Course Code 005636 (Fall 2021)

Multimedia

Multimedia Communications and Networking: Services and Protocols

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MM Comm. & Net: Services and Protocols

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- Protocol Layers of Computer Communication Networks
- Local Area Network and Access Networks
- Internet Technologies and Protocols

- Quality-of-Service (QoS) for Multimedia Communications
- Protocols for Multimedia Transmission and Interaction

MM Comm. & Net: Services and Protocols

Protocol Layers of Comp. Comm. Net.

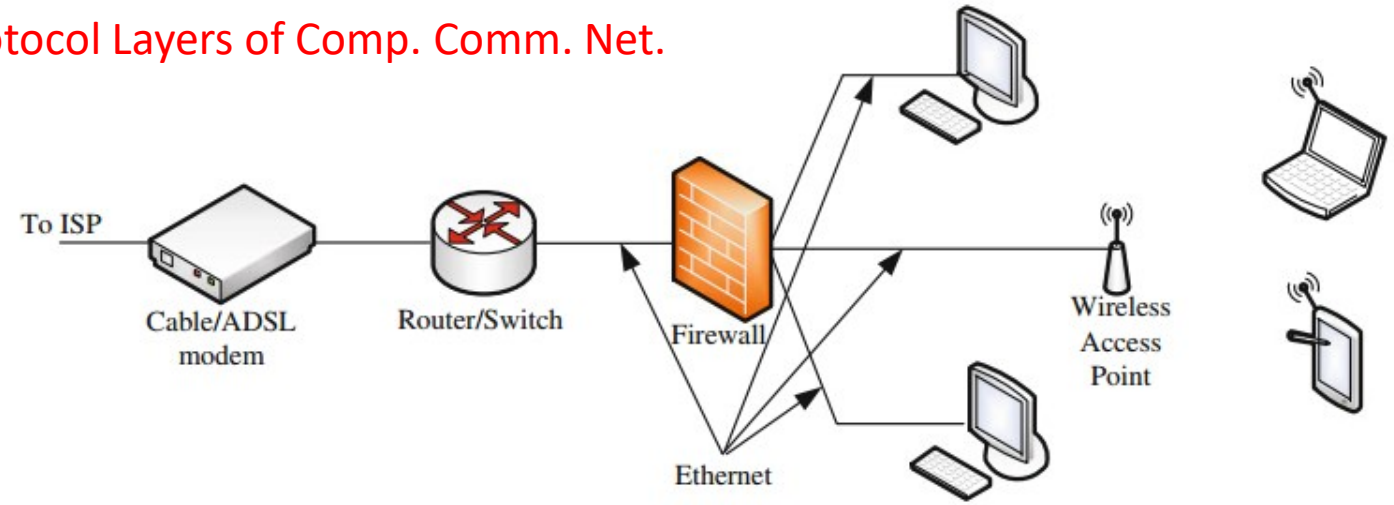
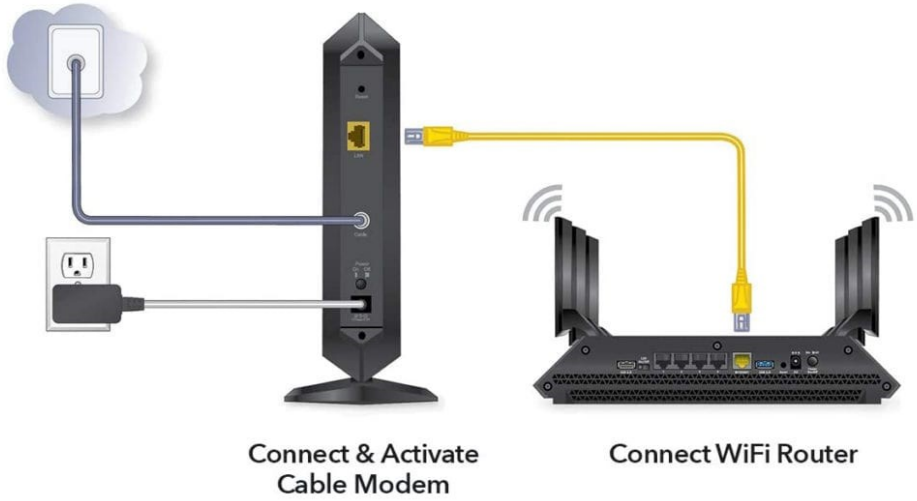


Fig. 15.2 A typical home/office network setup



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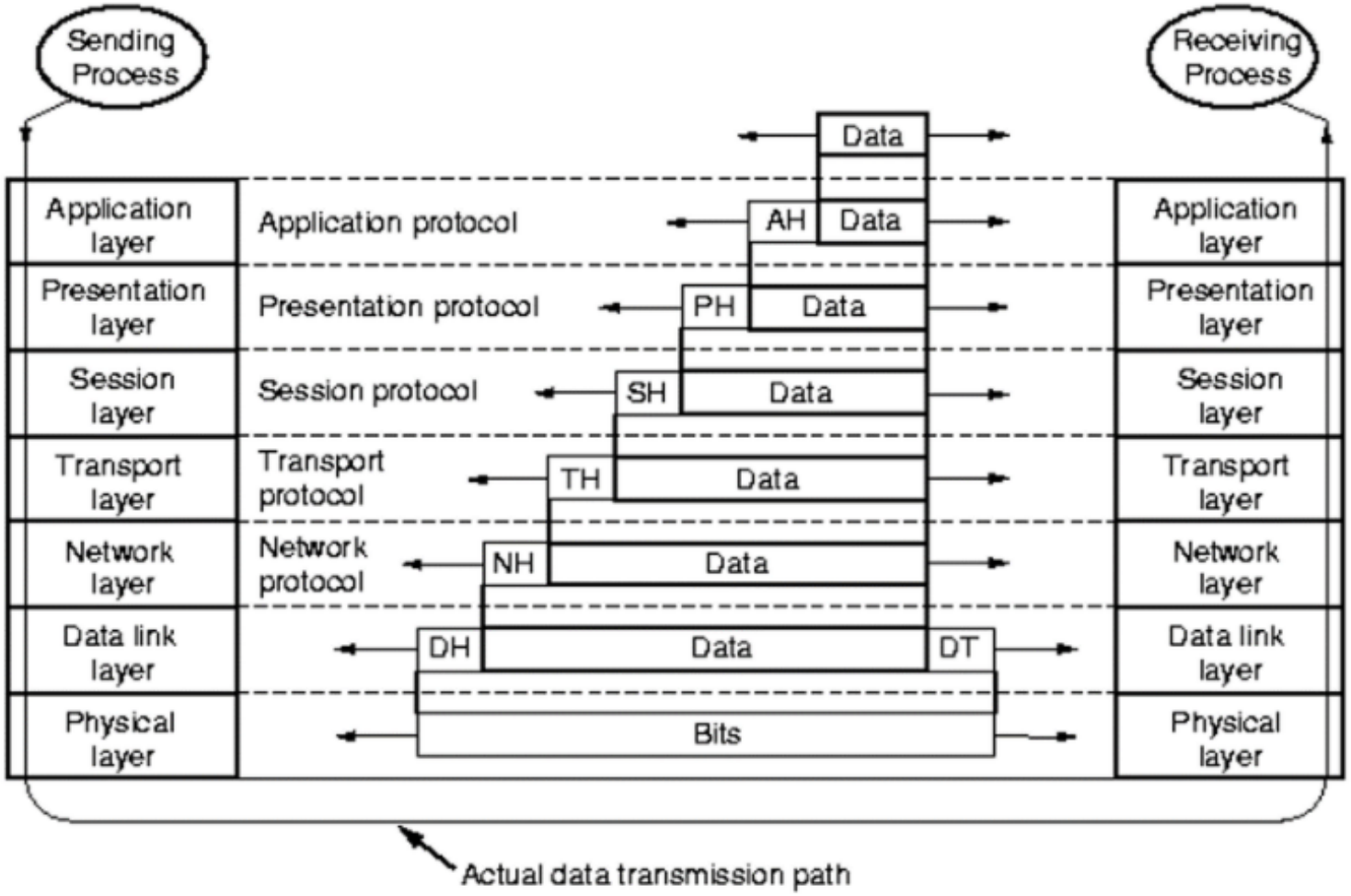
Protocol Layers of Comp. Comm. Net.



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1. **Physical Layer** Defines the electrical and mechanical properties of the physical interface (e.g., signal level, specifications of the connectors, etc.); also specifies the functions and procedural sequences performed by circuits of the physical interface.
2. **Data Link Layer** Specifies the ways to establish, maintain, and terminate a link, such as the transmission and synchronization of data frames, error detection and correction, and access protocol to the Physical layer.
3. **Network layer** Defines the routing of data from one end to the other across the network, using circuit switching or packet switching. Provides such services as addressing, internetworking, error handling, congestion control, and sequencing of packets.
4. **Transport layer** Provides end-to-end communication between *end systems* that support end-user applications or services. Supports either *connection-oriented* or *connectionless* protocols. Provides error recovery and flow control.
5. **Session layer** Coordinates the interaction between user applications on different hosts, manages sessions (connections), such as completion of long file transfers.
6. **Presentation layer** Deals with the syntax of transmitted data, such as conversion of different data formats and codes due to different conventions, compression, or encryption.
7. **Application layer** Supports various application programs and protocols, such as File sharing (FTP), remote login (Telnet), Email(SMTP/MIME), Web (HTTP), network management (SNMP), and so on.

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Protocol Layers of Comp. Comm. Net.

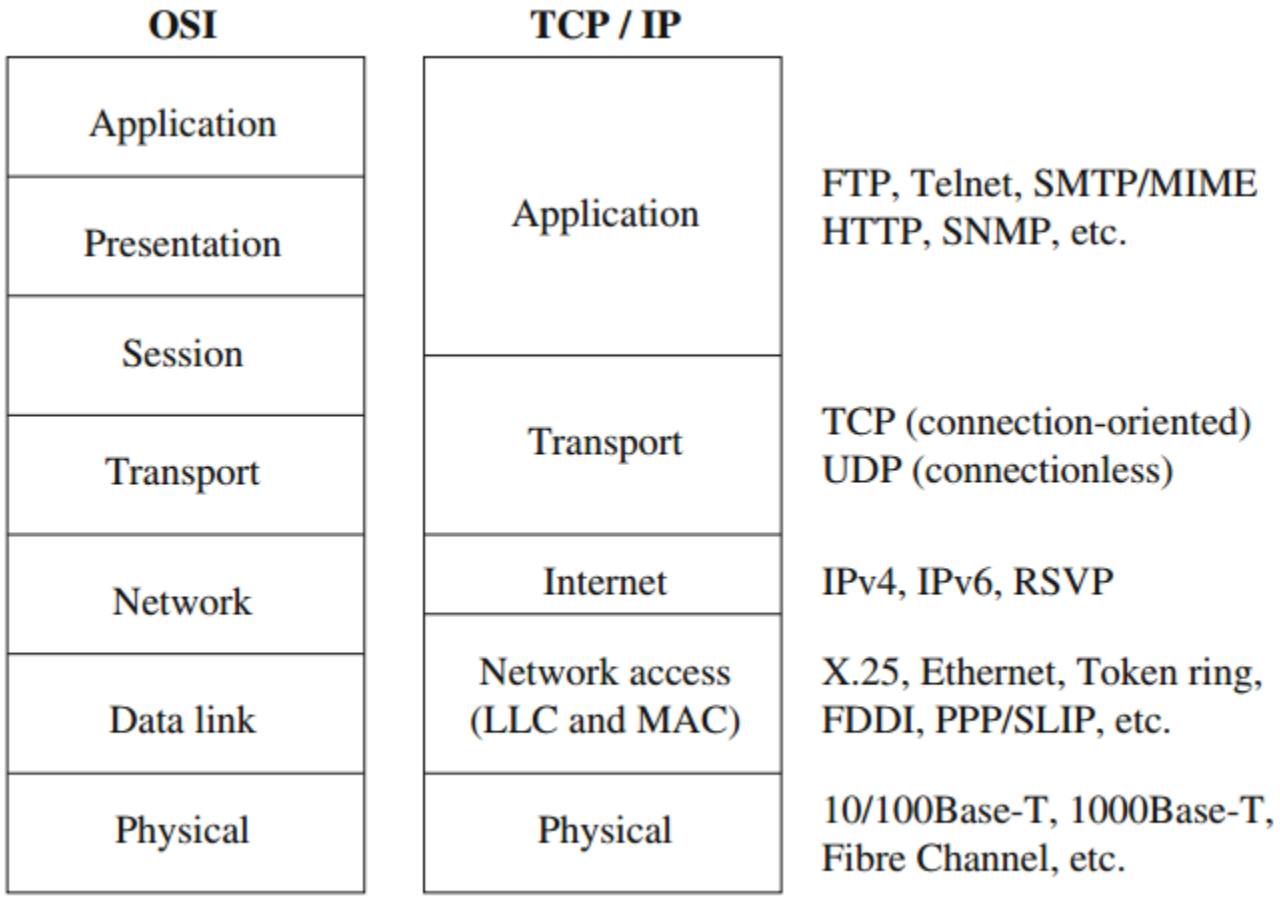

Fig. 15.1 Comparison of OSI and TCP/IP protocol architectures and sample protocols

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Local Area Network: LAN Standards

- **802.3 (Ethernet)** It defines the physical layer and the data link layer's MAC of the wired Ethernet, in particular the CSMA/CD method.
- **802.11 (Wireless LAN)** It defines the medium access method and physical layer specifications for wireless LAN (WLAN, also known as Wi-Fi).
- **802.16 (Broadband wireless)** It defines the access method and physical layer specifications for broadband wireless networks. One commercialized product is WiMAX (Worldwide Interoperability for Microwave Access), which targets the delivery of last mile wireless broadband access as an alternative to cable and DSL.

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Local Area Network: Ethernet Technology

Preamble 7 bytes	Start of Frame Delimiter 1 bytes	MAC destination 6 bytes	MAC source 6 bytes	Type or Length 2 bytes	Payload Data 46-1500 bytes	CRC 4 bytes

Fig. 15.3 Ethernet frame structure

CSMA/CD: A station that wishes to send a frame must first listen to the network (i.e., carrier sensing), wait until there is no traffic, and then send the frame.

Multiple stations could be waiting and then send their messages at the same time, causing a collision

Once a collision is detected, the station stops sending the frame, and the frame is retransmitted after a random delay

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Local Area Network: Ethernet Technology

- ✓ For a LAN with multiple stations, often a star topology is used, in which each station is connected directly to a hub (and recently a switch).
- ✓ The maximum data rate for the early Ethernet is 10 Mbps, using unshielded twisted pairs. In its long life span, the Ethernet's physical layer has encompassed coaxial, twisted pair and fiber optic physical media interfaces and speeds from 10 to 100 Gbps.
- ✓ Fast Ethernet like **100BASE-TX** and later 1000BASE-T run at **100 Mbps** and 1 Gbps, respectively. Recent fiber optic variants of Ethernet offer even higher performance, electrical isolation and distance (tens of kilometers with some versions).

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Access Networks: Dial-up and Integrated Services Digital Network

An access network bridges the LAN in a home or office to the external Internet.

Very earlier Internet accesses are often using the telephone Line (PSTN) to establish a dialed connection to an ISP. Note that the traditional telephone lines carry analog voice signal only. To transmit digital data, a modem is needed between the computer and the telephone jack.

Modern dial-up modems typically have a maximum theoretical transfer speed of 56 kbps. The connections usually have a latency as high as 300 ms or even more. Factors such as phone line noise as well as the quality of the modem itself play a large part in determining the connection speeds and delays. The low speed and relatively high delay make dial-up generally unsuitable for multimedia applications.

To overcome these limits, in the 1980s, the International Telecommunication Union (ITU) started to develop the Integrated Service Digital Network (ISDN.

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Access Networks: Dial-up and Integrated Services Digital Network

The earlier *Narrowband ISDN* (N-ISDN) typically provides a maximum of 128 kbps in both upstream and downstream directions. This relatively slow data rate, albeit higher than dial-up, can hardly provide quality multimedia services. The ITU-T has subsequently developed *Broadband ISDN* (B-ISDN). Two types of interfaces were available to users, depending on the data and subscription rates:

- **Basic Rate Interface (BRI)** provides two bearer channels (B-channels) for carrying data content, each at 64 kbps, and one data channel (D-channel) for signaling at 16 kbps. The total of 144 kbps ($64 \times 2 + 16$) is multiplexed and transmitted over a 192 kbps link.
- **Primary Rate Interface (PRI)** provides 23 B-channels and one D-channel, all at 64 kbps, in North America and Japan; 30 B-channels and two D-channels, all at 64 kbps, in Europe. The 23B and 1D fit in an industrial standard T1 carrier nicely, because T1 has 24 time slots and a data rate of 24 slots $\times$ 64 kbps/slot $\approx$ 1,544 kbps; whereas the 30B and 2D fit in a standard E1 carrier, which has 32 time slots (30 of them available for user channels) and a data rate of $32 \times 64 =$ 2,048 kbps.

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Digital Subscriber Line

✓ It also makes use of existing telephone's twisted-pair wires to transmit modulated digital data signal.

✓ Discrete Multi-Tone (DMT) is used for better transmission in potentially noisy channels.

Table 15.1 Maximum distances for DSL using Twisted-Pair Copper Wires

Data rate (Mbps)	Wire size (mm)	Distance (km)
1.544	0.5	5.5
1.544	0.4	4.6
6.1	0.5	3.7
6.1	0.4	2.7

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Digital Subscriber Line

Table 15.2 Different types of Digital Subscriber Lines

Name	Meaning	Data rate	Mode
HDSL	High data rate digital subscriber line	1.544 Mbps or 2.048 Mbps	Duplex
SDSL	Single line digital subscriber line	1.544 Mbps or 2.048 Mbps	Duplex
ADSL	Asymmetric digital subscriber line	1.5 to 9 Mbps 16–640 kbps	Down up
VDSL	Very high data rate digital subscriber line	13 to 52 Mbps 1.5–2.3 Mbps	Down up

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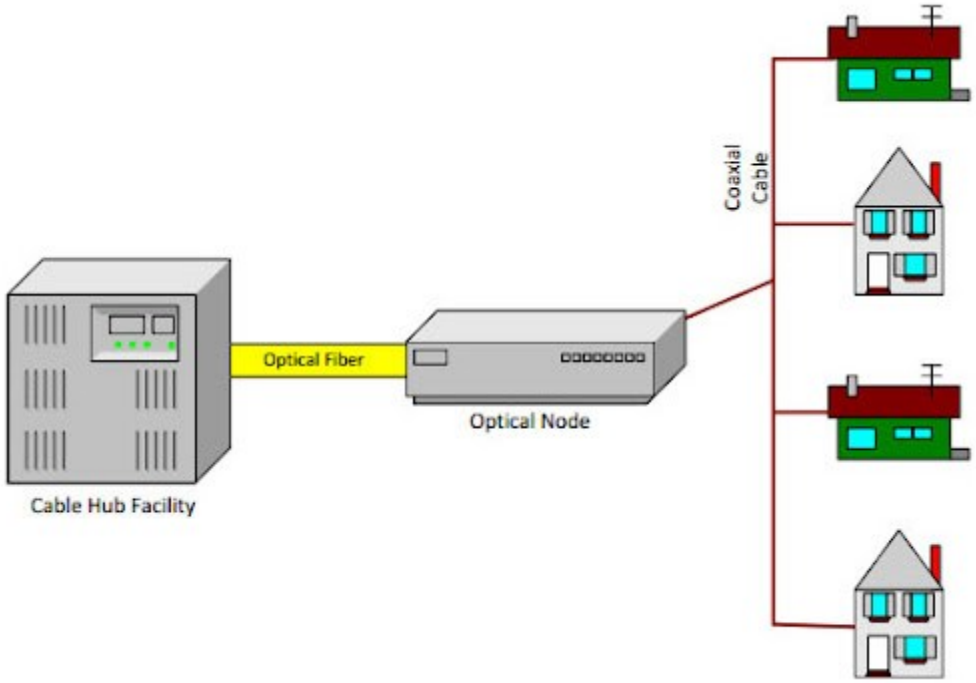
Access Networks: Hybrid Fiber-Coaxial Cable Networks

Besides telephone lines, another network access that is readily available in many homes is the **Cable TV network**. In such a network, optical fibers connect the core network with **Optical Network Units (ONUs)** in the neighborhood, each of which typically serves a few hundred homes through shared coaxial cables.



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Access Networks: Hybrid Fiber-Coaxial Cable Networks

- ✓ A cable modem can be used to provides bi-directional data communication via radio frequency channels on this Hybrid Fiber-Coaxial (HFC) network.

- ✓ The peak connection speed of a cable modem can be up to 30 Mbps, which is faster than most DSL accesses that are up to 10 Mbps. VDSL can match this performance, though has not been widely offered by ISPs. However, the cable Internet access is shared among many neighboring homes, while the DSL based on a telephone line is dedicated.

- ✓ DSL and cable accesses: have dominated home Internet access around the world

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Access Networks: Fiber-To-The-Home or Neighborhood (FTTH/FTTN)

- ✓ Optical fibers can be laid to connect home networks to the core network directly. It replaces all or part of the conventional metal local loop used for last-mile accesses, providing the highest bandwidth.

- ✓ Since existing homes generally have only twisted pairs and/or coaxial cables, the implementation cost of Fiber-To-The-Home (FTTH) will be high, but many new high-rise buildings have already had built-in fiber accesses.

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Access Networks: AT&T U-verse as an Example of FTTH/FTTN

Table 15.3 Connection speeds and services of U-verse

	Max turbo	Max plus	Max	Elite	Pro
Downstream speed up to	24 Mbps	18 Mbps	12 Mbps	6 Mbps	3 Mbps
	Best choice for:				
Video chat	√				
Online gaming	√	√			
Streaming SD video	√	√			
Downloading movies	√	√	√		
Emailing large files	√	√	√		
Watching video clips	√	√	√	√	
Online meetings	√	√	√	√	
Music downloading and streaming	√	√	√	√	√
Sharing photos	√	√	√	√	√
Social networking	√	√	√	√	√
Web surfing and emailing	√	√	√	√	√

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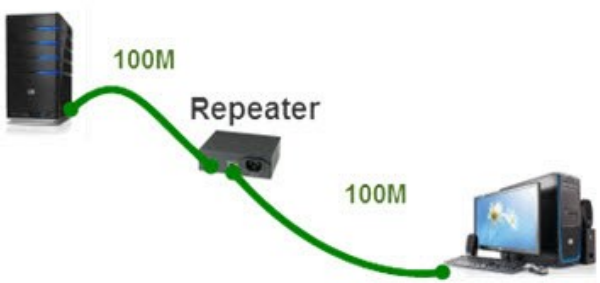
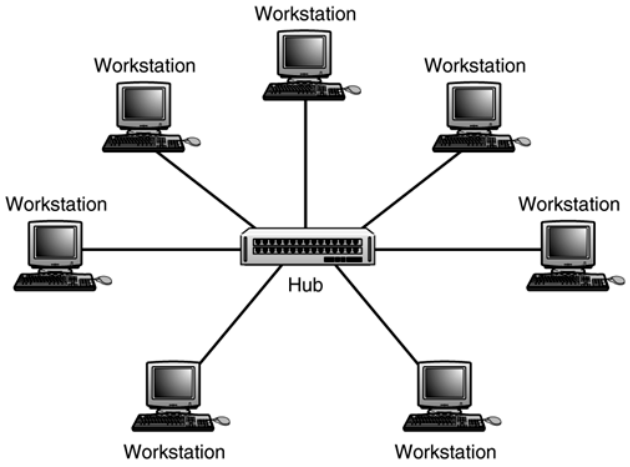
Internet Technologies and Protocols: Network Devices

NIC: Network Interface Card

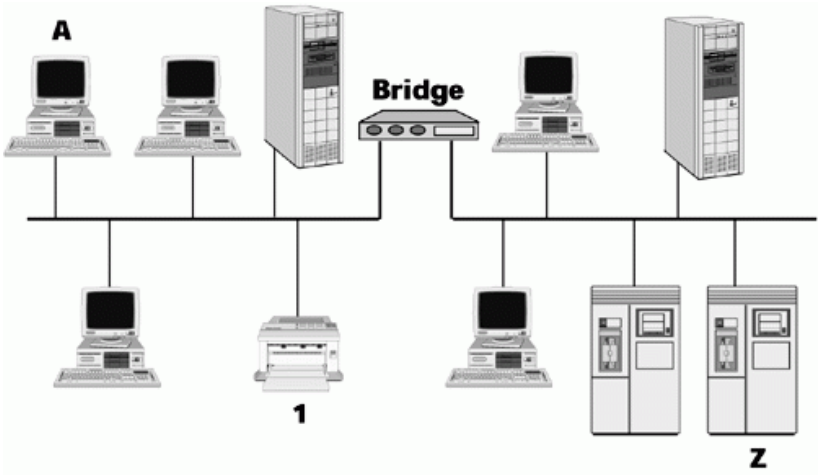


A multiport repeater



Switch

Divide a large network into smaller segments



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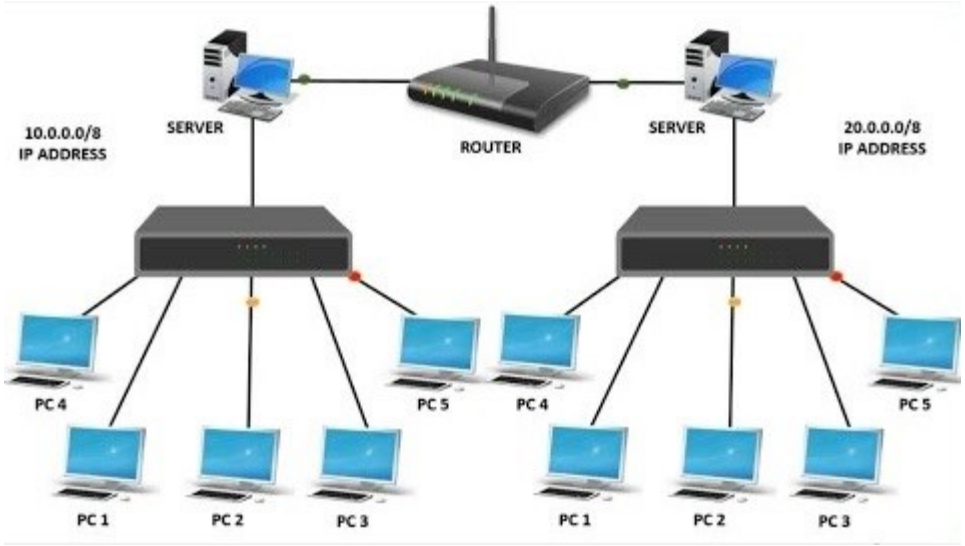
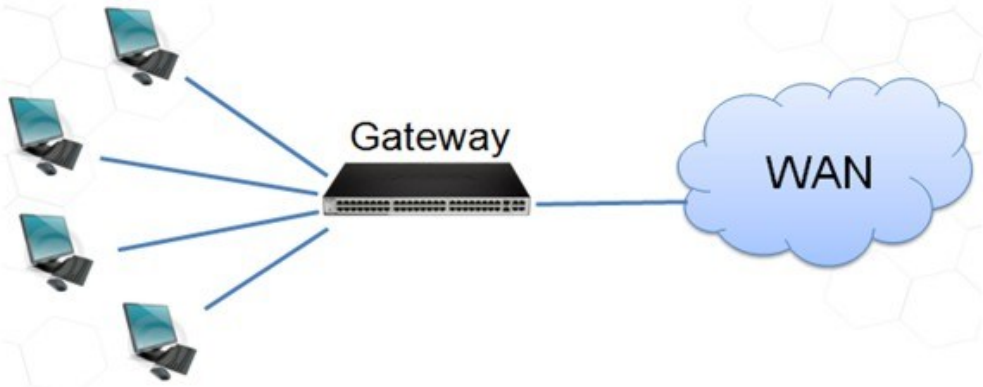
Internet Technologies and Protocols: Network Devices



A router is a device like a switch that routes data packets based on their IP addresses.

Gateway is a network device used to connect two or more networks having different protocols.



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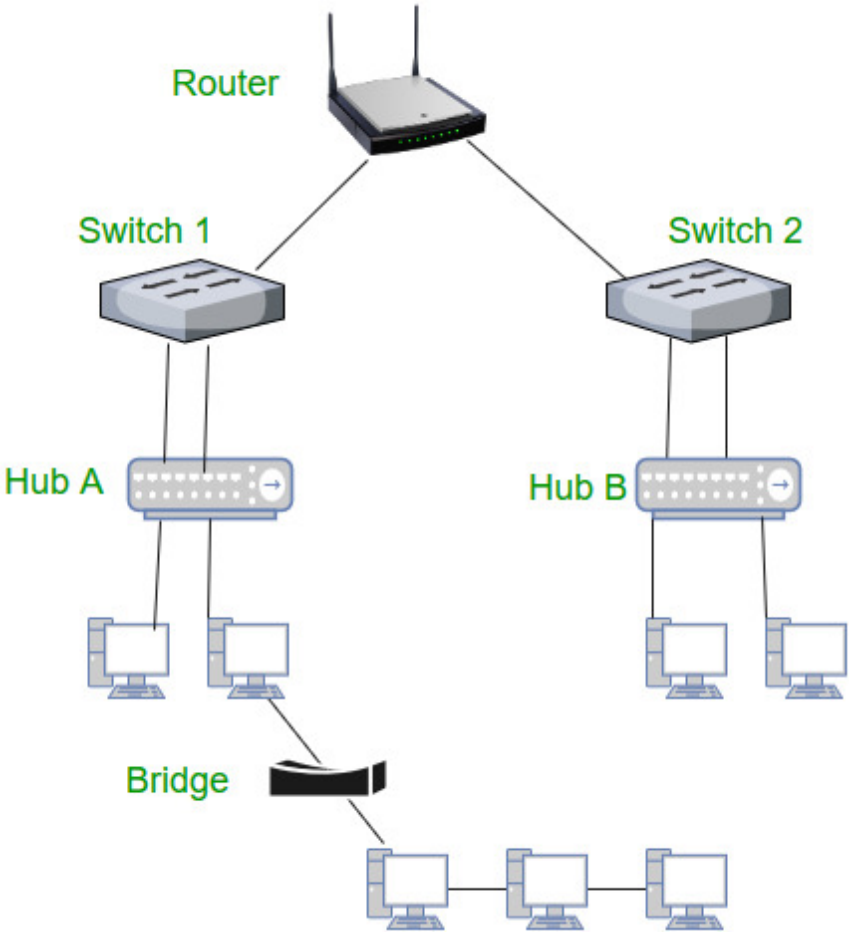
Internet Technologies and Protocols: Network Devices



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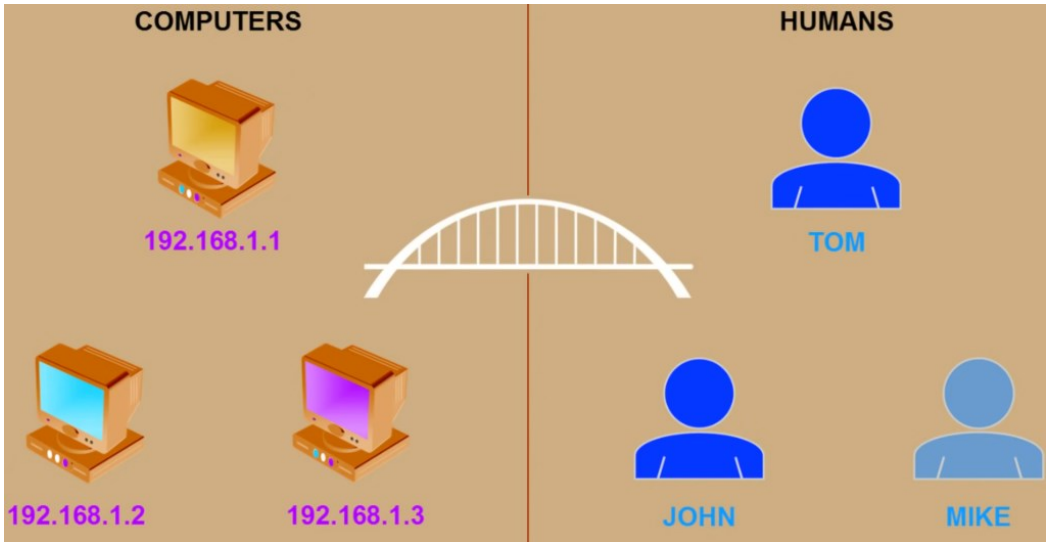
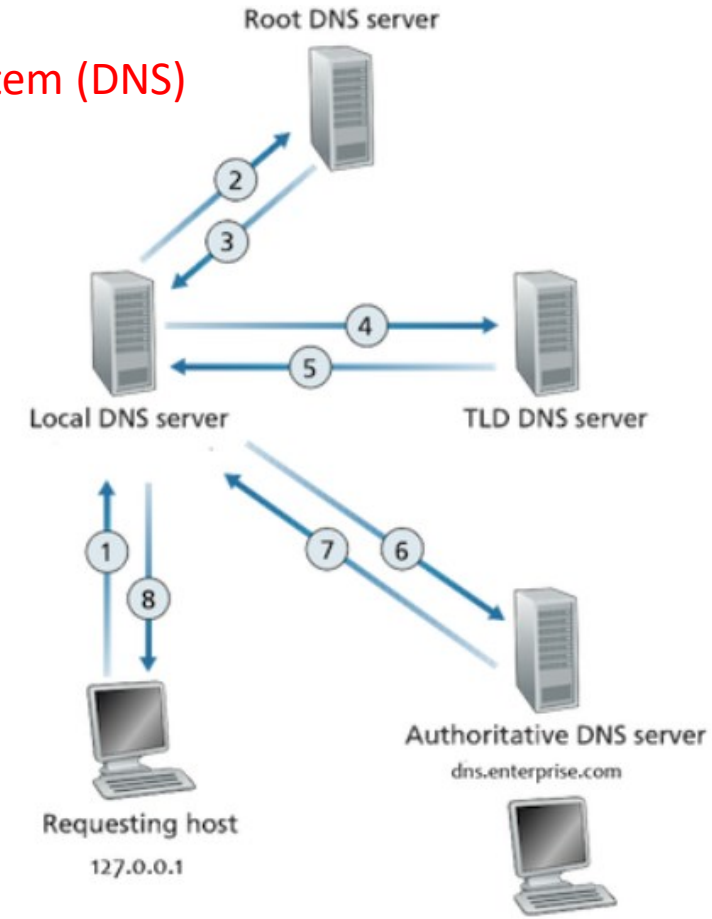
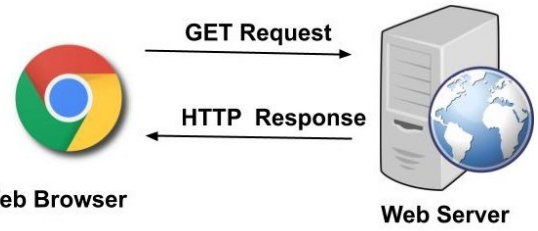
Internet Technologies and Protocols: Domain Name System (DNS)





http://142.250.207.36/ ⟸ https://www.google.com/

In windows OS, open CMD and type “ping www.google.com”
This will provide you with the servers IP address of Google



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Internet Technologies and Protocols: Network Layer: IP

The network layer provides two basic services: packet addressing and packet forwarding.

Point-to-point data transmission is readily supported within any LANs, and in fact, the LANs usually support broadcast.

For a network-layer packet to be transmitted across different LANs or a WAN, routers are employed, that receive and forward packets according to their destination addresses.

Two common ways to move data through a network of links and routers:
Circuit switching (Example: PSTN)
Packet switching (Internet)

For **packet switching**, two approaches are available:
Datagram: Each packet is treated independently, and no specific route is predetermined prior to the transmission.

Virtual circuit: A route is predetermined through request and accept by all nodes along the route.

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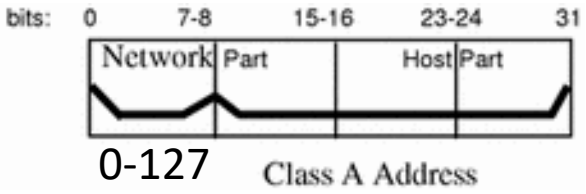
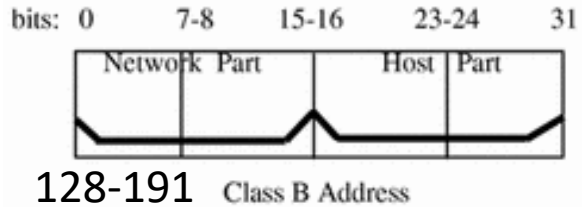
Internet Technologies and Protocols: Network Layer: IP Address

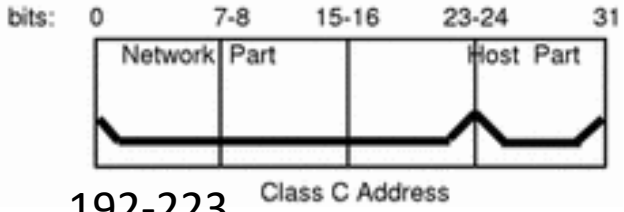
Classes of TCP/IP networks: class A, class B, and class C.



75.4.10.4



129.144.50.56



192.5.2.5

- ✓ The numbers in the first byte of the IP address define network class and are always assigned by the InterNIC.
- ✓ The remaining three bytes have a range from 0-255.
- ✓ The numbers 0 and 255 are reserved; you can assign the numbers 1-254 to each byte.

Class B IP Address: 129.144.50.56
Network ID: 129.144.0.0
Broadcast ID: 129.144.255.255

Useable IP: 2^{16}-2= 65534

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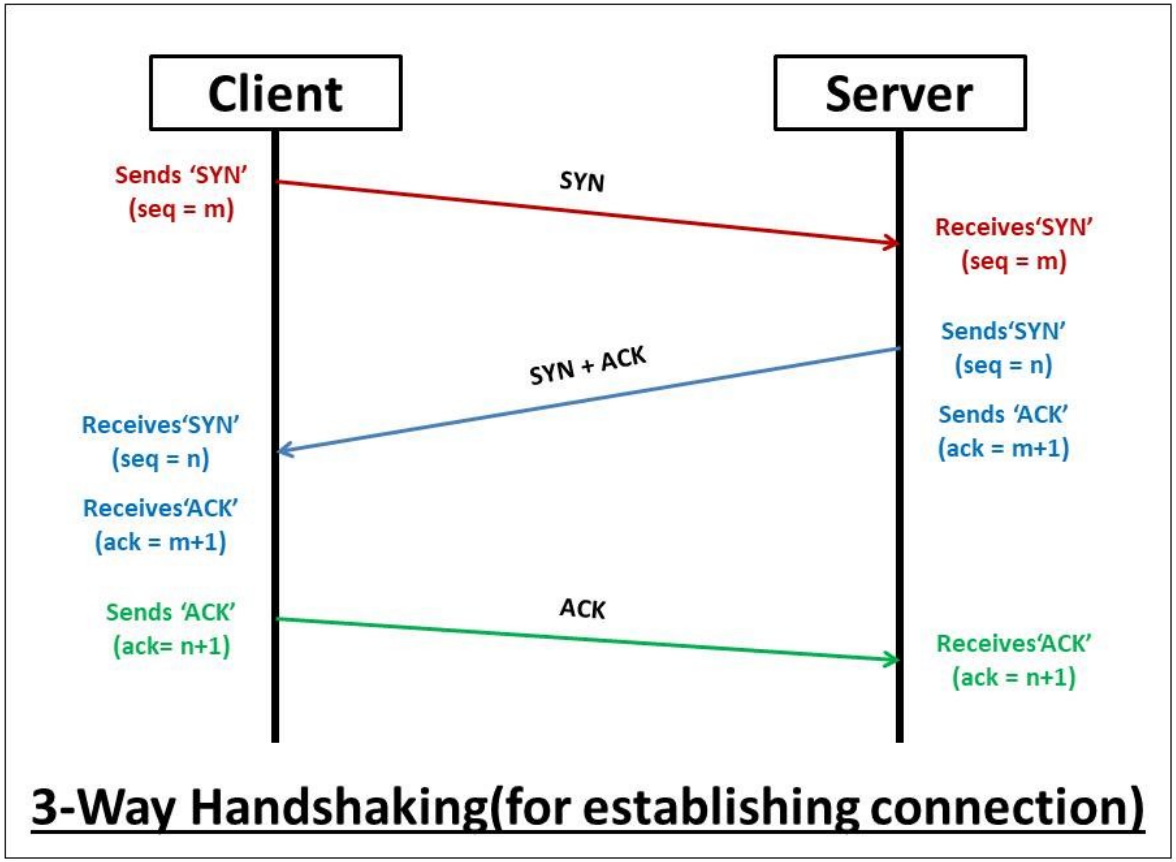
Internet Technologies and Protocols: Transport Layer: TCP

Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) are two transport layer protocols used in the Internet to facilitate host-to-host (or end-to-end) communications.

TCP is connection-oriented: a connection must be established through a 3-way handshake before the two ends can start communicating.

It relies on the IP layer for delivering the data to the destination specified by its IP address.



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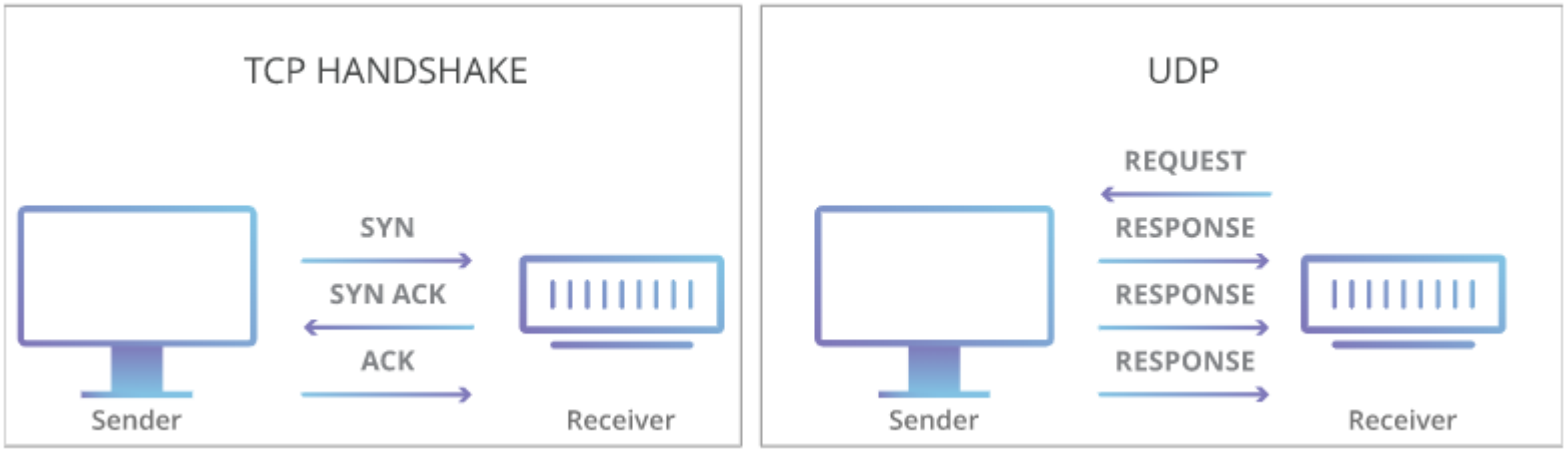
Internet Technologies and Protocols: Transport Layer: UDP

UDP is connectionless with no guarantee on delivery. If a message is to be reliably delivered, it has to be handled by its own application in the application layer.



UDP is commonly used in time-sensitive communications where occasionally dropping packets is better than waiting.

However, UDP can be exploited for malicious purposes

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Quality-of-Service (QoS) for Multimedia Communications

Fundamentally, MM network communication and traditional computer network communication are similar. However, challenges in arise due to a series of distinct characteristics of audio/video data:

Voluminous and Continuous: They demand high data rates, and often have a lower bound to ensure continuous playback.

Real-Time and Interactive: They demand low startup delay and synchronization between audio and video for “lip sync”

Rate fluctuation: The multimedia data rates fluctuate drastically and sometimes bursty.

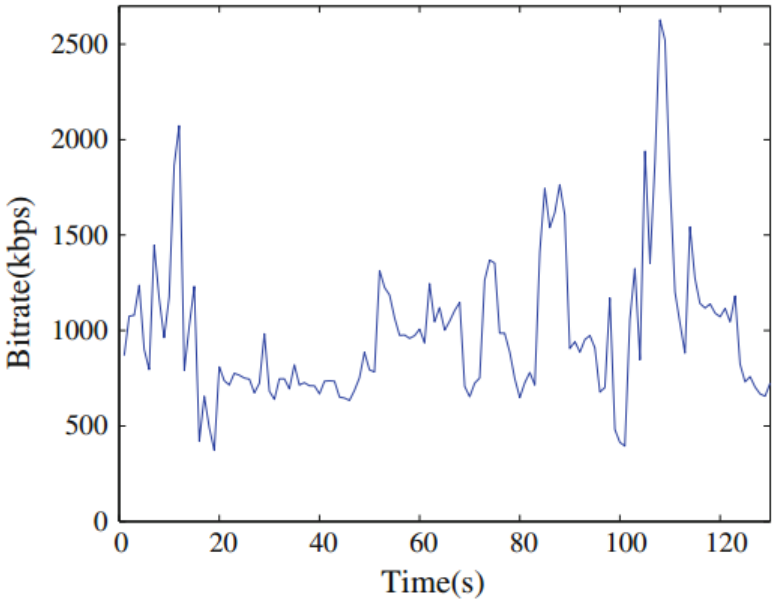

Fig. 15.10 The bitrate over time of an MPEG-4 video

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QoS for MM Comm.: Parameters

Bandwidth: A measure of transmission speed over digital links or networks (in kbps/Mbps).

Latency: Max. time needed from transmission to reception (often measured in ms).

Packet loss or error: A measure of the loss- or error rate of the packetized data transmission.

Delay jitter: A measure of smoothness (along time axis) of the audio/video playback.

Sync skew: A measure of multimedia data synchronization (in ms). For a good lip synchronization, the limit of sync skew is ±80 ms between audio and video.

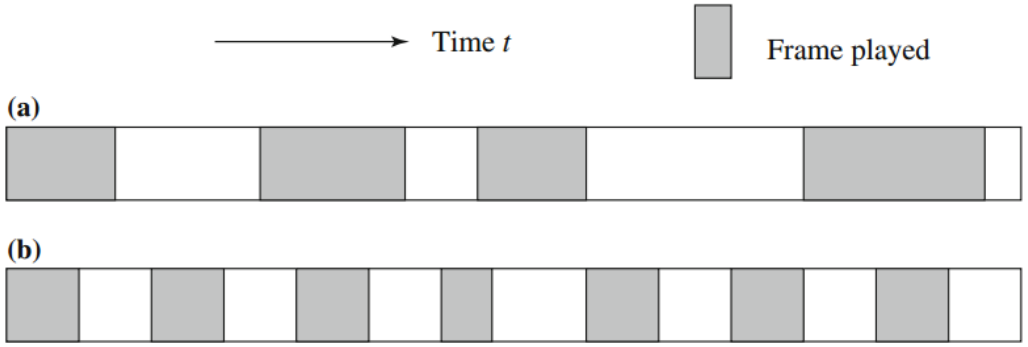

Fig. 15.11 Jitters in frame playback: **a** high jitter; **b** low jitter

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QoS for MM Comm.: Multimedia Service Classes

A broad spectrum of **MM data** (from audio to image to video, and from low quality audio/video to medium quality and to high quality) and **applications** (one way or two way, interactive or noninteractive, real-time or nonrealtime, and etc.)

- Two-way traffic, low latency and jitter, possibly with prioritized delivery, such as voice telephony and video telephony.
- Two-way traffic, low loss and low latency, with prioritized delivery, such as e-commerce applications.
- Moderate latency and jitter, strict ordering and sync. One-way traffic, such as streaming video; or two-way interactive traffic, such as web surfing and online gaming.
- No real-time requirement, such as downloading or transferring large files (movies). No guarantees for transmission.

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QoS for MM Comm.: Multimedia Service Classes

Application	Speed requirement
Telephone	16 kbps
Audio conferencing	32 kbps
CD-quality audio	128–192 kbps
Digital music (QoS)	64–640 kbps
H. 261	64–2 Mbps
H. 263	<64 kbps
H. 264	1–12 Mbps
MPEG-1 video	1.2–1.5 Mbps
MPEG-2 video	4–60 Mbps
MPEG-4 video	1–20 Mbps
HDTV (compressed)	>20 Mbps
HDTV (uncompressed)	>1 Gbps
MPEG-4 video-on-demand (QoS)	250–750 kbps
Videoconferencing (QoS)	384 kbps–2 Mbps

Table 15.4 Requirement on network bandwidth/bitrate

Application	Average latency tolerance (msec)	Average jitter tolerance (msec)
Low-end videoconference (64 kbps)	300	130
Compressed voice (16 kbps)	30	130
MPEG NTSC video (1.5 Mbps)	5	7
MPEG audio (256 kbps)	7	9
HDTV video (20 Mbps)	0.8	1

Table 15.5 Tolerance of latency and jitter in digital audio and video

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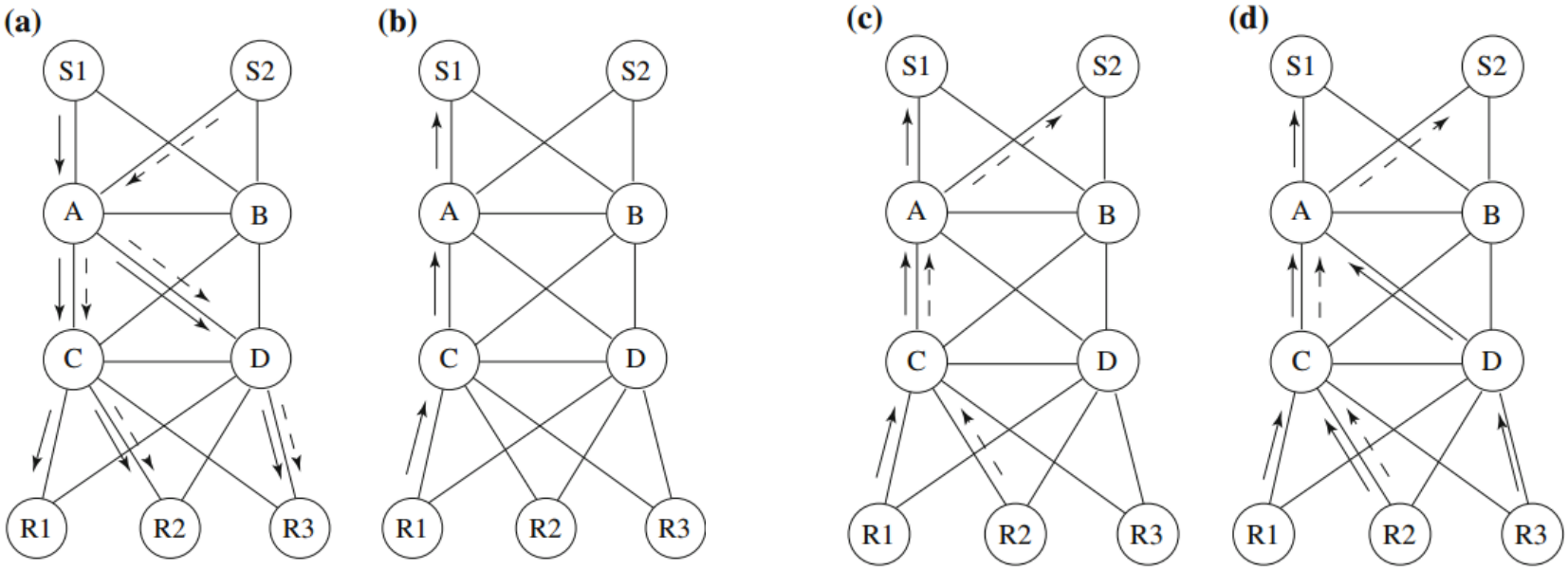
QoS for MM Comm.: Internet QoS

Two approaches for improving QoS within the Internet: Integrated Service (**Resource ReSerVation Protocol**, as explained below) and Differentiated Service



A network with two senders, three receivers, and four routers. Figure (a) shows that S1 and S2 send ***Path*** messages along their paths to R1, R2, and R3. In (b) and (c), R1 and R2 send out ***Resv*** messages to S1 and S2, respectively, to make reservations for S1 and S2 resources. From C to A, two separate channels must be reserved since R1 and R2 request different data streams. In (d), R2 and R3 send out their ***Resv*** messages to S1, to make additional requests. R3's request is merged with R1's previous request at A, and R2's is merged with R1's at C.

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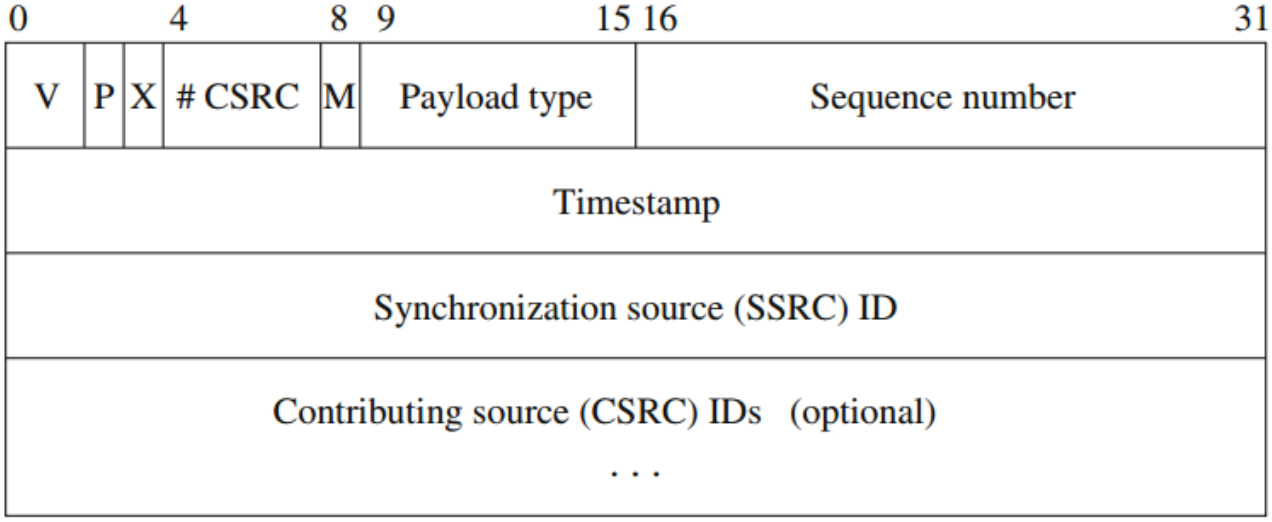
Protocols for Multimedia Transmission and Interaction

Real-Time Transport Protocol (RTP):

- ✓ Designed for delivering audio and video streams over IP networks
- ✓ RTP usually runs on top of UDP
- ✓ Two key principles: Application Layer Framing and Integrated Layer Processing



RTP packet header

The first 12 octets are of a fixed format, followed by optional (0 or more) 32-bit Contributing Source (CSRC) IDs. Bits 0 and 1 are for the version of RTP, bit 2 (P) for signaling a padded payload, bit 3 (X) for signaling an extension to the header, and bits 4 through 7 for a 4-bit CSRC count that indicates the number of CSRC IDs following the fixed part of the header

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Protocols for Multimedia Transmission and Interaction

RTP Control Protocol (RTCP):

- ✓ RTP monitors QoS
- ✓ It provides feedback to the source on quality of data transmission
- ✓ Conveys information about the participants of a multicast session.
- ✓ Also, provides the necessary information for audio and video synchronization,

- ✓ Note that, while RTCP offers QoS feedbacks, it does not specify how these feedbacks are to be used, but leaves the operations to the application layer.

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Protocols for Multimedia Transmission and Interaction

Real-Time Streaming Protocol (RTSP):

- ✓ RTSP is a signaling protocol to control streaming media servers.
- ✓ The protocol is used for establishing and controlling media sessions between end points.
- ✓ Clients of media servers issue VCR-like commands, such as play, random-seek, and pause, to facilitate real-time control of playback of media files from the server.

RTSP Operations:

Requesting presentation description The client issues a `DESCRIBE` request to the media server to obtain the presentation description, such as, media types (audio, video, graphics, etc.), frame rate, resolution, codec, and so on, from the server.

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Protocols for Multimedia Transmission and Interaction

RTSP Operations:

Session setup The client issues a `SETUP` to inform the server of the destination IP address, port number, protocols, and TTL (for multicast). The session is set up when the server returns a session ID.

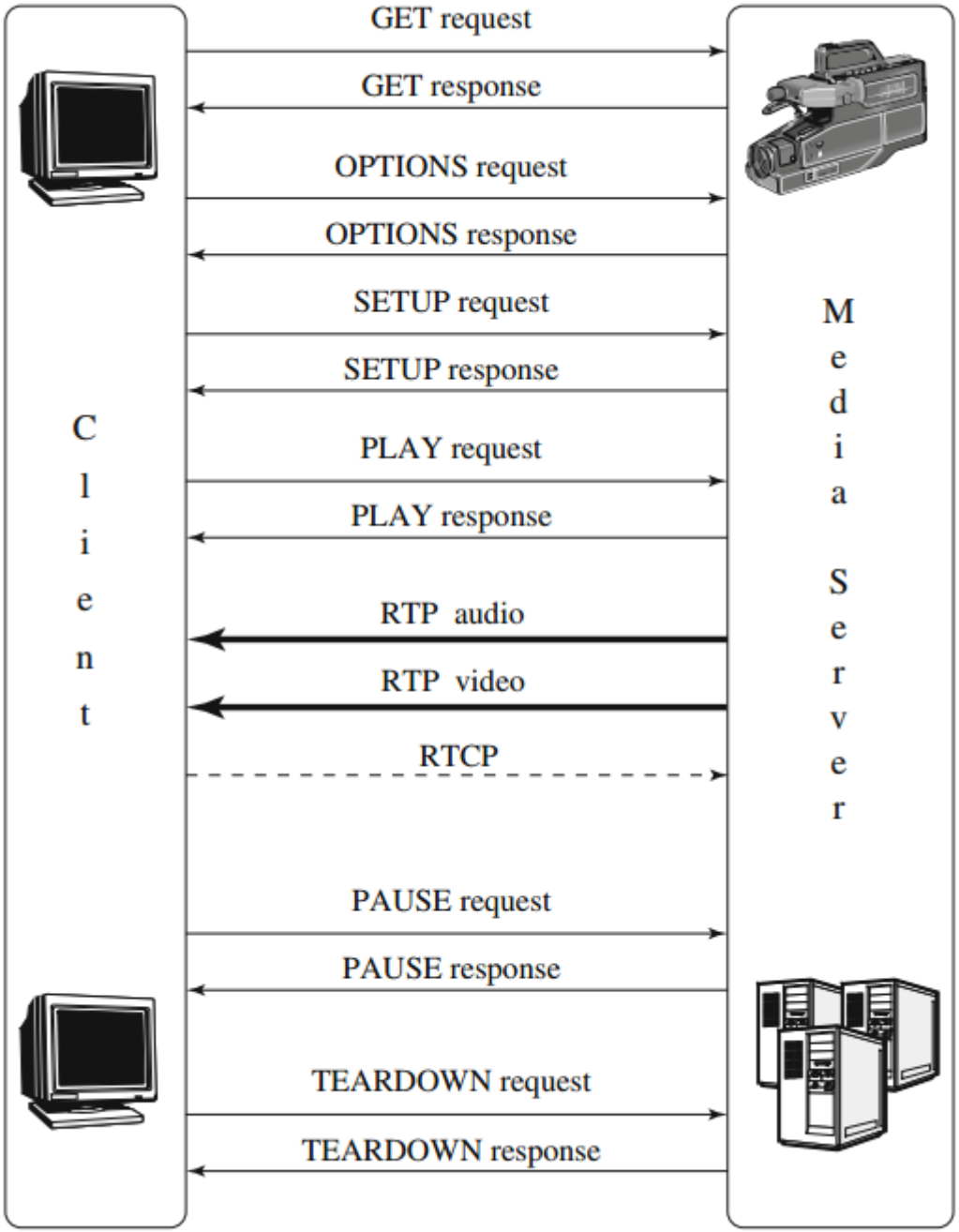
Requesting and receiving media After receiving a `PLAY`, the server starts to transmit streaming audio/video data, using RTP. It is followed by a `RECORD` or `PAUSE`. Other VCR commands, such as `FAST-FORWARD` and `REWIND` are also supported. During the session, the client periodically sends an RTCP packet to the server, to provide feedback information about the QoS received

Session closure `TEARDOWN` closes the session.

MM Comm. & Net: Services and Protocols

Protocols for Multimedia Transmission and Interaction

A possible scenario of four typical RTSP operations:

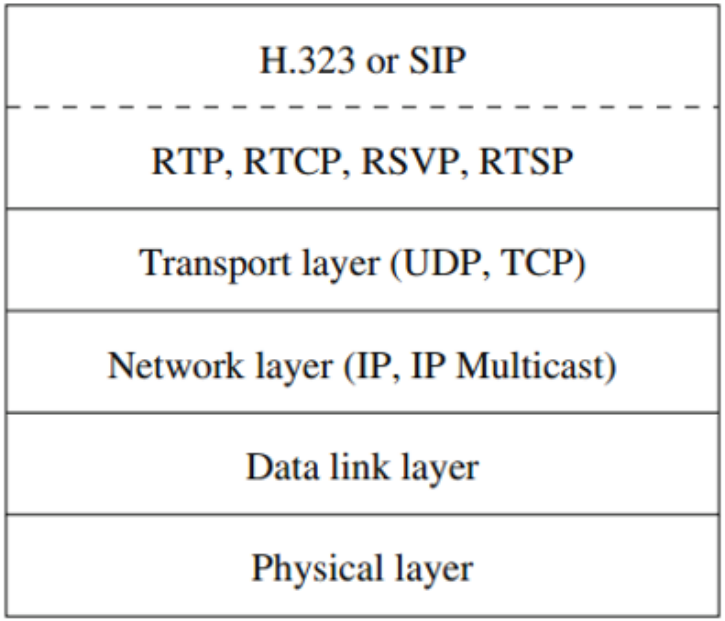


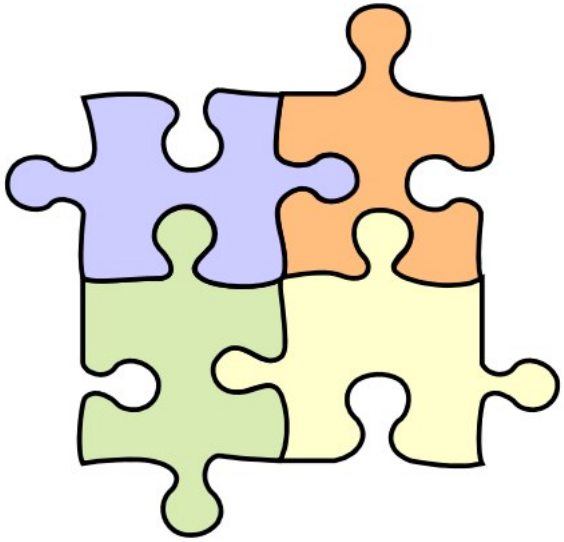
MM Comm. & Net: Services and Protocols

Protocols for Multimedia Transmission and Interaction

Case Study: Internet Telephony:

- ✓ H.323 is an ITU standard for packet-based multimedia communication services.
- ✓ Session Initiation Protocol (SIP): Different from H.323, SIP is a text-based protocol, and is not limited to VoIP communications.



Network protocol structure for internet telephony

Q&A