Government Arts and Science College (Women),
Sathankulam – 628704

Class : III B.Sc. (Computer Science)

Semester : V

Subject : Data Communication and Computer Network

Topic : Unit – III

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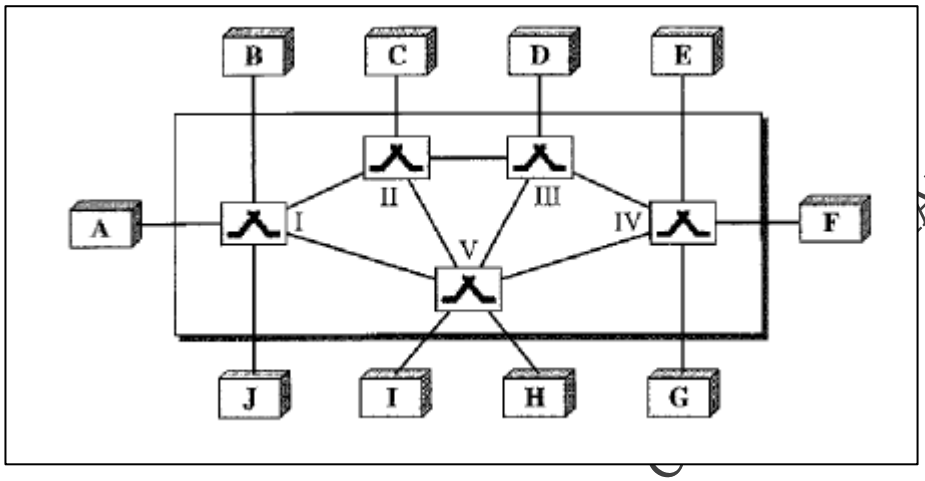
Switching

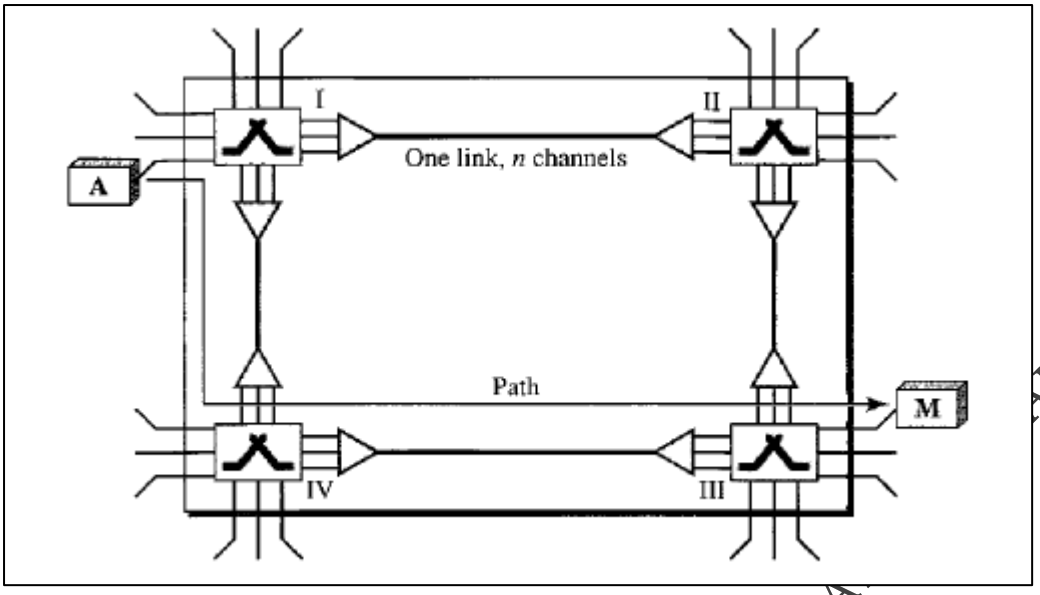
- A switched network consists of a series of interlinked nodes called switches.
- Switches create temporary connections between two or more devices linked to the switch.
- In a switched network some nodes are connected to end systems and others for routing.



- The end systems are labeled A, B, C, D and so on, and the switches are labeled I, II, III, IV and V.
- Each switch is connected to multiple links

Circuit-Switched Network

- A circuit-switched network consists of a set of switches connected by physical links.
- Each connection uses only one dedicated channel on each link.
- Each link is divided into n channels using FDM or TDM.



- Circuit switching takes place at the physical layer.
- Before starting communication, the stations must make a reservation for the resources such as channels, switch buffers, switch processing time, switch input/output ports.
- It must remain dedicated during the entire duration of data transfer until teardown phase.
- The data are continuous flow sent by the source station and received by the destination station.
- There is no addressing during data transfer. The switches route data based on their occupied band or time slot.

Three Phases

Setup Phase

- Before the two parties can communicate, a dedicated circuit needs to be established.
- When system A needs to connect to system M, it sends a setup request with address of system M to switch I.
- Switch I finds a channel between itself and switch IV. It then sends a request to switch IV.
- Switch IV finds a dedicated channel between itself and switch III.
- Switch III informs system M of system A's intention.
- An acknowledgment from system M is sent in the opposite direction to system A.

- Only after system A receives this acknowledgment, the connection is established.

Data Transfer Phase

- After the establishment of the dedicated circuit, the two parties can transfer data.

Teardown Phase

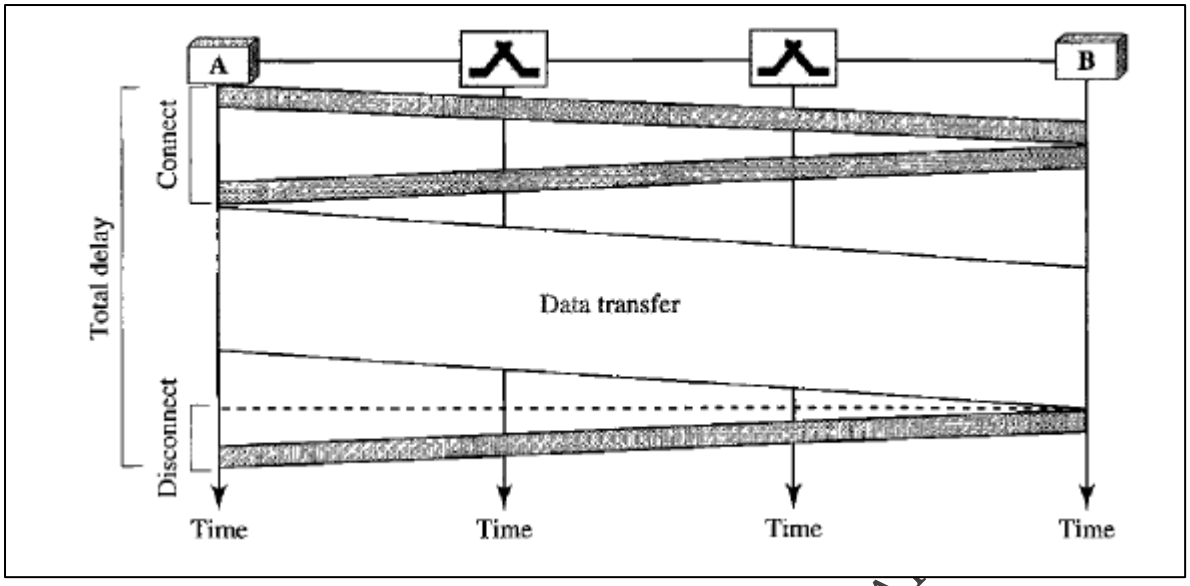
- When the two parties need to disconnect, a signal is sent to each switch to release the resources.

Efficiency

- Circuit-switched networks are not as efficient as the other two types because resources are allocated during the entire duration of the connection.
- In telephone network, people normally terminate when they have finished their conversation.
- In computer networks, a computer is connected to another computer even if there is no activity for a long time.

Delay

- Delay is minimal in circuit-switched network.
- There is no waiting time at each switch.
- The total delay is due to the time needed to create the connection, transfer data and disconnect the circuit.
- The delay caused by the setup is the sum of propagation time, request signal transfer time, propagation time of acknowledgement and signal transfer time of the acknowledgement.
- The delay due to data transfer is the sum of propagation time and data transfer time.
- The third is the time needed to tear down the circuit.

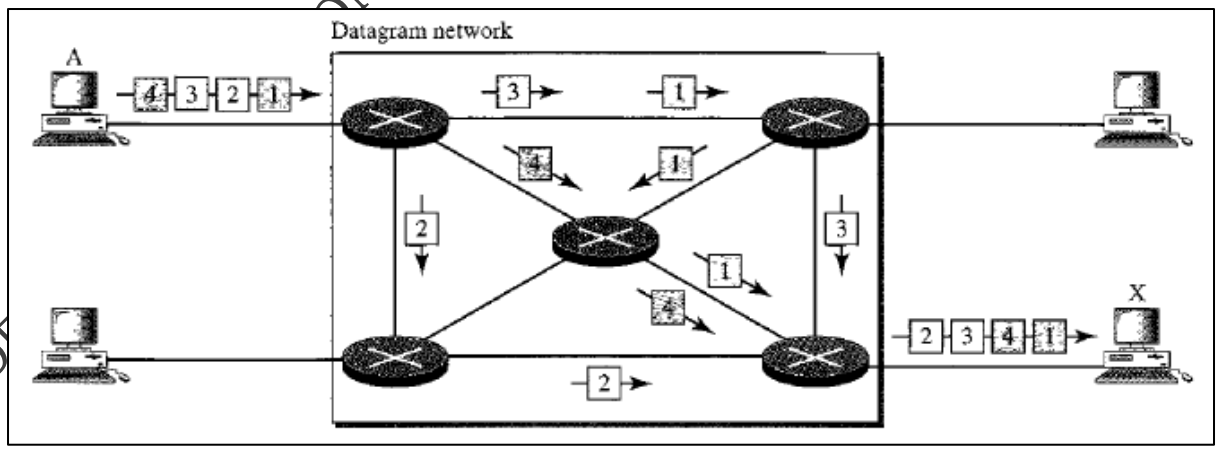


Packet-Switched Networks

- In packet-switched network, the message is divided into packets of fixed or variable size.
- In packet switching there is no reserved bandwidth on the links and there is no scheduled processing time for each packet.
- Resources are allocated on demand that is on first-come, first-served basis.

Datagram Network

- In a datagram network each packet is treated independently.
- Packets are referred to as datagrams.
- Datagram switching is done at the network layer.

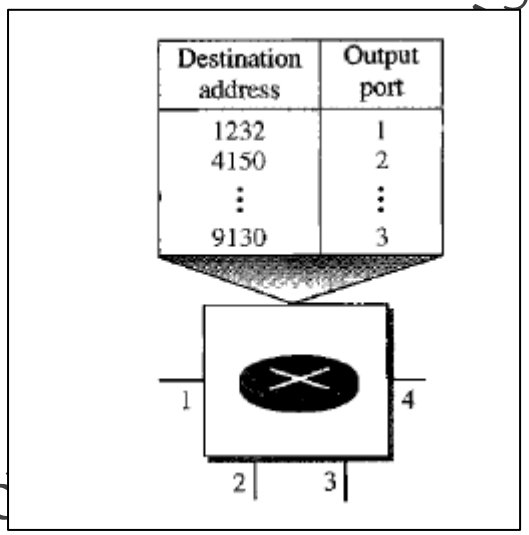


- In this example, all four packets belong to the same message but travel different paths to reach their destination.
- The links do not have the necessary bandwidth to carry all the packets from A to X

- The datagrams arrive the destination out of order with different delays between the packets.
- Packets may be lost or dropped due to lack of resources.
- The upper layer protocols reorder the datagrams or ask for lost datagrams before passing them to the application.
- The datagram networks are referred to as connectionless network.
- There are no setup or teardown phases.
- Each packet is treated the same by a switch regardless of its source or destination.

Routing Table

- Each switch has a routing table based on their destination address.
- The routing tables are dynamic and updated periodically.
- The destination addresses and the corresponding forwarding output ports are recorded in the tables.



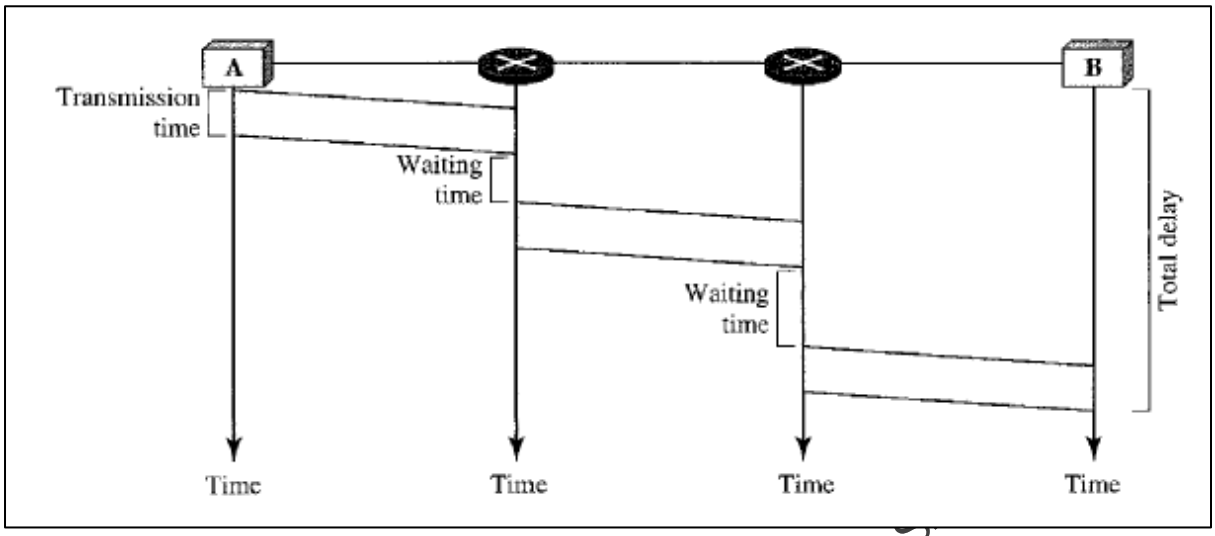
Destination Address

- Every packet carries a header that contains, the destination address among other information.
- When the switch receives the packet, the destination address is examined and consulted with routing table to find the corresponding port to forward the packet.
- This address remains the same during the entire journey of the packet.

Efficiency

The efficiency is better than circuit-switched networks. Resources are allocated only when there are packets to be transferred.

Delay



The packet travels through two switches. There are three transmission times (3T), three propagation delays (3τ) and two waiting times (w_1 + w_2).

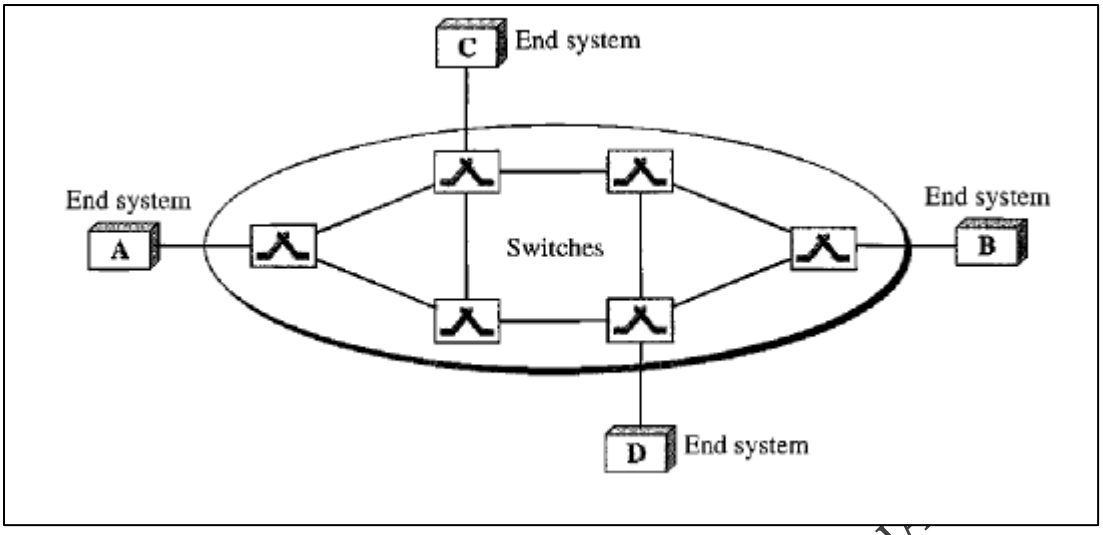
Total delay = 3T + 3τ + w_1 + w_2

Virtual-Circuit Networks

A virtual-circuit network is a cross between a circuit-switched network and a datagram network.

Characteristics

- There are setup and teardown phases in addition to the data transfer phase.
- Resources can be allocated during the setup phase as in circuit-switched network or on demand as in datagram network.
- As in datagram network, data are packetized and each packet carries an address in the header. The address defines what should be the next switch and the channel on which the packet is being carried.
- As in a circuit-switched network, all packets follow the same path established during the connection.
- A virtual-circuit network is implemented in the data link layer.



Addressing

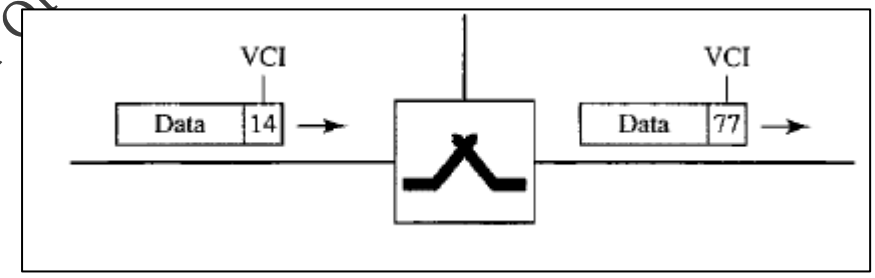
Two types of addressing are involved: global and local (virtual-circuit identifier)

Global addressing

An address that can be unique in the scope of the network or internationally if the network is part of an international network.

Virtual-Circuit Identifier

- The identifier used for data transfer is called the virtual-circuit identifier (VCI).
- A VCI is a small number that has only switch scope and is used by a frame between two switches.
- When a frame arrives at a switch it has a VCI; when it leaves it has different VCI.

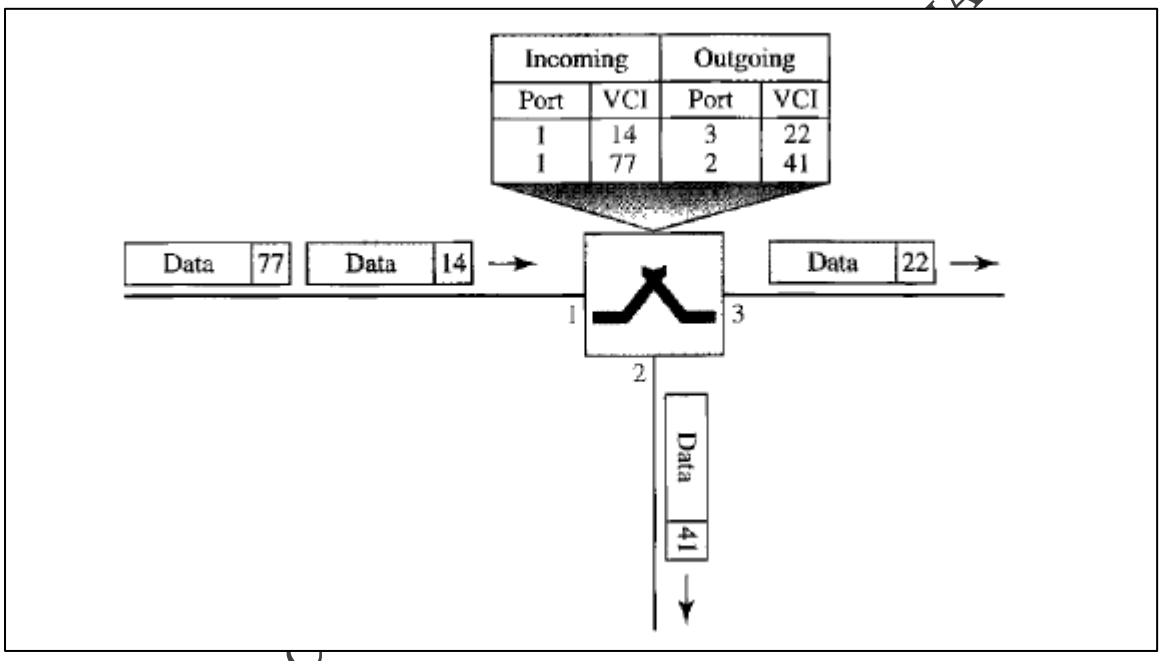


Three Phases

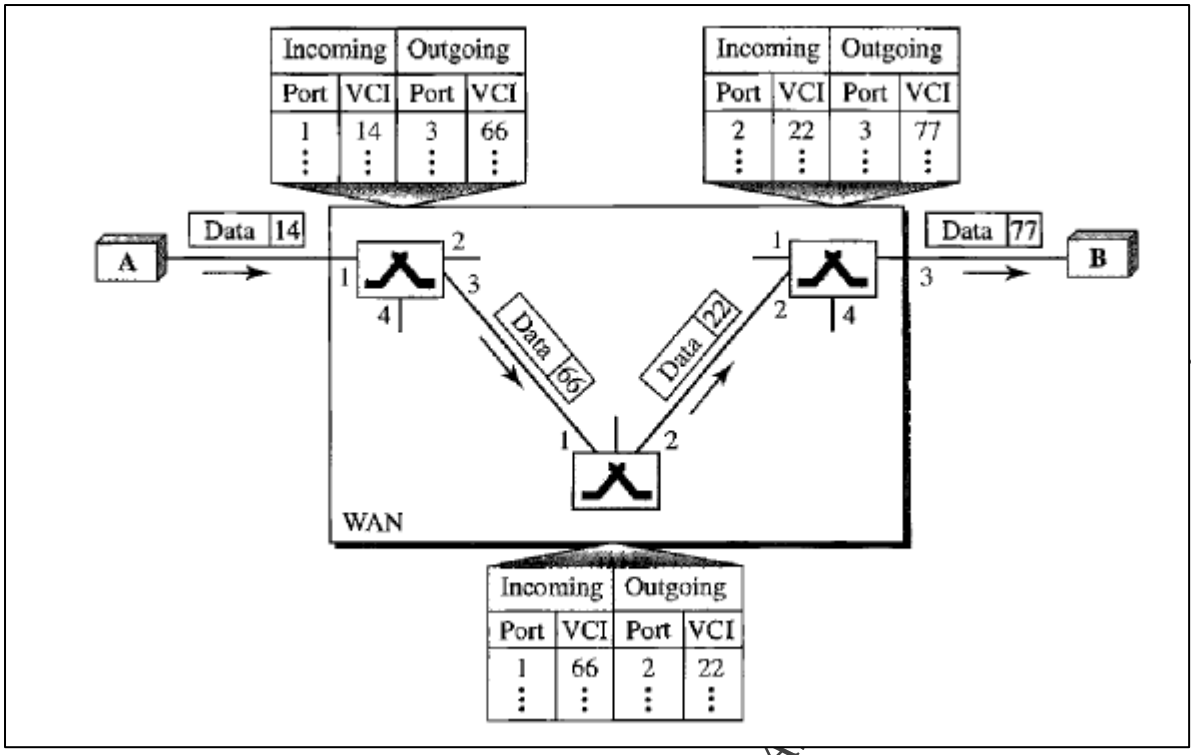
In the setup phase, the source and destination use their global addresses to make table entries for the connection. In the teardown phase, the source and destination inform the switches to delete the corresponding entry. Data transfer occurs between these two phases.

Data Transfer Phase

- To transfer a frame from source to destination all the switches have a table entry for this virtual circuit.
- The table has four columns which hold four pieces of information for each virtual circuit.
- The figure shows a frame arriving at port 1 with a VCI of 14.
- When the frame arrives the switch looks in its table to find port 1 and a VCI of 14.
- When it is found, the switch knows to change the VCI to 22 and send out the frame from port 3.



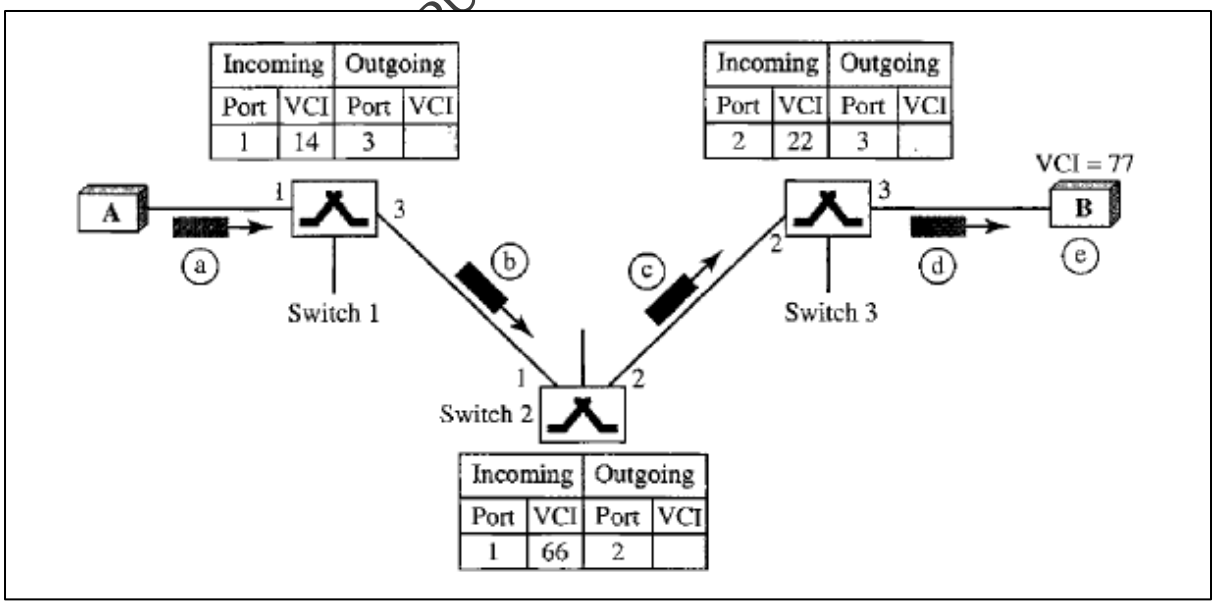
The following figure shows how a frame from source A reaches destination B and how its VCI changes during the trip. Each switch changes the VCI and routes the frame.



Setup Phase

In setup phase, a switch creates an entry for a virtual circuit. It requires two step: setup request and acknowledgment.

Setup Request



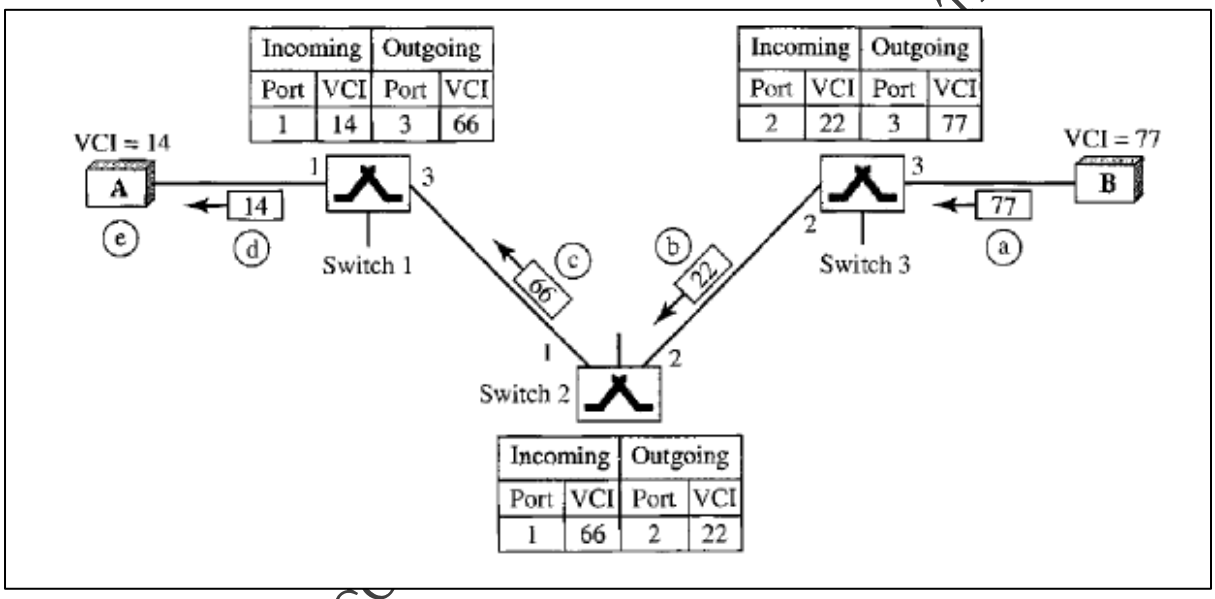
- Source A sends a setup frame to switch 1.
- Switch 1 receives the setup request frame. It knows that a frame going from A to B goes through port 3. The switch assigns incoming port (1) and

chooses an available incoming VCI (14). The switch then forwards the frame through port 3 to switch 2.

- Switch 2 receives the setup request frame. Three columns are completed: the incoming port (1), incoming VCI (66) and outgoing port (2).
- Switch 3 receives the setup request frame. Three columns are completed: the incoming port (2), incoming VCI (22), and outgoing port (3).
- Destination B receives the setup frame and if it is ready to receive frames from A it assigns a VCI to the incoming frames as 77.

Acknowledgement

A special frame called the acknowledgement frame completes the entries in the switching tables.



- The destination sends an acknowledgement to switch 3. The acknowledgement carries the global source and destination address so the switch completes the table entry. The frame also carries VCI 77 as the incoming VCI for frames from A.
- Switch 3 sends an acknowledgement to switch 2 that contains its incoming VCI in the table. Switch 2 uses this as outgoing VCI in the table.
- Switch 2 sends an acknowledgement to switch 1 that contains its incoming VCI in the table. Switch 1 uses this as outgoing VCI in the table.
- Finally switch 1 sends an acknowledgement to source A that contains its incoming VCI in the table.
- The source uses this as the outgoing VCI for the data frames to be sent to destination B.

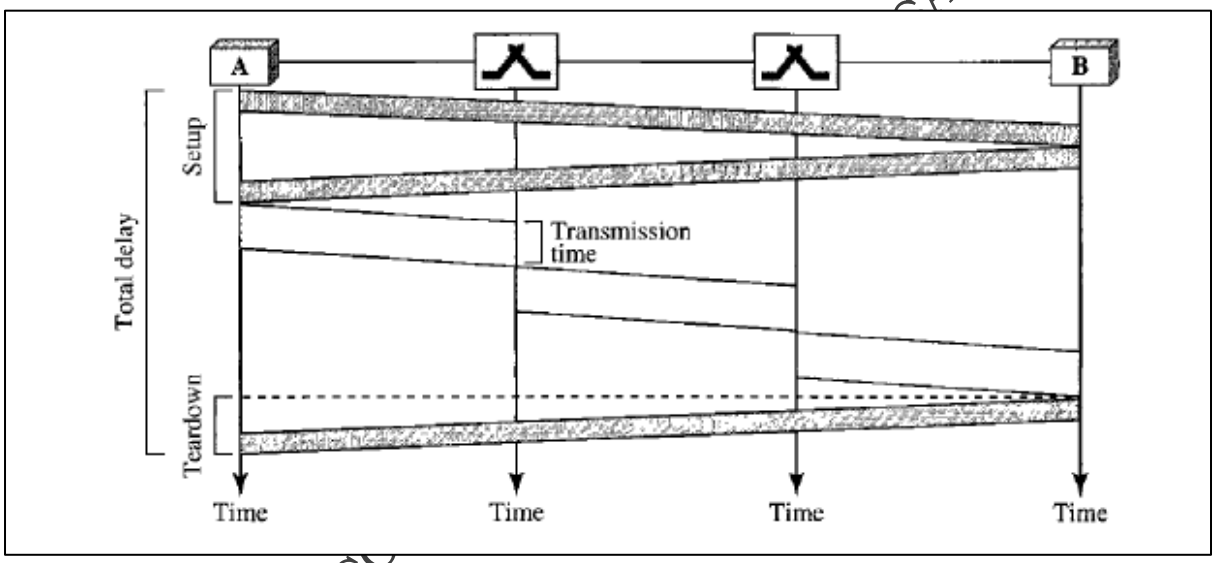
Teardown Phase

- Source A after sending all frames to B, sends a special frame called a teardown request.
- Destination B responds with a teardown confirmation frame.
- All switches delete the corresponding entry from their tables.

Efficiency

- If resource reservation is made during the setup phase the delay for each packet is the same.
- If the resource reservation is made during data transfer phase, the delay is different.

Delay



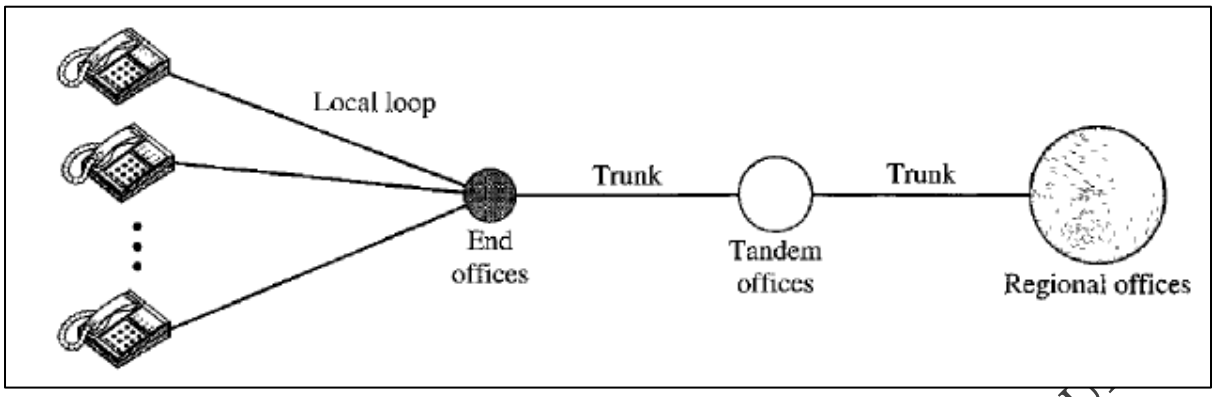
In virtual-circuit network, there is one-time delay for setup and one-time delay for teardown. The packet travels through two switches. There are three transmission times (3T), three propagation delays (3τ), a setup delay and a teardown delay.

Total delay = 3T + 3τ + setup delay + teardown delay

Telephone Network

- Telephone networks use circuit switching.
- It was originally an analog system using analog signals to transmit voice.
- In 1980s the network began to carry data in addition to voice.
- The network now digital as well as analog.

Major Components



The telephone network is made of local loops, trunks and switching offices.

Local loops

It is made of twisted-pair cable that connects the subscriber telephone to the nearest end office or local central office. The first three digits of a telephone number define the office, and the next four digits define the local loop number.

Trunks

Trunks are transmission media that handle communication between offices. Transmission is usually through optical fibers or satellite links.

Switching offices

To avoid permanent physical link between any two subscribers, the telephone company has switches located in a switching office. A switch connects several local loops or trunks and allows a connection between different subscribers.

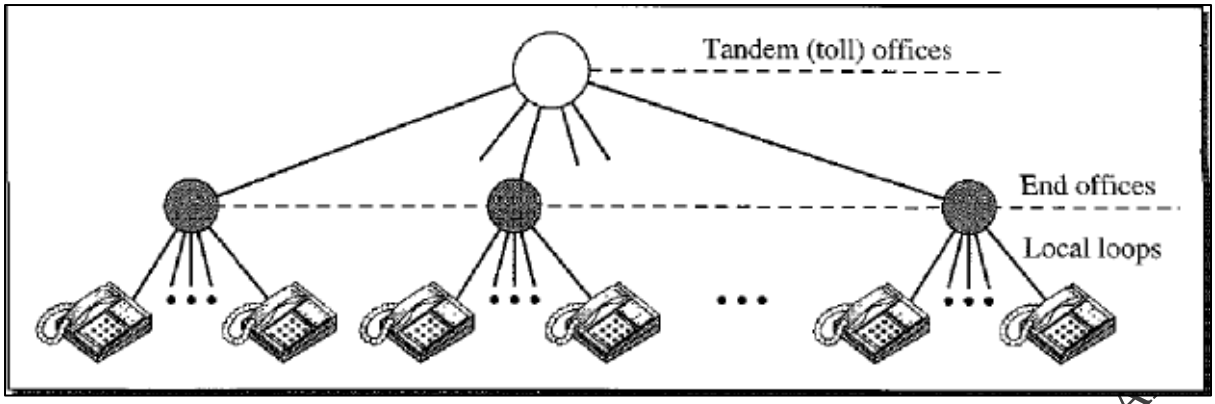
Telephone network has several levels of switching offices such as end offices, tandem offices and regional offices.

LATAs (Local-access transport areas)

A LATA can be a small or large metropolitan area. A LATA boundary may overlap the boundary of a state; part of a LATA can be in one state, part in another state.

Intra-LATA services

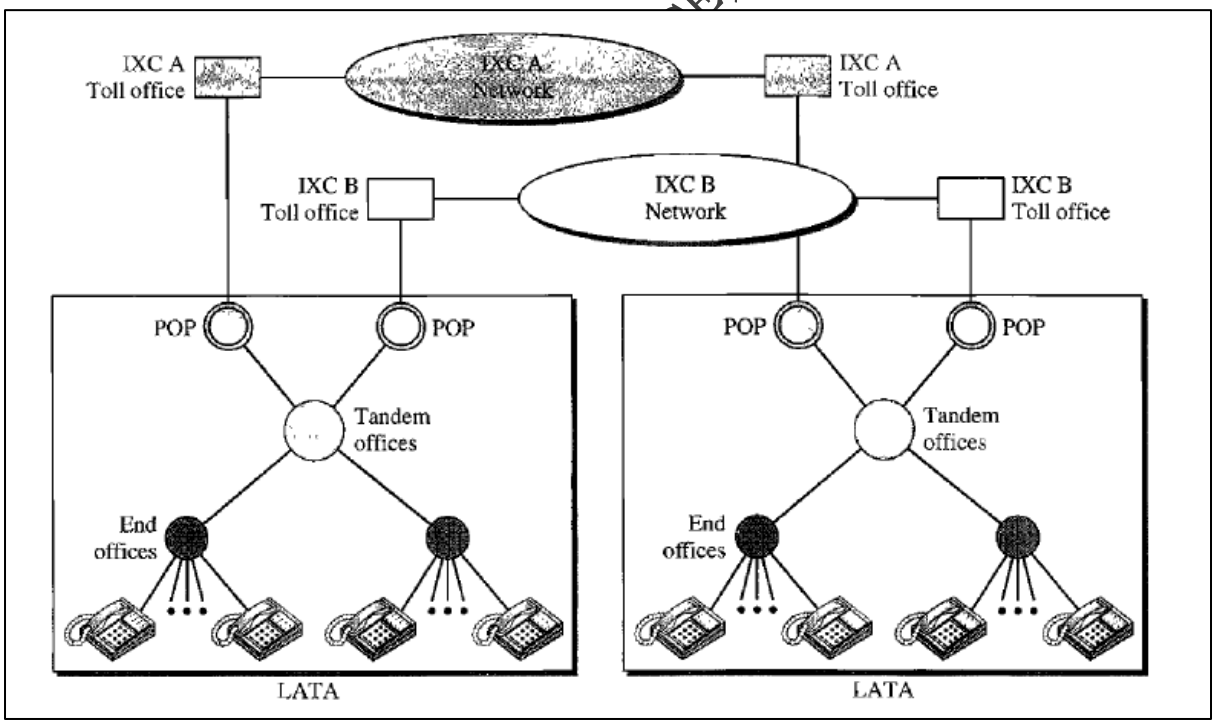
- The services offered by the common carriers inside a LATA are called intra-LATA services.
- The carrier of these services is called local exchange carrier (LEC).
- The carrier that provided services before 1996 is called incumbent local exchange carrier (ILEC).
- New carriers that can provide services are called competitive local exchange carriers (CLECs)



Inter-LATA Services

- The services between LATAs are handled by interchange carriers (IXCs).
- These carriers sometimes called long-distance companies, provide services between two customers in different LATAs.
- Carriers providing inter-LATA services include AT&T, MCI, WorldCom, Sprint and Verizon.

Point of Presence



- Intra-LATA services can be provided by several LECs.
- Inter-LATA services can be provided by several IXCs.
- These carriers interact with one another through a switching office called a point of presence (POP)

- Each IXC that wants to provide inter-LATA services must have a POP in that LATA.
- The LECs that provide services inside the LATA must provide connections so that every subscriber can access to all POPs.
- A subscriber who needs to make a connection with another subscriber is connected first to an end switch and then either directly or through a tandem switch to a POP.
- The call now goes from the POP of an IXC in the source LATA to the POP of the same IXC in the destination LATA.
- The call is passed through the toll office of the IXC and is carried through the network provided by the IXC.

Signaling

- The telephone network used a circuit switched network with dedicated links to transfer voice communication.
- In the beginning this task was done by human operators.
- The operator connects and disconnects the circuit.
- This type of signaling is called in-band signaling because the same circuit is used for both signaling and voice communication.
- Later the signaling system became automatic.
- The switches in the telephone companies used digital signals to create a connection between the caller and the called parties.
- Both in-band and out-band signaling were used.
- In out-band signaling the voice and signaling bandwidth were separate.

The tasks provided by signaling system:

- Providing dial tone, ring tone and busy tone
- Transferring telephone numbers between offices
- Maintaining and monitoring the call
- Keeping billing information
- Maintaining and monitoring the status of the telephone network equipment
- Providing caller ID, voice mail etc.

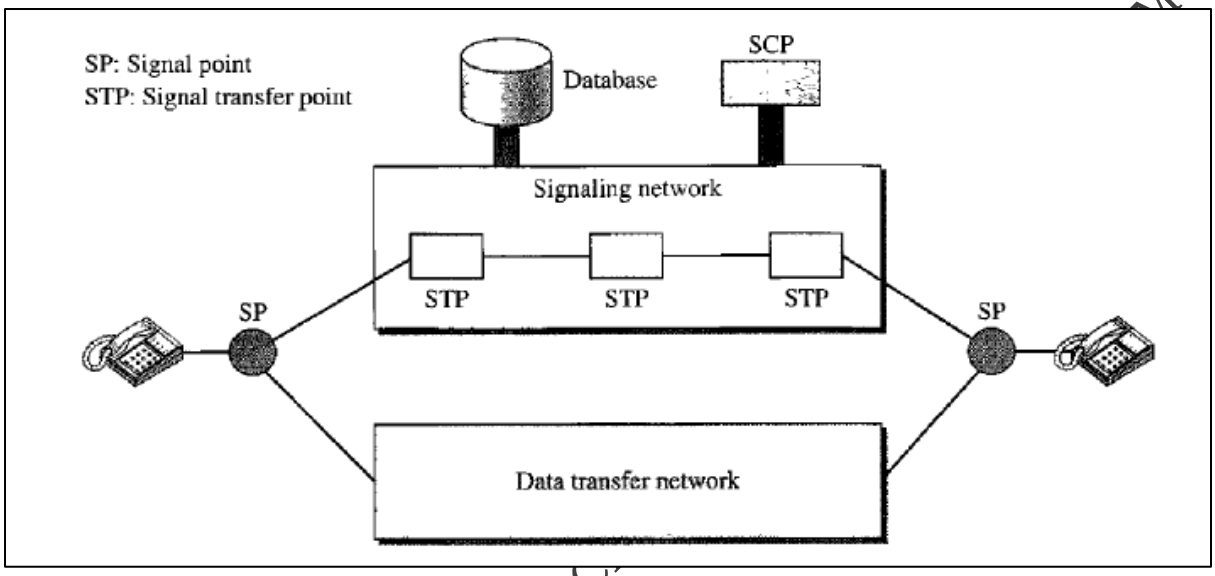
Telephone network today has two networks: signaling network and data transfer network.

Data Transfer Network

- Data transfer network that can carry multimedia information is circuit switched network and also a packet-switched network.

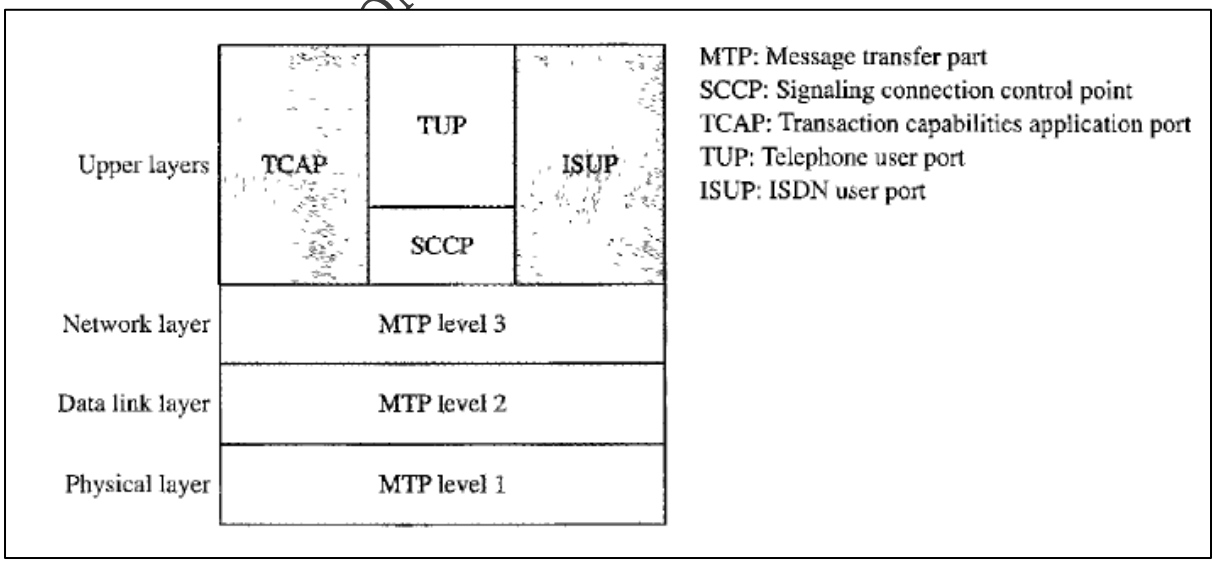
Signaling Network

- It is a packet-switched network involving the layers similar to OSI model.
- The user telephone or computer is connected to the signal points (SPs).
- The signaling network uses nodes called signal transport ports (STPs) that receive and forward signaling messages.
- The signaling network also includes service control point (SCP) that controls the whole operation of the network.



Signaling System Seven (SS7)

The protocol used for signaling network is called Signaling System Seven (SS7).



- Physical Layer: MTP Level 1

It is called message transport part (MTP) level1which has specifications such as T-1(1.544Mbps) and DC0(64kbps)

- Data Link Layer: MTP Level 2

It provides services such as packetizing, using source and destination address in the packet header, and CRC for error checking.

- Network Layer: MTP Level 3

It provides end-to-end connectivity by using the datagram approach to switching. Routers and switches route the signal packets from the source to the destination.

- Transport Layer: SCCP

The signaling connection control point (SCCP) is used for special services such as 800 call processing.

- Upper Layers: TUP, TCAP and ISUP

Telephone user port (TUP) is responsible for setting up voice calls. Transaction capabilities application port (TCAP) provides remote calls. ISDN user port (ISUP) provides services similar to an ISDN network.

Services Provided by Telephone Networks

Telephone companies provide two types of services: analog and digital.

Analog Services

In the beginning they provided their subscribers analog services. These services as either analog switched services or analog leased services.

Analog Switched Services

- The signal on a local loop is analog and the bandwidth is between 0 and 4000 Hz.
- A local call service is provided for a monthly rate. The carrier charges for each call or a set of calls.
- A toll call can be intra-LATA or inter-LATA.
- If the LATA is geographically large, a call may go through a tandem office and the subscriber will pay a fee for the call.
- Another service is called 800 service. If a subscriber needs to provide free connections for other subscribers it can request 800 service.
- Wide-area telephone service (WATS) opposite of 800 service. They are inbound calls paid by the organization. This service is less expensive and charged based on the number of calls.

- The 900 service are inbound calls to a subscriber. The call is paid by the caller and is expensive than a normal long-distance call. It charges two fees: fee for long distance toll and fee paid to the callee for each call.

Analog Leased Service

It offers to lease a line called a dedicated line that is permanently connected to another customer. No dialing is needed.

Digital Services

Digital services are less sensitive to noise and other interference. The two common digital services: switched/5 service and digital data service.

Switched/56 service

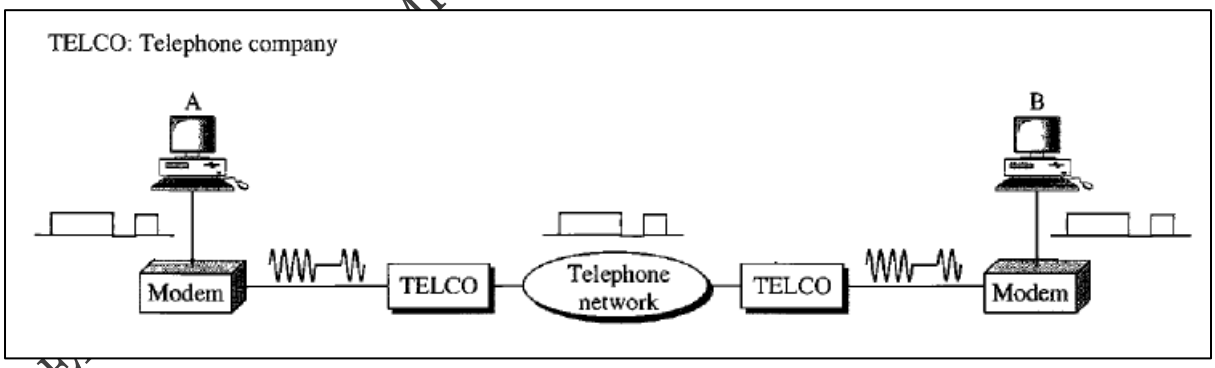
- It is digital service that allows data rates up to 56 kbps.
- To communicate both parties must subscribe.
- Subscribers do not need modem to transmit digital data.
- They need another device called a digital service unit (DSU).

Digital Data Service

It is the digital version of an analog leased line with maximum data rate of 64 kbps.

Dial-Up Modems

The term modem is a word that refers two functional entities: a signal modulator and signal demodulator. A modulator creates a bandpass analog signal from binary data. A demodulator recovers binary data from the modulated signal.

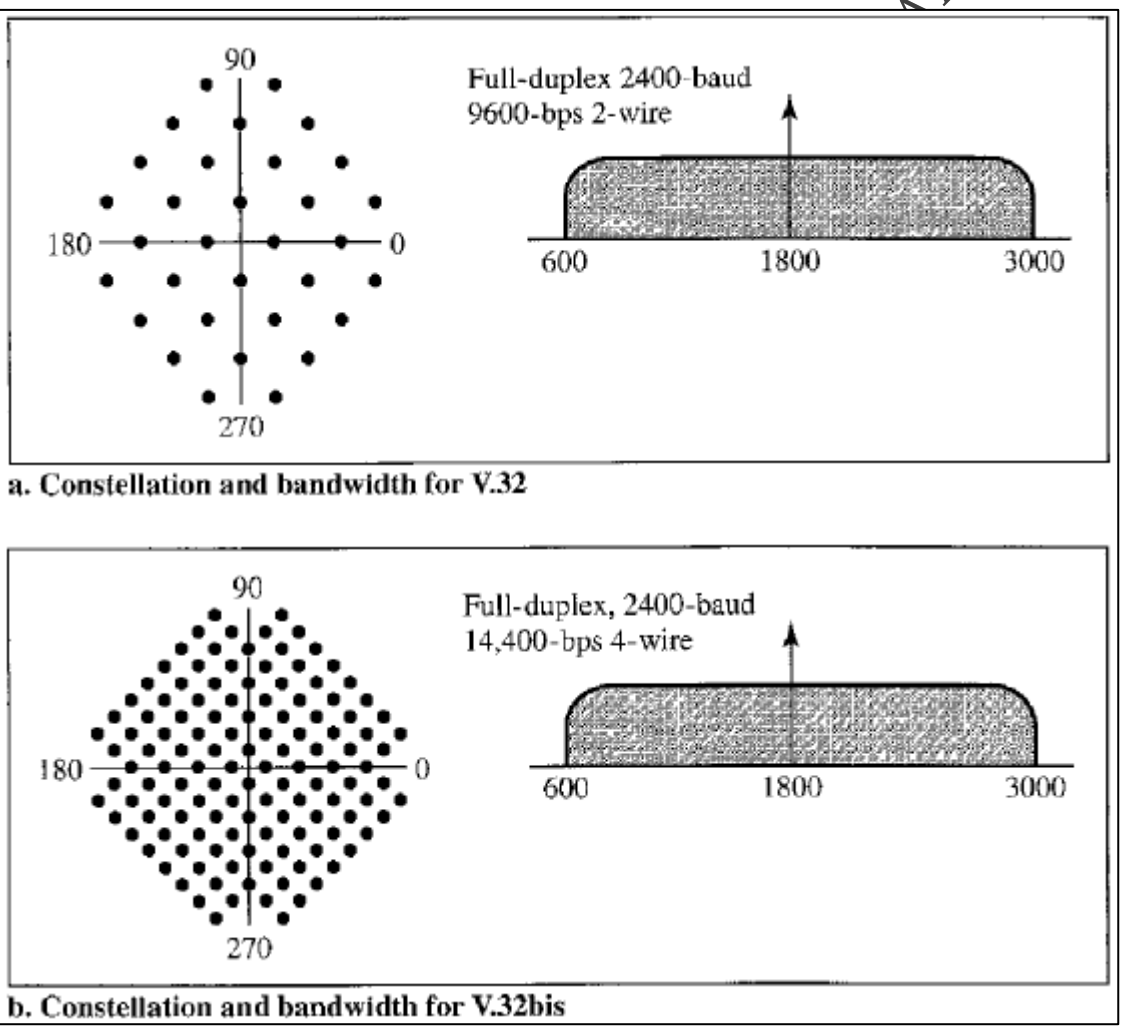


- The computer on the left sends a digital data signal to the modem. The data are sent as analog signal on the telephone lines.
- The modem on the right receives the analog signal, demodulates it through its demodulator and delivers data to the computer.
- The communication can be bidirectional.

Modem Standards

V.32 and V.32 bis

- It uses combined modulation and encoding technique called trellis-coded modulation. It is QAM (Quadrature Amplitude Modulation) plus a redundant bit.
- The data stream is divided into 4-bit (quadbit) sections however a pentabit(5 bit pattern) is transmitted.
- The extra bit is used for error detection.
- The V.32 calls for 32-QAM with a baud rate of 2400.
- The V.32bis modem was the first of the ITU-T standards to support 14,400 bps. It uses 128-QAM transmission at a rate of 2400 baud.



a. Constellation and bandwidth for V.32

b. Constellation and bandwidth for V.32bis

V.34bis

- It provides a bit rate of 28,800 with a 960-point constellation and a bit rate of 33,600 bps with a 1664-point constellation.

V.90

- V.90 modems with a bit rate of 56,000 bps are available and are called 56k modems.
- They are used only if one party is using digital signaling.
- The downloading rate is 56 kbps and uploading rate is 33.6 kbps.
- In uploading the analog signal is sampled at the switching station. Quantization noise is introduced into the signal to reduce the SNR ratio and limits the rate to 33.6 kbps.
- There is no sampling in downloading.

V.92

- The standard above V.90 is called V.92.
- They can adjust their speed and if the noise allows they can upload data at the rate of 48 kbps.
- The downloading rate is 56 kbps.
- The modem can interrupt the Internet connection when there is an incoming call if the line has call-waiting service.

DIGITAL SUBSCRIBER LINE (DSL)

It is one of the technology for supporting high-speed digital communication over existing local loops. It is a set of technologies differing in the first letter ADSL, VDSL, HDSL, SDSL. The set is often referred as xDSL, where x can be replaced by A, V, H and S.

ASDL

- The first technology is asymmetric DSL (ADSL).
- It provides higher speed in the downstream direction than the upstream direction.
- ADSL divides the available bandwidth of the local loop unevenly for the residential customers.

Using Existing Local Loops

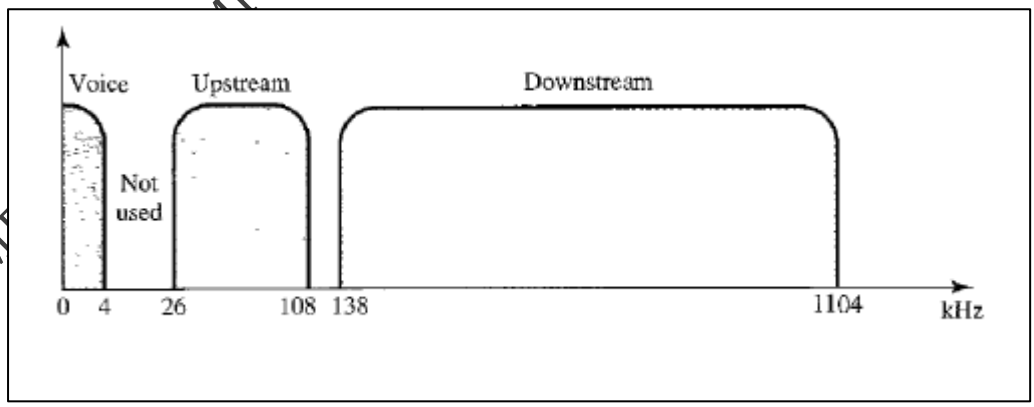
- ADSL uses the existing local loops.
- The twisted-pair local loop is capable of handling bandwidths up to 1.1MHz.
- The filter at the end office of the telephone company limits the bandwidth to 4kHz.
- If the filter is removed, the entire bandwidth is available for data and voice communication.

Adaptive technology

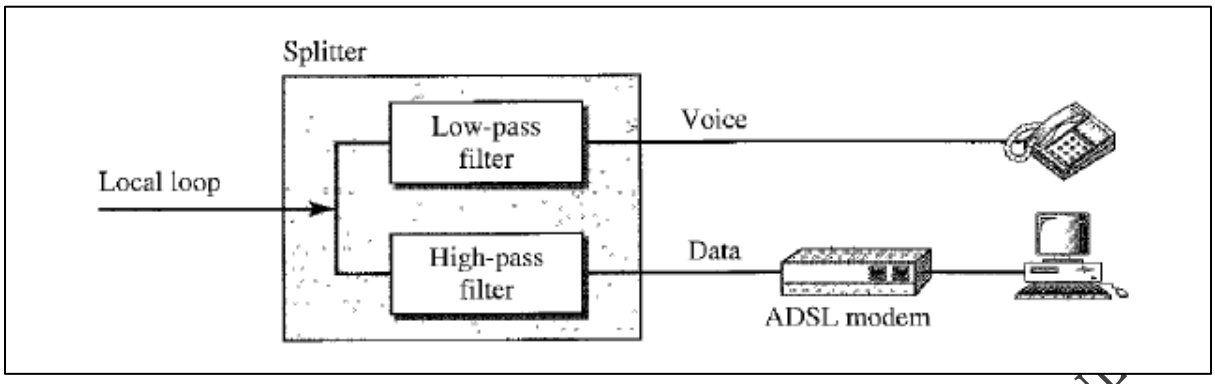
- Factors such as distance, the size of the cable, the signaling used affect the bandwidth.
- The designers used adaptive technology that tests the condition and bandwidth availability of the line.
- The data rate of ADSL is not fixed, it changes based on the type of the local loop cable.

Discrete Multitone Technique

- The modulation technique for ADSL is called Discrete Multitone Technique which combines QAM and FDM.
- Available bandwidth 1.104MHz is divided into 256 channels.
- Each channel uses a bandwidth 4.312 kHz.
- Voice: Channel 0 is reserved for voice communication.
- Idle: Channels 1 to 5 are not used
- Upstream data and control: channels 6 to 30 are used for upstream data transfer and control. One channel is for control and 24 channels for data transfer. Each channel using 4 kHz with QAM modulation has 1.44 Mbps bandwidth in upstream direction.
- Downstream data and control: channels 31 to 255 are used for downstream data transfer and control. One channel is for control and 224 channels for data transfer. Bandwidth is 13.4 Mbps

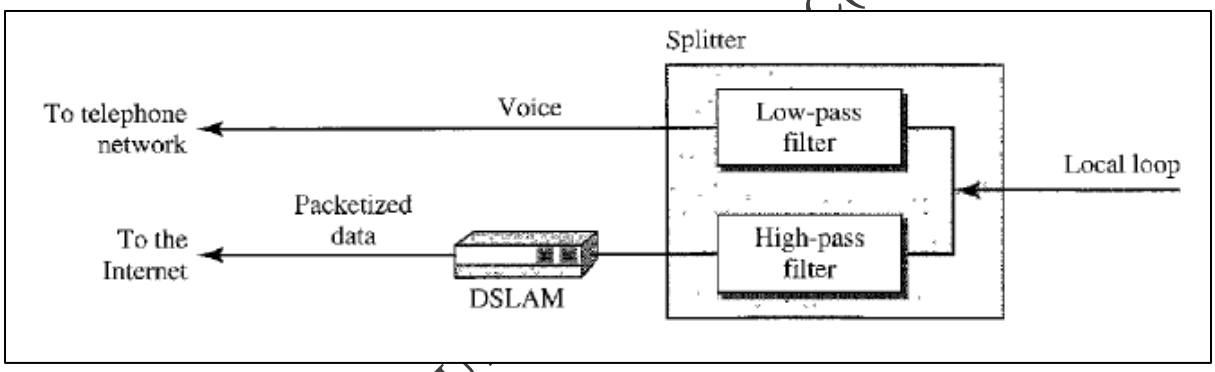


Customer Site: ADSL Modem



- The local loop connects to a splitter which separates voice and data communication.
- ADSL modem modulates and demodulates the data using DMT and create downstream and upstream channels.

Telephone Company Site: DSLAM



- At the telephone company site a device called Digital Subscriber Line Access Multiplexer (DSLAM) is installed.
- It packetizes the data to be sent to the Internet.

ADSL Lite

- This technology allows modem to be plugged directly into a telephone jack and connected to the computer.
- The splitting is done at the telephone company.
- ADSL Lite uses 256 DMT carriers with 8-bit modulation.
- It can provide downstream data rate of 1.5 Mbps and an upstream data rate of 512 kbps.

HDSL

- The High-bit-rate Digital subscriber line (HDSL) was an alternative to T-1 line.
- T-1 line uses AMI encoding which is subject to attenuation at high frequencies.

- The length of T-1 line is 3200 ft. for longer distances a repeater is used.
- HDSL uses 2B1Q encoding which is less subject to attenuation.
- A data rate of 1.544 Mbps can be achieved without using repeaters up to a distance of 12,000 ft.
- HDSL uses two twisted pairs to achieve full-duplex transmission.

SDSL

- The symmetric digital subscriber line (SDSL) is a one twisted-pair version of HDSL.
- It provides full-duplex communication up to 768 kbps in each direction.
- It is considered as an alternate to ADSL.
- It is used by residential subscribers and not suitable for businesses because it does not send and receive data in large volumes.

VDSL

- The very high-bit-rate digital subscriber line (VDSL) uses coaxial, fiber-optic or twisted-pair cable for short distances.
- The modulating technique is DMT.
- It provides 25 to 55Mbps for upstream communication and downstream at 3.2Mbps

Technology	*Downstream Rate*	*Upstream Rate*	*Distance (ft)*	*Twisted Pairs*	*Line Code*
ADSL	1.5–6.1 Mbps	16–640 kbps	12,000	1	DMT
ADSL Lite	1.5 Mbps	500 kbps	18,000	1	DMT
HDSL	1.5–2.0 Mbps	1.5–2.0 Mbps	12,000	2	2B1Q
SDSL	768 kbps	768 kbps	12,000	1	2B1Q
VDSL	25–55 Mbps	3.2 Mbps	3000–10,000	1	DMT

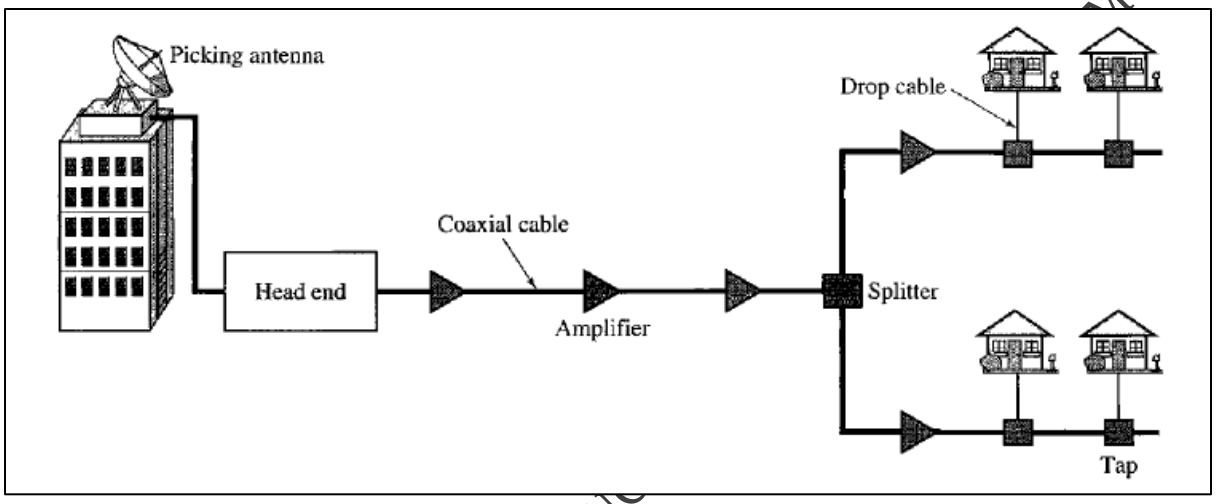
Cable TV Networks

The cable TV network started as a video service provider but it has moved to Internet access.

Traditional Cable Networks

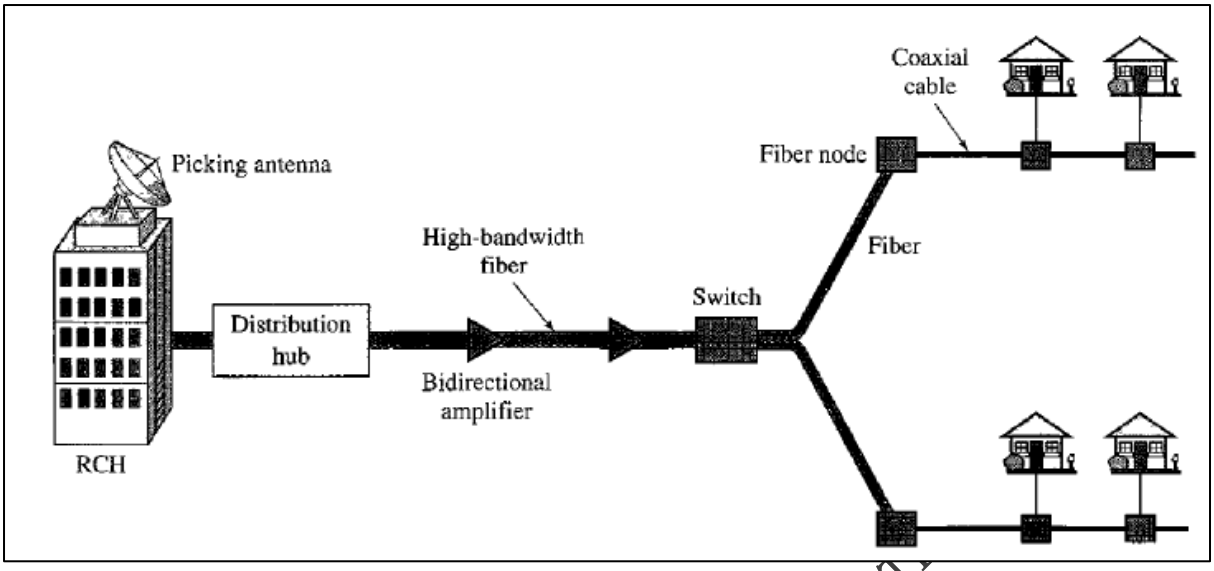
- Cable TV started to broadcast video signals to location in 1940s was called community antenna TV (CATV).
- It has antenna at the top of a tall hill or building received signals from the TV stations and distributed through coaxial cables to the community.
- The cable TV office called head end receives video signals from broadcasting stations and feeds signals into coaxial cables.

- The signals became weaker with distance, so amplifiers are installed.
- There could be up to 35 amplifiers between head end and subscriber premises.
- At the other end splitters split the cable, taps and drop cables make connections to the subscriber premises.
- The communication is unidirectional. Videos were transmitted downstream from the head end to the subscriber premises.



Hybrid Fiber-Coaxial (HFC) Network

- It is the second generation of cable networks.
- It uses a combination of fiber-optic and coaxial cable.
- The transmission medium from the cable TV office to a box called fiber node, is optical fiber.
- From the fiber node through the neighborhood and into the house is coaxial cable.
- The regional cable head (RCH) normally serves 4 lakh subscribers.
- The RCH feed the distribution hubs each of which serves up to 40,000 subscribers.
- Modulation and distribution of signals are done here.
- The signals are fed to fiber nodes through fiber-optic cables.
- The fiber node splits the analog signal and sent to each coaxial cable.
- Each coaxial cable serves up to 1000 subscribers.
- Fiber-optic cables reduces the need for amplifiers to eight.
- The cable network is bidirectional.

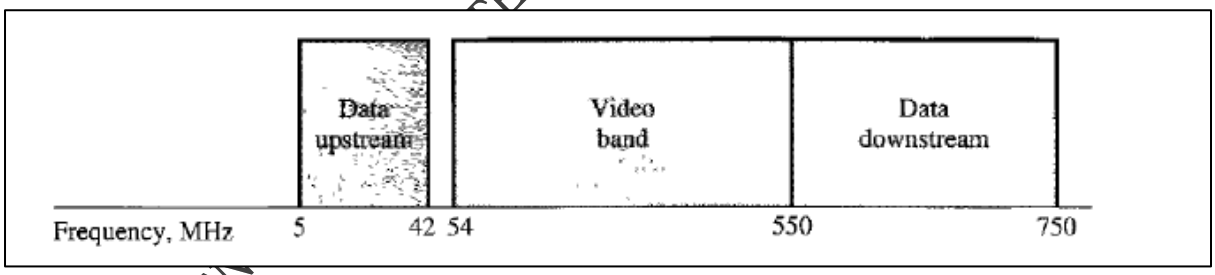


Cable TV for Data Transfer

Cable companies are competing with telephone companies for the residential subscribers over local loop. DSL uses unshielded twisted-pair cable which is subject to interference. It imposes an upper limit on the data rate. The solution is the use of cable TV network.

Bandwidth

To provide Internet access, the cable company has divided the bandwidth into three bands: video, downstream data, and upstream data.



Downstream Video Band

The downstream video band occupies frequencies from 54 to 550MHz. It can accommodate more than 80 channels each with 6MHz.

Downstream Data Band

The downstream data occupies upper band from 550 to 750MHz. it is also divided into 6MHz channels.

- Modulation – uses 64-QAM modulation technique.
- Data rate – there is 6 bits/baud in 64-QAM. One bit is used for forward error correction. The standard specifies 1Hz for each baud, which means downstream data can be received at 30 Mbps.

Upstream Data Band

The upstream data occupies the lower band from 5 to 42MHz. this band also divided into 6MHz channels.

- Modulation – uses QPSK modulation technique.
- Data rate – There are 2 bits/baud in QPSK. The standard specifies 1Hz for each baud, which means upstream data can be sent at 12 Mbps.

Sharing

Upstream sharing

The upstream data bandwidth is 37MHz. There are only six 6-MHz channels available in the upstream direction. It can be shared using timesharing. The band is divided into channels using FDM.

Downstream sharing

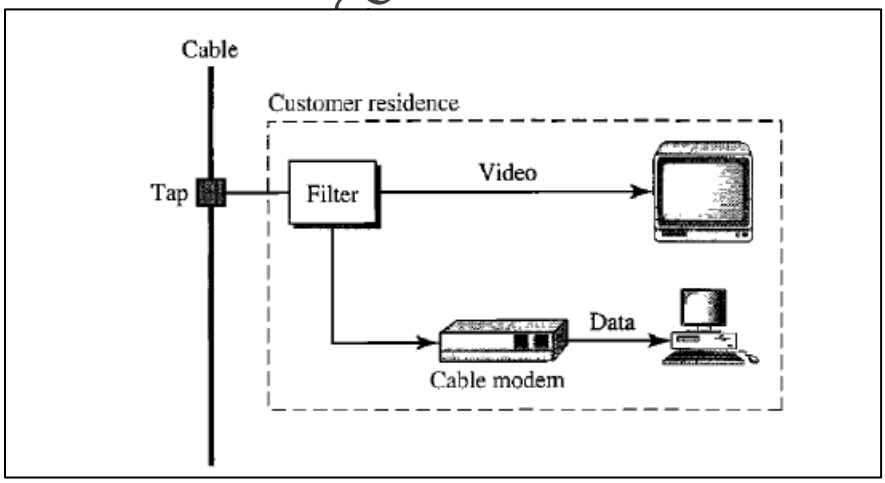
The downstream band has 33 channels of 6MHz. the channels are shared by multicasting. Each subscriber is sent the data. Each subscriber has an address, the cable modem carries the data to the address assigned. If the address matches, the data are kept otherwise they are discarded.

CM and CMTS

To use a cable network for data transmission we need two devices: cable modem (CM) and cable mode transmission system (CMTS).

CM

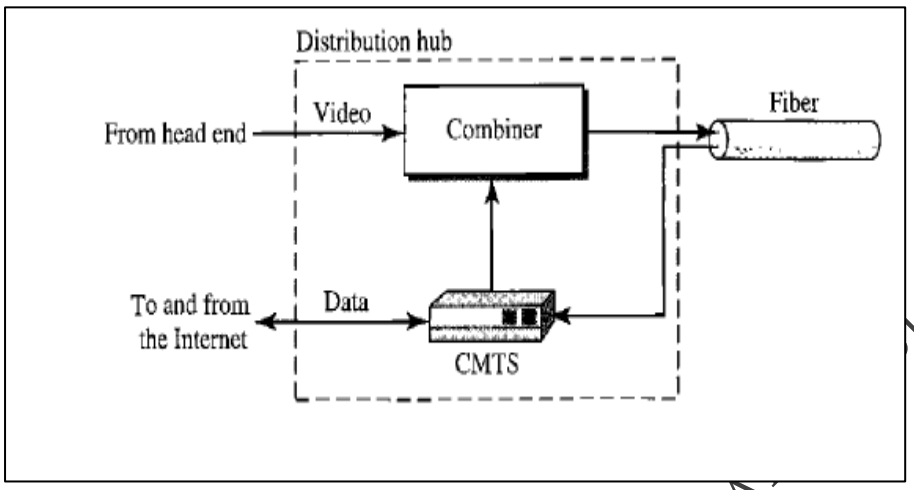
The cable modem (CM) is installed on the subscriber premises. It is similar to ADSL.



CMTS

The cable modem transmission system (CMTS) is installed inside the distribution hub by the cable company. It receives data from the Internet and

passes them to the combiner, which sends them to the subscriber. The CMTS also receives data from the subscriber and passes to the Internet.



Data Transmission Schemes: DOCSIS

Data Over Cable System Interface Specification (DOCSIS) defines all the protocols necessary to transport data from CMTS to a CM.

Upstream Communication

- The CM checks the downstream channels for a specific packet sent by the CMTS.
- The CMTS sends a packet to the CM, defining its allocated downstream and upstream channels.
- The CM then starts a process called ranging which determines the distance between CM and CMTS.
- The CM sends a packet to ISP asking for Internet address.
- The CM and CMTS then exchange some packets to establish security parameters which are needed for public network.
- The CM sends its unique identifier to CMTS.
- Upstream communication can start in the upstream channel. CM contend for minislots to send data.

Downstream Communication

There is no conflict because there is only one sender. The CMTS sends the packet with the address of the receiving CM, using the allocated downstream channel.