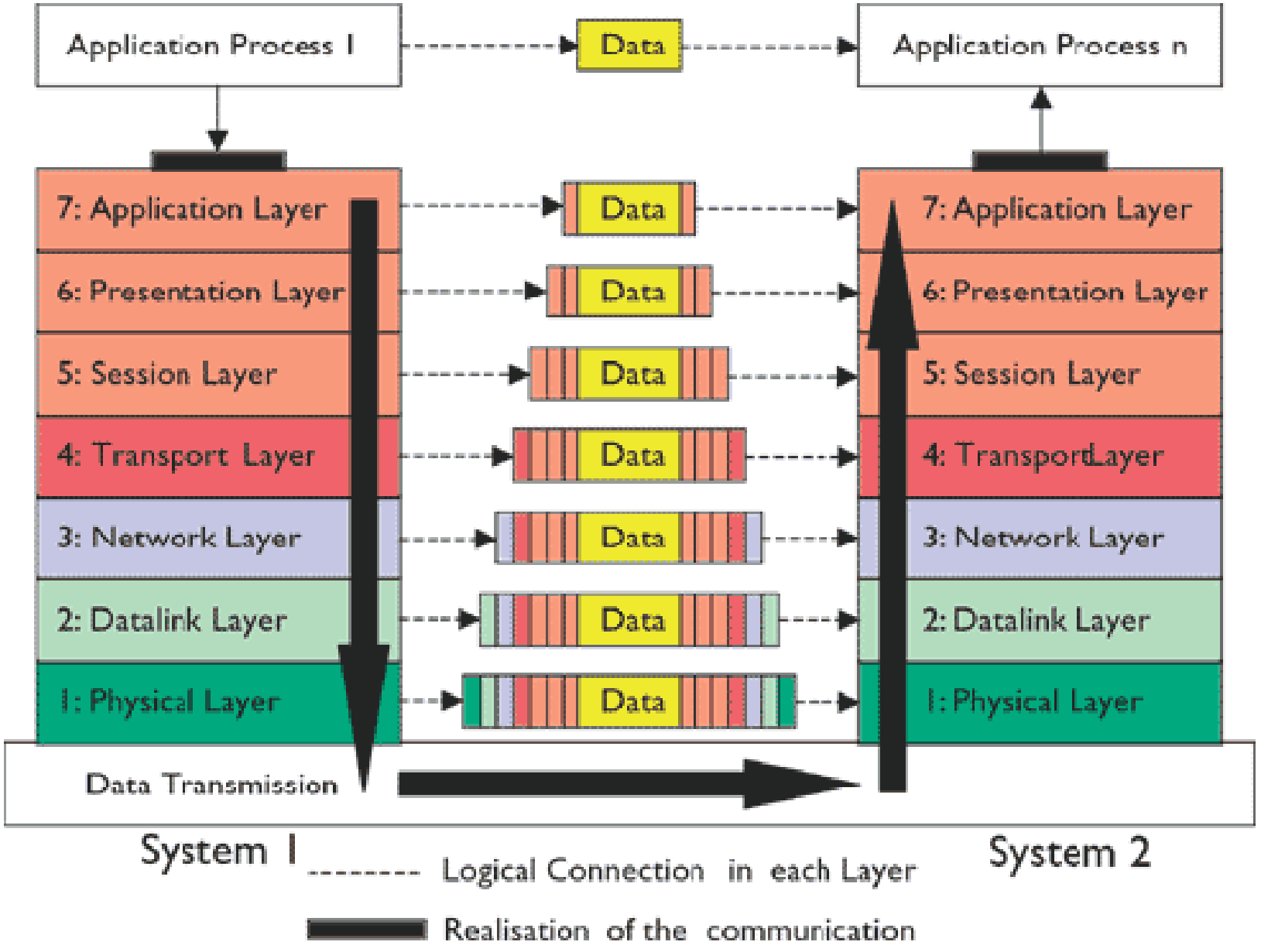

Layer 7
Layer 6
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1
Application
Presentation
Session
Transport
Network
Data Link
Physical
LLC
MAC

Layer Function

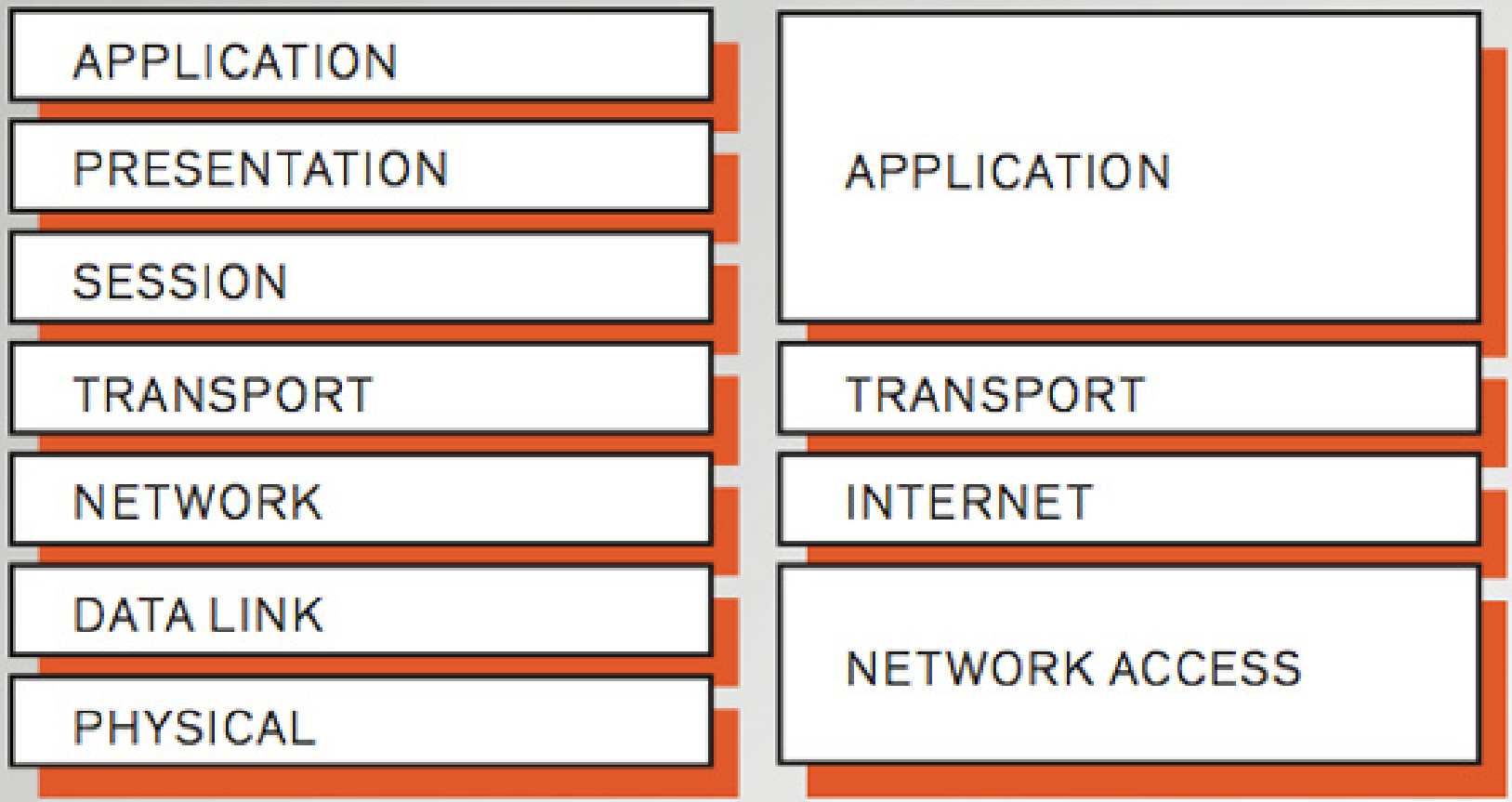
7. Application Layer	Provision of interfaces to applications
6. Presentation Layer	Format conversion such as encryption and compression
5. Session Layer	Provision of session management for individual application
4. Transport Layer	Provision of data transfer service (TCP/UDP)
3. Network Layer	Decision of communication path across the network (IP Address)
2. Data Link Layer	Decision of communication path between adjacent nodes and data transfer (MAC Address)
1. Physical Layer	Electrical connection

OSI (Open Source Interconnection) 7 Layer Model

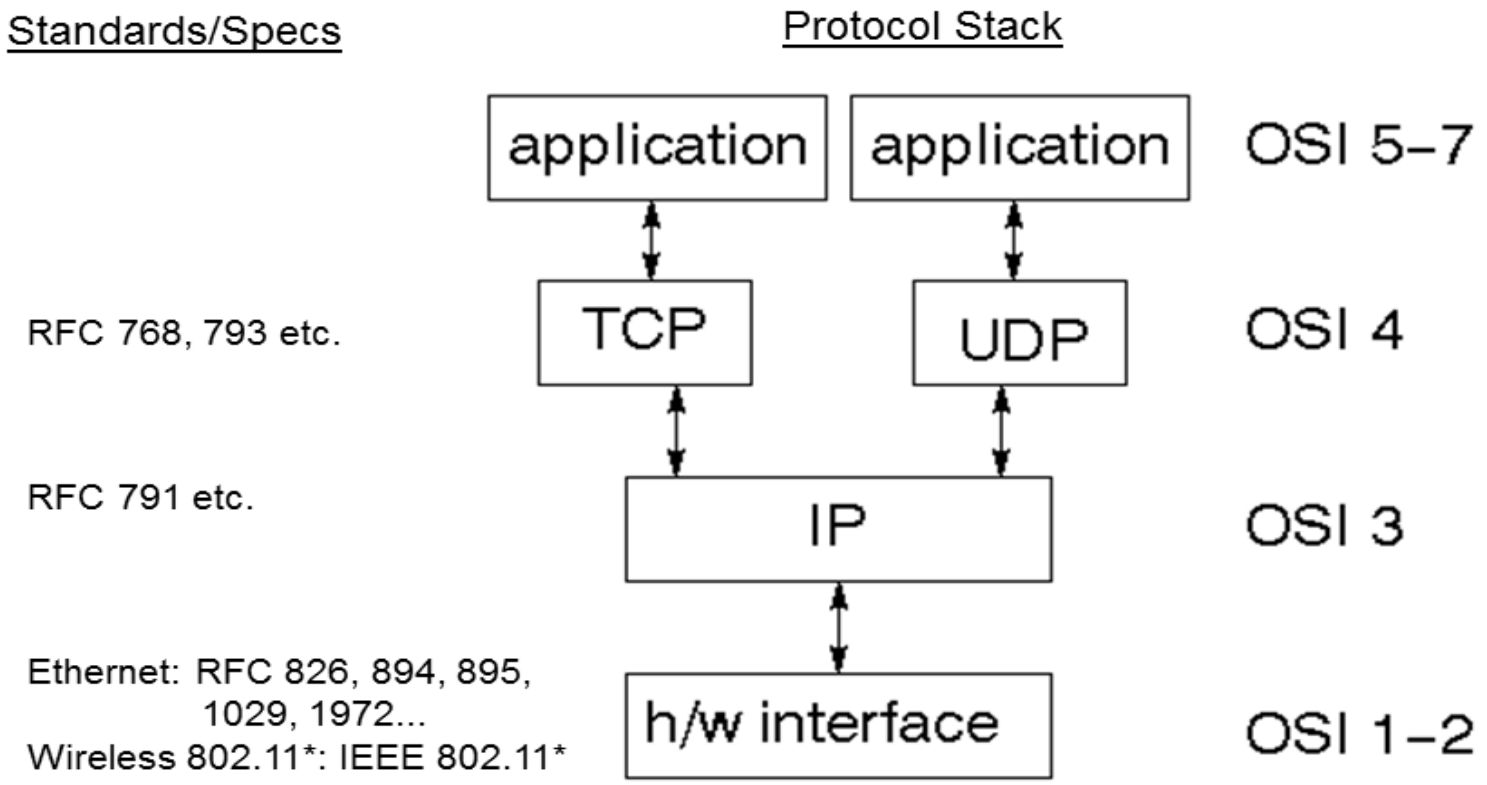
Layer	Application/Example		Central Device/ Protocols		DOD4 Model
Application (7) Serves as the window for users and application processes to access the network services.	**End User layer** Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management		**User Applications** SMTP	**GATEWAY** Can be used on all layers	Process
Presentation (6) Formats the data to be presented to the Application layer. It can be viewed as the "Translator" for the network.	**Syntax layer** encrypt & decrypt (if needed) Character code translation • Data conversion • Data compression • Data encryption • **Character Set Translation**		JPEG/ASCII EBDIC/TIFF/GIF PICT		
Session (5) Allows session establishment between processes running on different stations.	**Synch & send to ports** (logical ports) Session establishment, maintenance and termination • Session support - perform security, name recognition, logging, etc.		**Logical Ports** RPC/SQL/NFS NetBIOS names		
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	**TCP** Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing	PACKET FILTERING	TCP/SPX/UDP		Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting		**Routers** IP/IPX/ICMP		Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control		**Switch Bridge WAP** PPP/SLIP	Land Based Layers	Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts		**Hub**		


Application Process I
Data
Application Process n
7: Application Layer
6: Presentation Layer
5: Session Layer
4: Transport Layer
3: Network Layer
2: Datalink Layer
1: Physical Layer
Data
Data
Data
Data
Data
Data
Data
7: Application Layer
6: Presentation Layer
5: Session Layer
4: TransportLayer
3: Network Layer
2: Datalink Layer
1: Physical Layer
Data Transmission
System 1
System 2
Logical Connection in each Layer
Realisation of the communication

OSI vs. TCP/IP

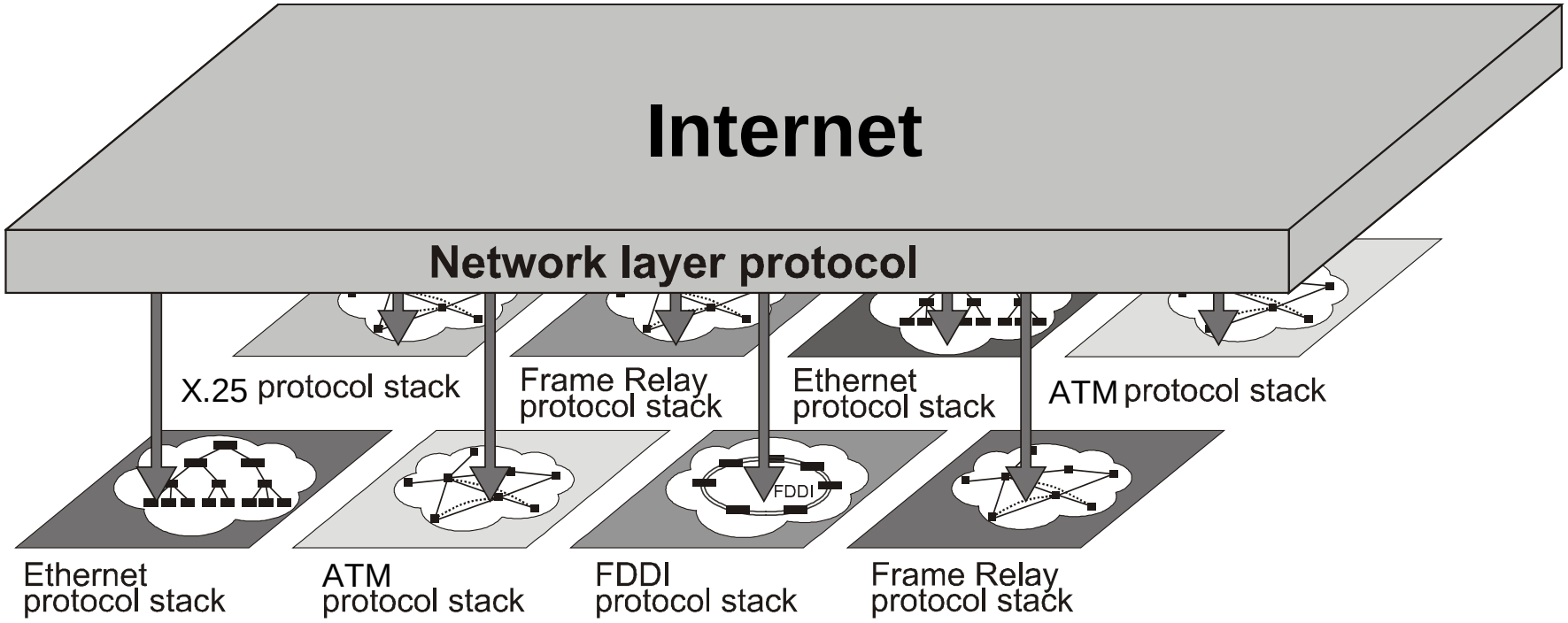

APPLICATION
PRESENTATION
SESSION
TRANSPORT
NETWORK
DATA LINK
PHYSICAL
APPLICATION
TRANSPORT
INTERNET
NETWORK ACCESS

TCP/IP Stack

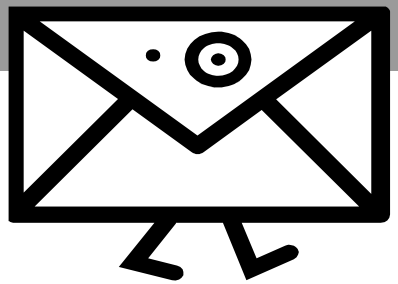

Standards/Specs
Protocol Stack
application
application
OSI 5–7
TCP
UDP
RFC 768, 793 etc.
OSI 4
RFC 791 etc.
IP
OSI 3
Ethernet: RFC 826, 894, 895,
1029, 1972...
Wireless 802.11*: IEEE 802.11*
h/w interface
OSI 1–2

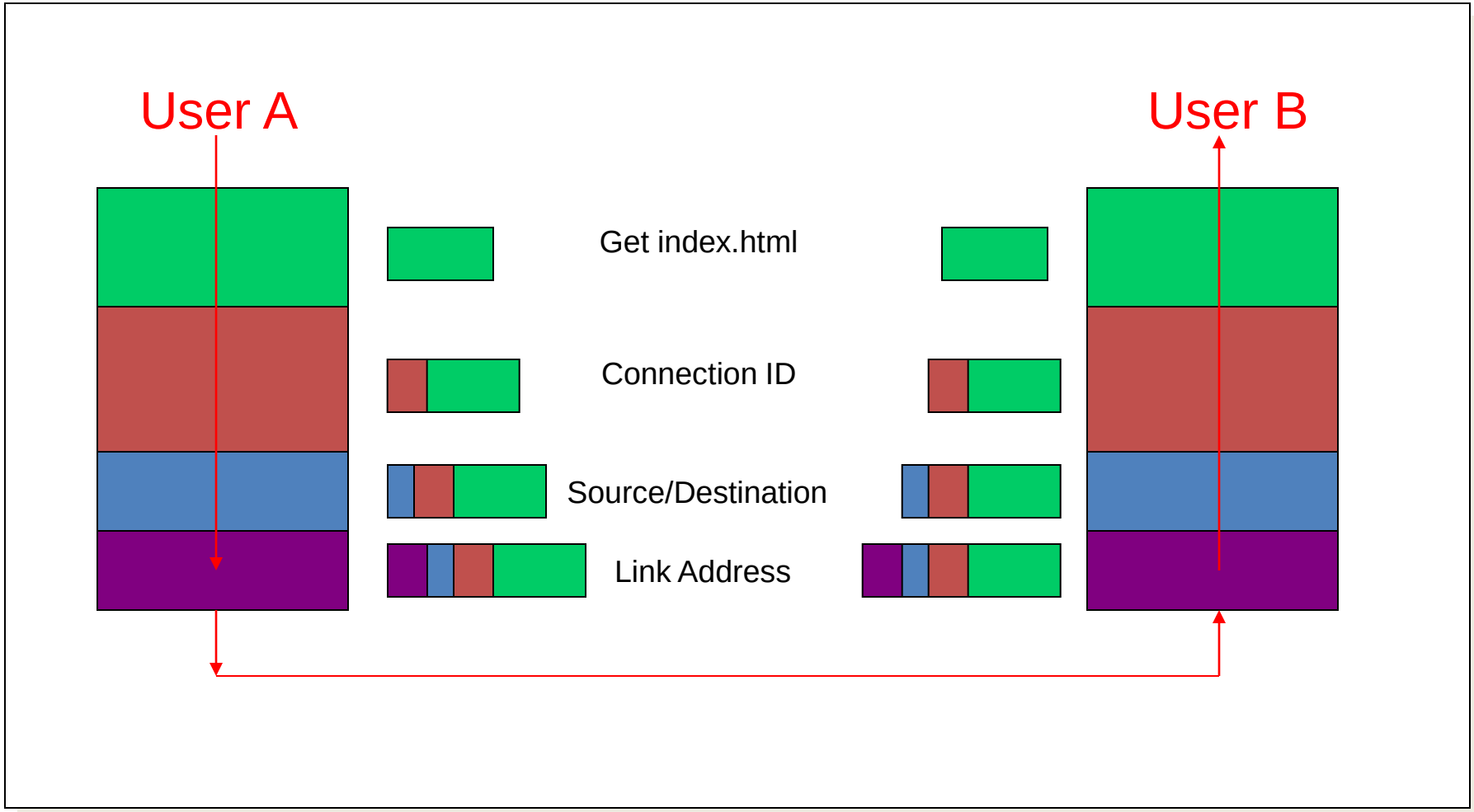
TCP/IP Reference Model—The Internet Architecture

- **The Internet Architecture (Section 1 of RFC 1122)**
  - Necessity of the network layer



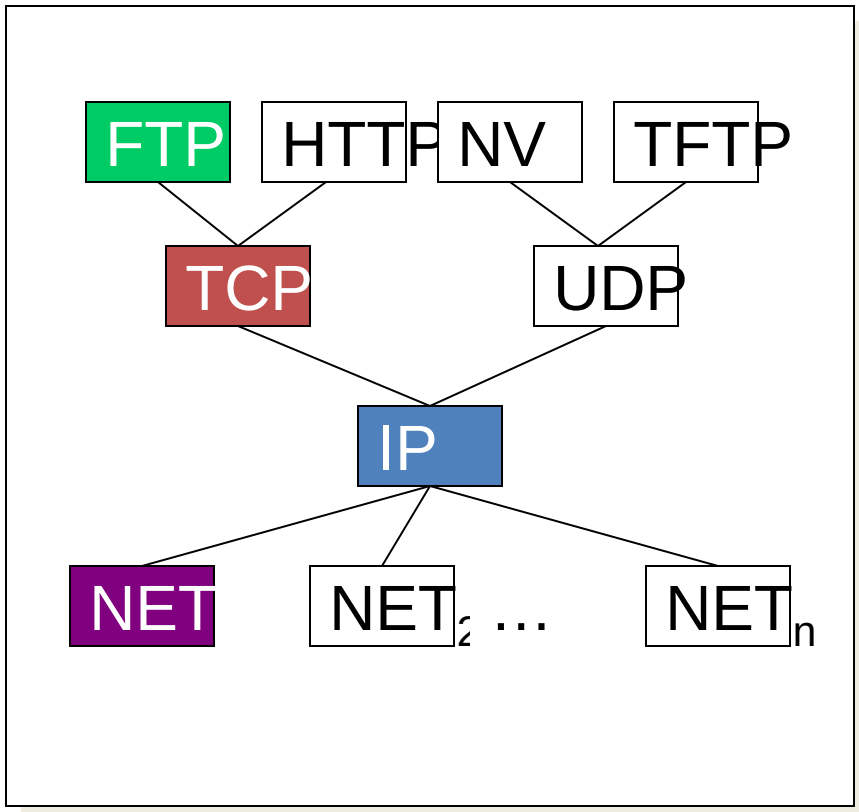
Layer Encapsulation

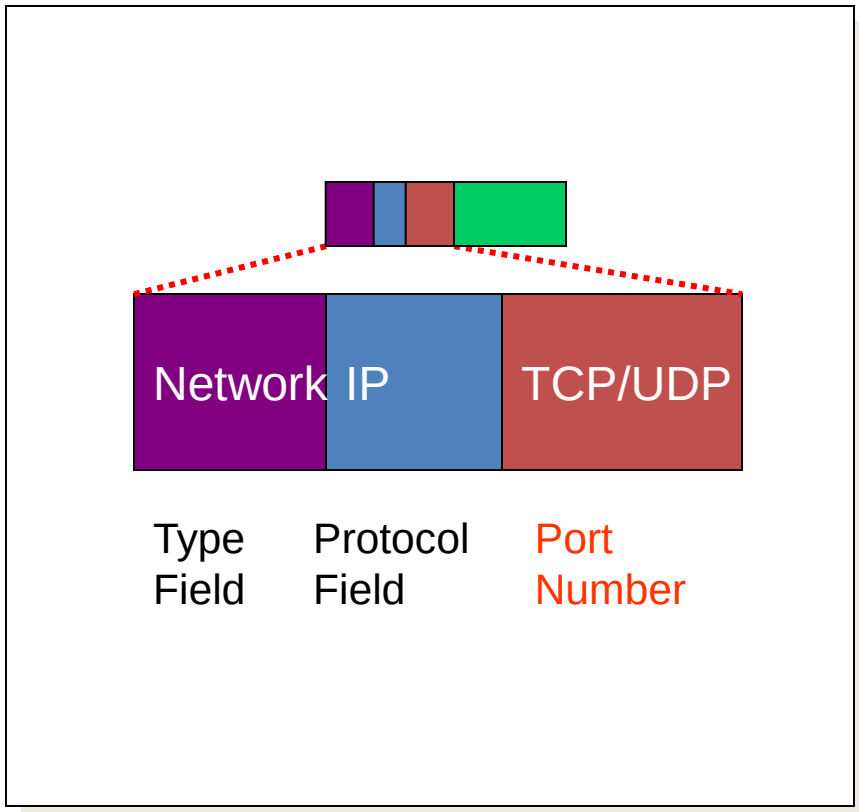




Protocol Demultiplexing

- Multiple choices at each layer





Chapter 1: roadmap

- What *is* the Internet?
- What *is* a protocol?
- Network edge: hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History

Chapter 1: introduction

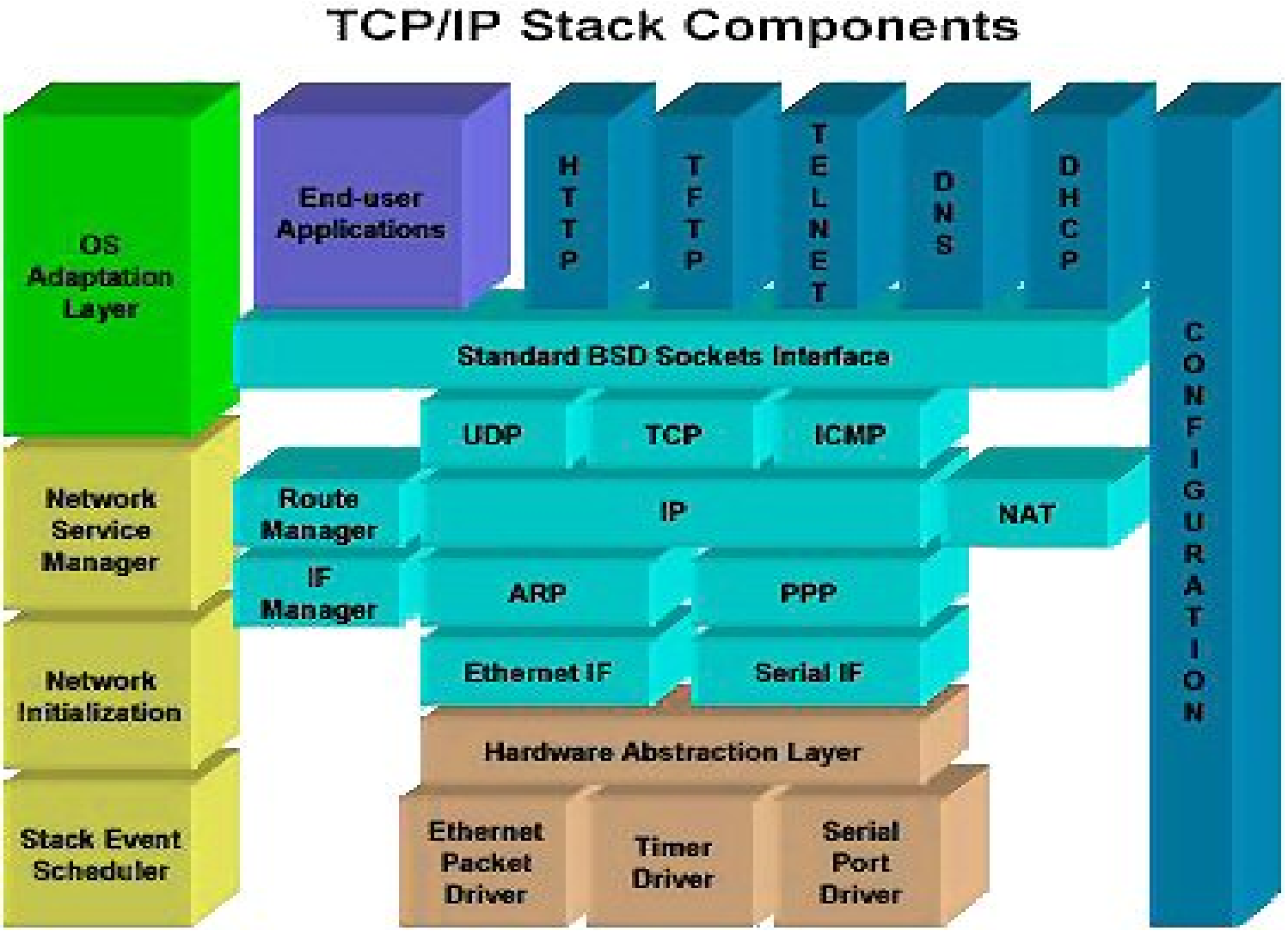
our goal:

- get "feel" and terminology
- more depth, detail *later* in course
- approach:
  - use Internet as example

overview:

- what's the Internet?
- what's a protocol?
- network edge; hosts, access net, physical media
- network core: packet/circuit switching, Internet structure
- performance: loss, delay, throughput
- security
- protocol layers, service models
- history

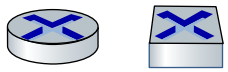
TCP/IP Stack


TCP/IP Stack Components
OS Adaptation Layer
End-user Applications
HTTP
TFTP
TELNET
DNS
DHCP
CONFIGURATION
Standard BSD Sockets Interface
UDP
TCP
ICMP
Network Service Manager
Route Manager
IP
NAT
IF Manager
ARP
PPP
Network Initialization
Ethernet IF
Serial IF
Hardware Abstraction Layer
Stack Event Scheduler
Ethernet Packet Driver
Timer Driver
Serial Port Driver

The Internet: a "nuts and bolts" view

Billions of connected computing *devices*:

- *hosts* = *end systems*
- running *network apps* at Internet's "edge"



Packet switches: forward packets (chunks of data)

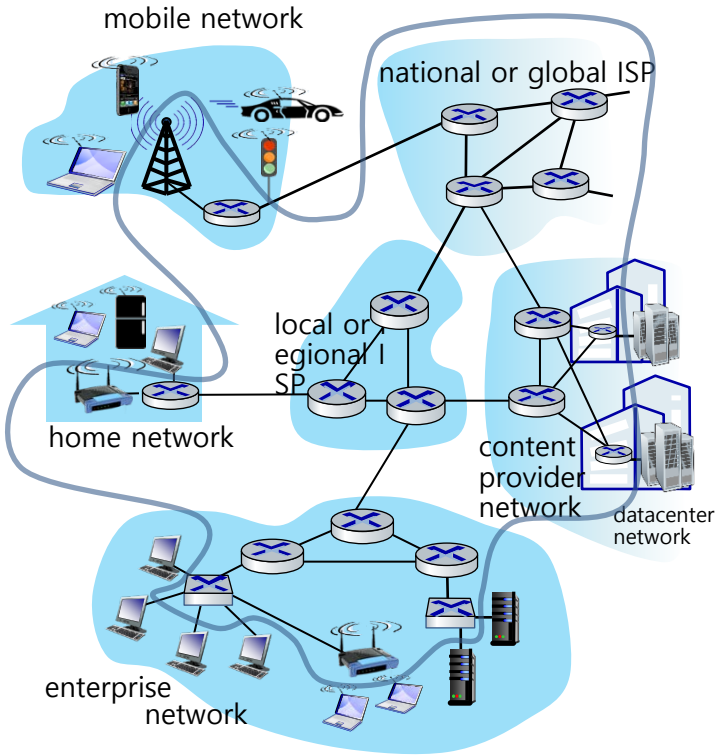
- *routers*, *switches*

Communication links

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

Networks

- collection of devices, routers, links: managed by an organization



“Fun” Internet-connected devices

Amazon Echo

Internet refrigerator

IP picture frame

Pacemaker & Monitor

Tweet-a-watt: monitor energy use

Security Camera

Slingbox: remote control cable TV

Web-enabled toaster + weather forecaster

AR devices

Internet phones

sensorized, bed mattress

Fitbit

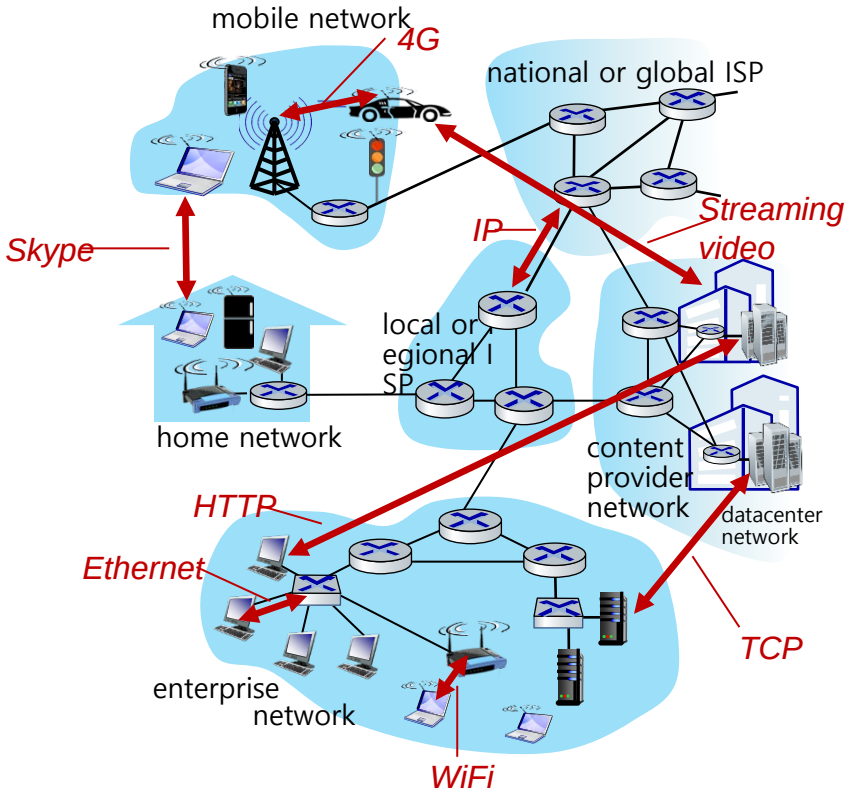
Others?

Connected car

The Internet: a "nuts and bolts" view

- *Internet:* "network of networks"
  - Interconnected ISPs

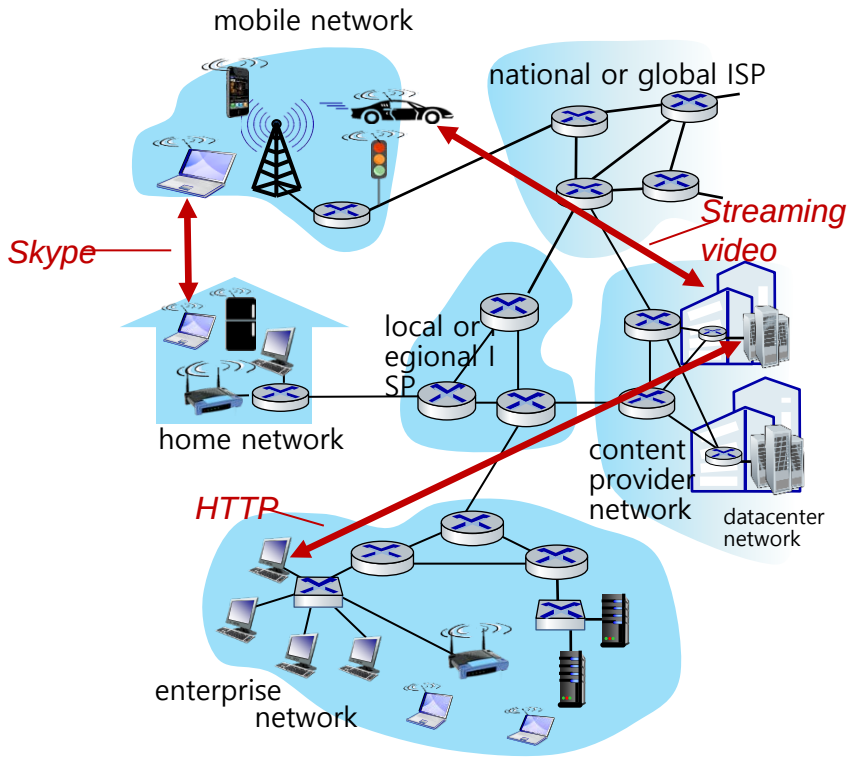
- *protocols* are *everywhere*
  - control sending, receiving of messages
  - e.g., HTTP (Web), streaming video, Skype, TCP, IP, WiFi, 4G, Ethernet
- *Internet standards*
  - RFC: Request for Comments
  - IETF: Internet Engineering Task Force



The Internet: a "service" view

- *Infrastructure* that provides services to applications:
  - Web, streaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, …

- provides *programming interface* to distributed applications:
  - "hooks" allowing sending/receiving apps to "connect" to, use Internet transport service
  - provides service options, analogous to postal service



What's a protocol?

Human protocols:

- "what's the time?"
- "I have a question"
- introductions

… specific messages sent

… specific actions taken when message received, or other events

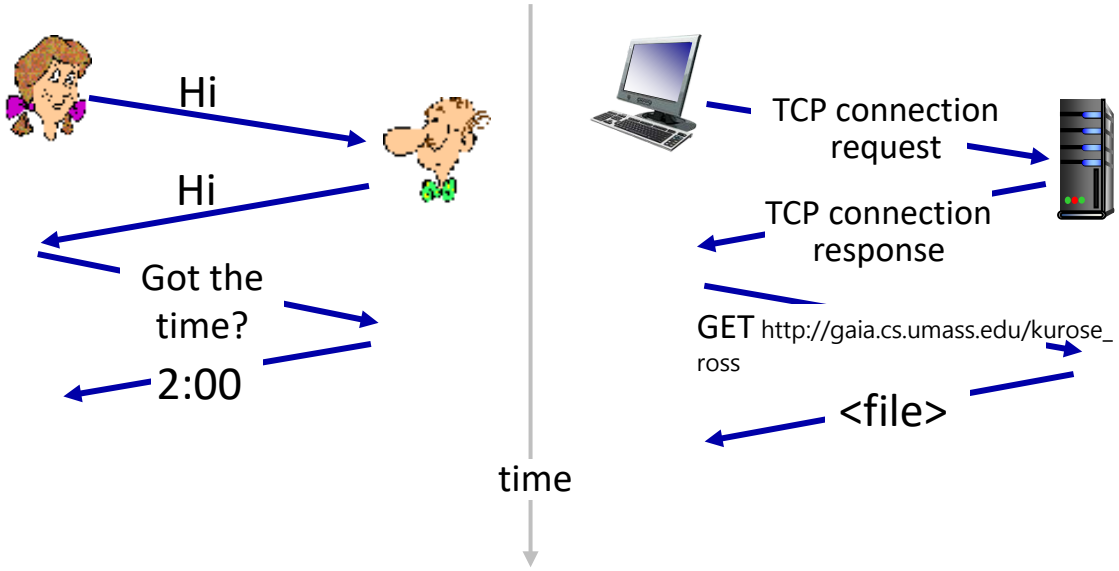
Network protocols:

- computers (devices) rather than humans
- all communication activity in Internet governed by protocols

Protocols define the format, order of messages sent and received among network entities, and actions taken on msg transmission, receipt

What's a protocol?

A human protocol and a computer network protocol:



Q: other human protocols?

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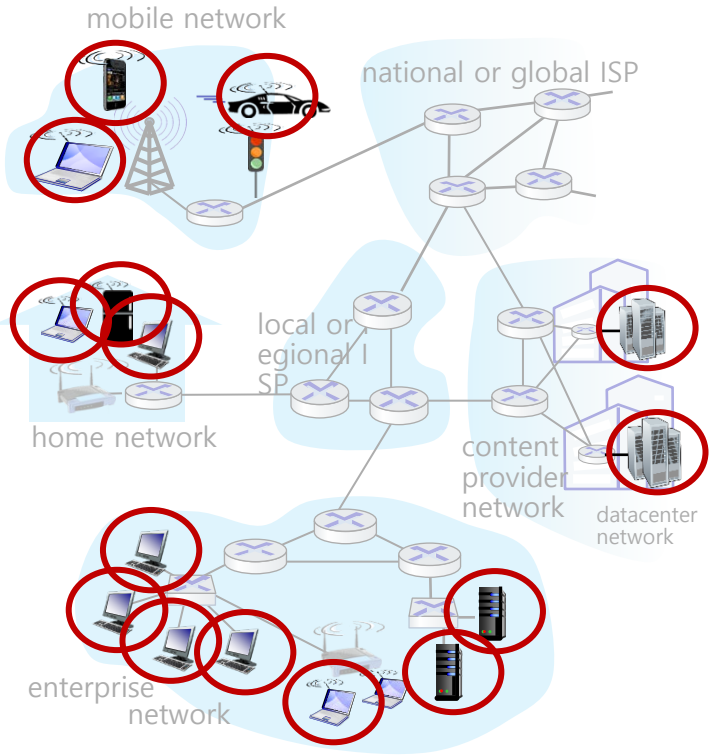
- Protocol layers, service models
- History

A closer look at Internet structure

Network edge:

- hosts: clients and servers
- servers often in data centers



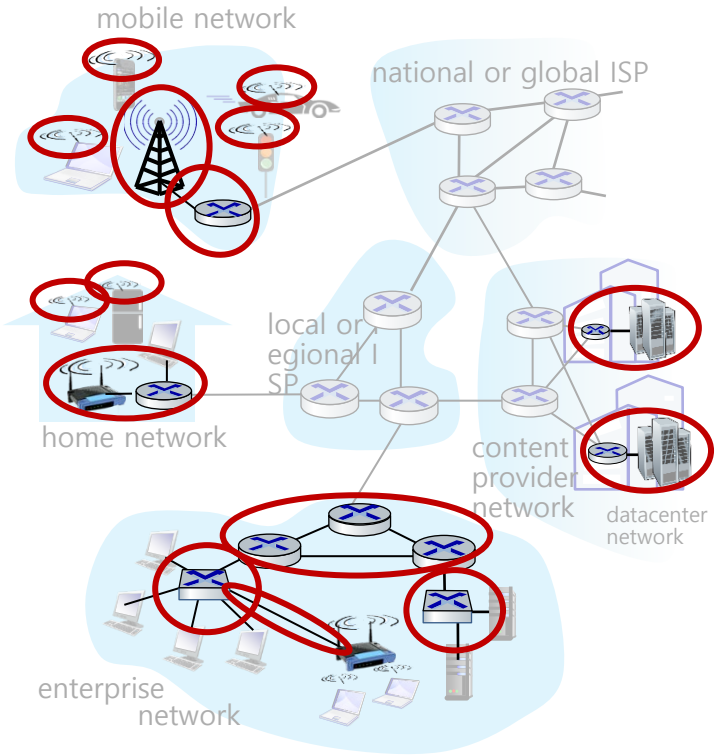
A closer look at Internet structure

Network edge:

- hosts: clients and servers
- servers often in data centers

Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

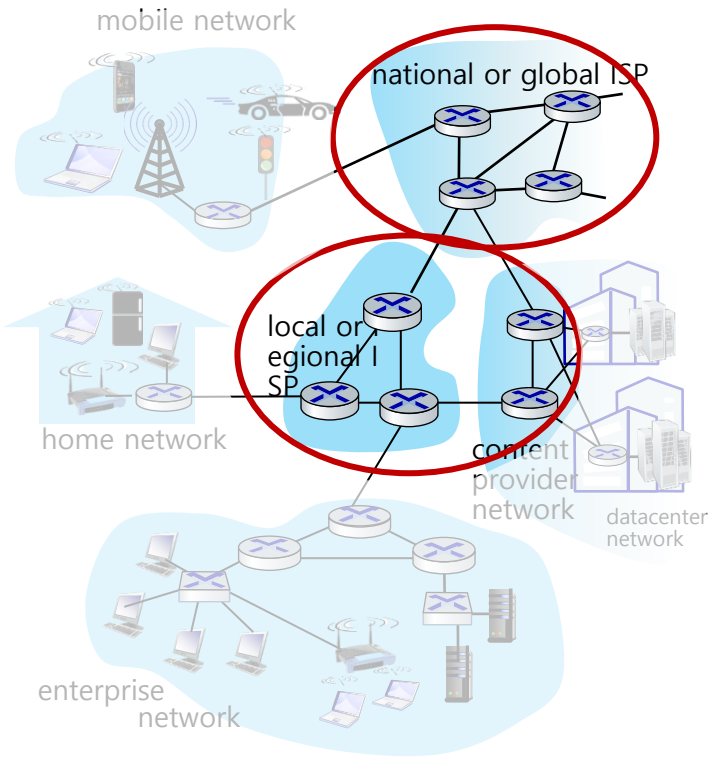
- hosts: clients and servers
- servers often in data centers

Access networks, physical media:

- wired, wireless communication links

Network core:

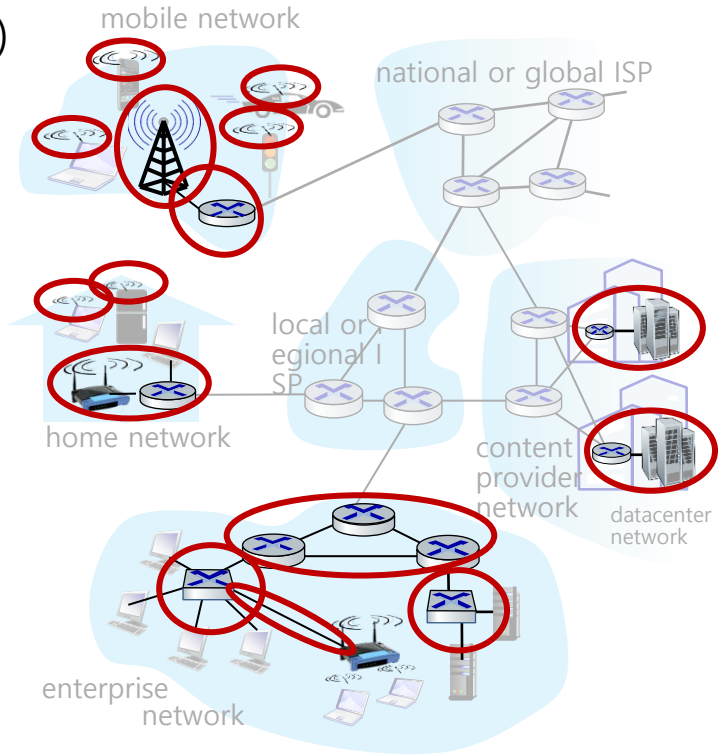
- interconnected routers
- network of networks



Access networks and physical media

Q: How to connect end systems to edge router?

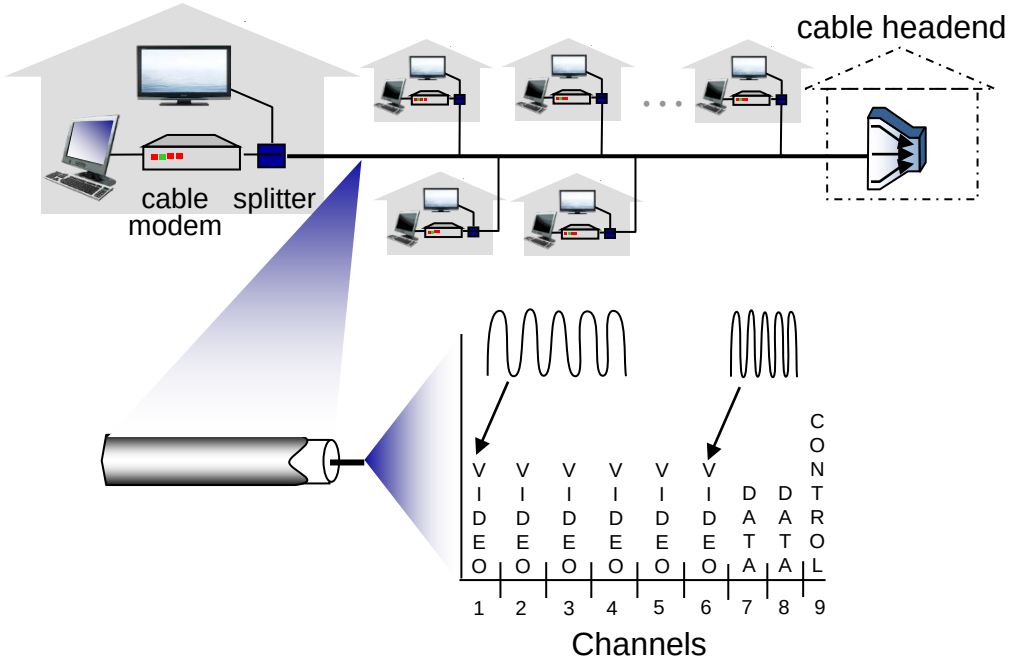
- residential access nets
- institutional access networks (school, company)
- mobile access networks (WiFi, 4G/5G)



What to look for:

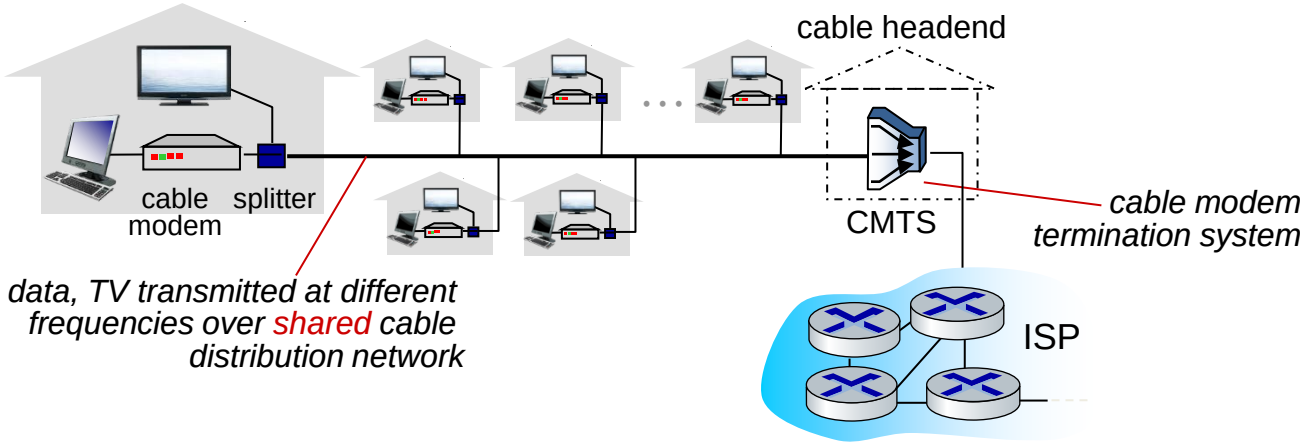
- transmission rate (bits per second) of access network?
- shared or dedicated access among users?

Access networks: cable-based access



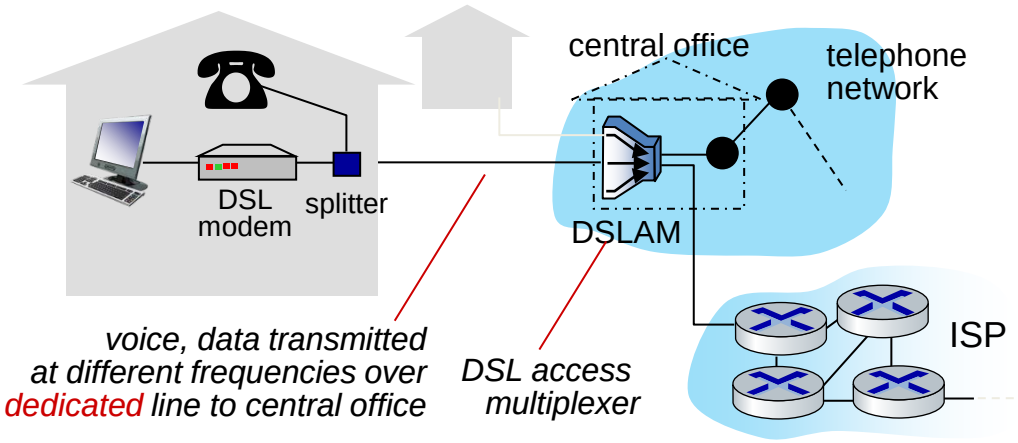
frequency division multiplexing (FDM): different channels transmitted in different frequency bands

Access networks: cable-based access



- HFC: hybrid fiber coax
  - asymmetric: up to 40 Mbps – 1.2 Gbs downstream transmission rate, 30-100 M bps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend

Access networks: digital subscriber line (DSL)



- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- 24-52 Mbps dedicated downstream transmission rate
- 3.5-16 Mbps dedicated upstream transmission rate

Review

- Protocol graph
- Reliable data transfer (rdt) in Ch. 3
- IEEE 802.11, .11b, .11a, .11n, .11ac, .11ax, .11be
- ATM
- FDDI
- Network core
- Network edge
- SAP
- Ethernet
- Network layers

- Quiz 1 will be… in March