Multimedia communications

1.1 Introduction:

- Multimedia indicates that the information/data being transferred over the network may be composed of one or more of the following types: Text, images, audio and video.

- Applications:
  - person-to-person communications (e.g. email)
  - person-to-system communications (e.g. web-browsing)

- In this chapter, we'll talk about
  - How the different media types are represented.
  - Different types of network that are used to provide multimedia communication services
  - A selection of the applications that these networks support
  - Meaning of a range of terms that are associated with multimedia communications.

1.2 Multimedia information representation

- Form of representation
  - In applications that involve just a single type of media, the basic form of representation of the particular media type is required.
  - Otherwise, different media types should be integrated together in a digital form.

- In applications involving text and images:
  - It comprise blocks of digital data each of which is represented by a fixed bit pattern known as *codeword*.
  - The duration of the overall transaction is relatively short.
  - No streaming is required.

- In applications involving audio & video:
  - The signals vary continuously with time.
  - The duration of application can be relatively long.
  - Streaming is required.
  - The amount of data used to represent the signal is measured in *bits per second* (bps).

- Compression is generally applied to digitized signals to reduce (i) the resulting bit rate to a level a network can support and (ii) the time delay between a request being made for some information and the information becoming available.

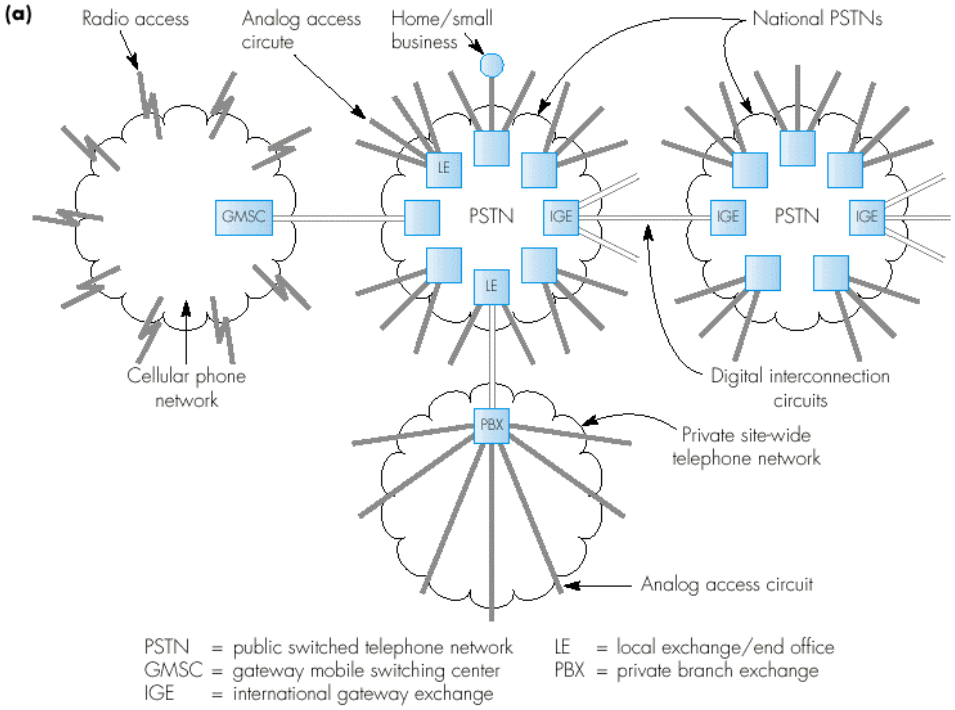
1.3 Multimedia networks

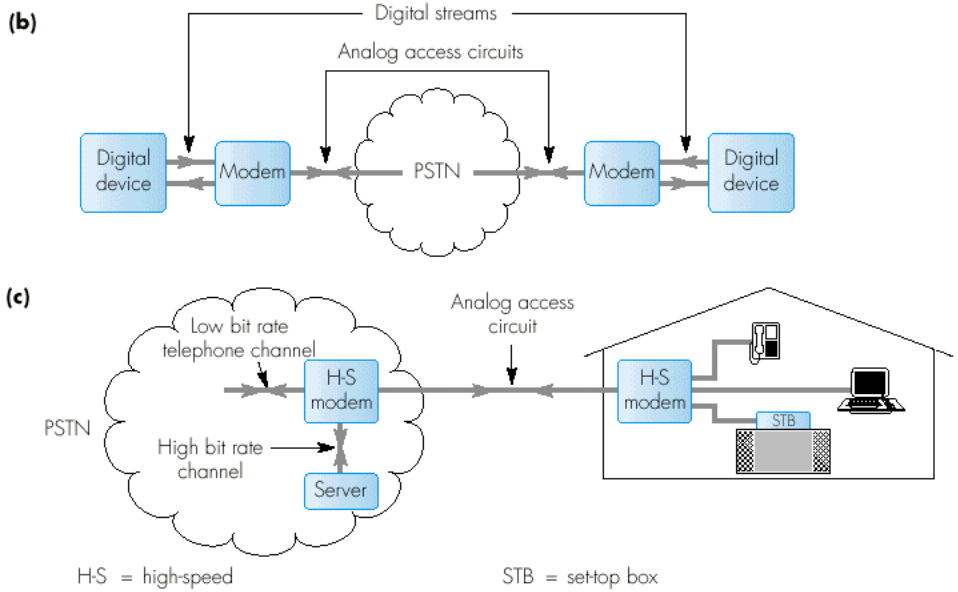
- There are 5 types of communication network that are used to provide multimedia communication services:
  - Telephone networks
  - Data networks
  - Broadcast television networks
  - Integrated services digital networks (ISDN)
  - Broadband multuiservice networks
- Characteristics:
  - The first 3 types were initially designed to provide just a single type of service.
  - The last 2 types were designed to provide multiple services.

1.3.1 telephone networks

- Designed to provide a basic switched telephone service.
- 'Switched' means that a subscriber can make a call to any other telephone that is connected to the total network.

Fig. 1.1 Telephone networks:
(a) network components;
(b) digital transmission using modems;
(c) multiple services via an H-S modem



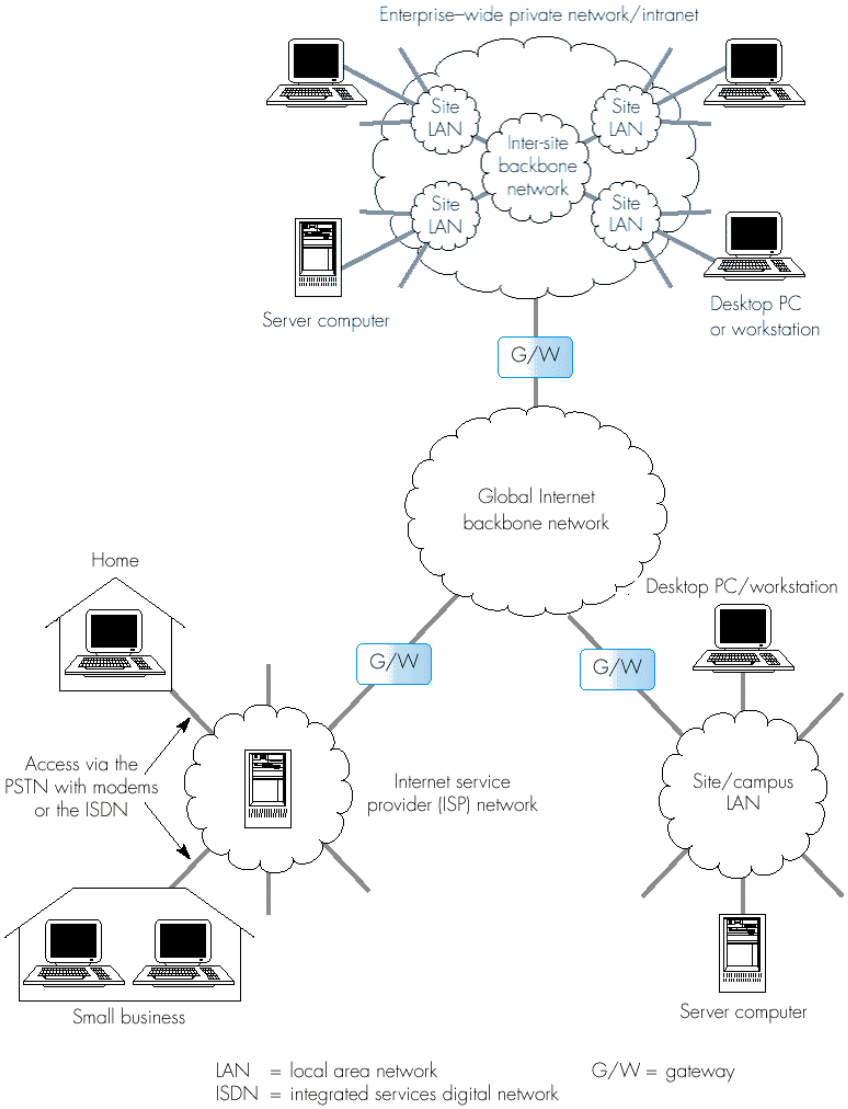


- Telephone networks operate in *circuit mode*.
- For each call, a separate circuit is set up through the network for the duration of the call.
- The *access circuits* that link the telephone handsets to a PSTN or PBX were designed to carry the 2-way analog signals associated with a call.
- Though modern PSTNs operate in a digital mode, a modem is used to carry a digital signal over the analog access circuits.

1.3.2 data networks

- It's designed to provide basic data communication services such as email and general file transfer.
- Two most widely deployed networks of this type are the X.25 network and the Internet.
- The X.25 network is restricted to relatively low bit rate data applications only.
- The Internet is made up of a vast collection of interconnected networks all of which operate using the same set of *communication protocols*.
- Communication protocol
  - is an agreed set of rules that are adhered to by all communication parties for the exchange of information.
  - defines (i) the sequence of messages for the exchange of information and (ii) the syntax of these messages.
- A user may access to the Internet through an intermediate *Internet service provider* (ISP) network.

Figure 1.2 A selection of the network types connected to the Internet.

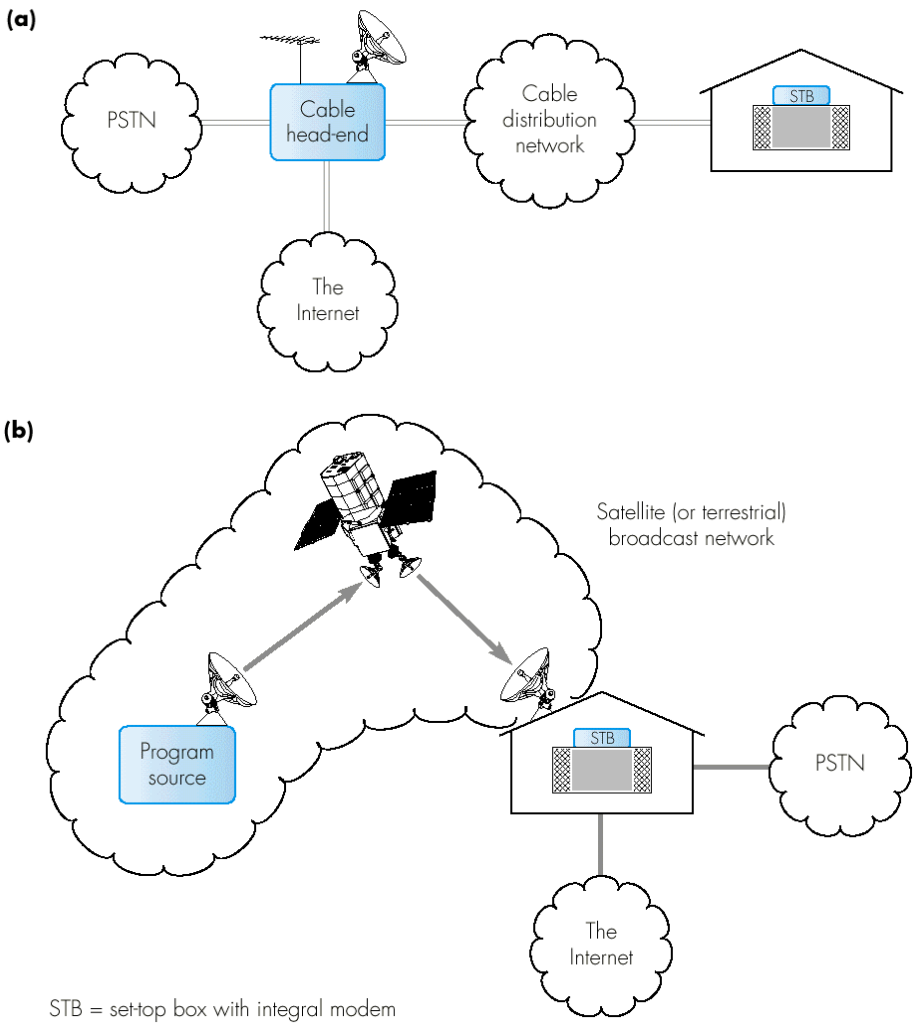


- A network is called *intranet* if all internal services are provided using the same set of communication protocols.
- Different types of network are connected to the Internet backbone network through an internetworking unit called a *gateway*.
- A *gateway* is also known as a *router* as it is responsible for routing and relaying all messages to and from the connected networks.
- All data networks operate in *packet mode*.
- A *packet* is a container for a block of data and the information for routing the packet to the destination through the network.
- This mode is used because the format of the data associated with data applications is normally in the form of discrete blocks of text or binary data with varying time intervals between each block.

1.3.3 Broadcast television networks

- designed to support the diffusion of analog television (and radio) programs throughout wide geographical areas.
- Broadcast media include
  - Cable distribution network : for a town or city
  - Satellite network : for larger areas
  - Terrestrial broadcast network : for larger areas
- The traffic is 1-way or asymmetric.
- It generally works with a low bit rate return channel offered by a cable network for interaction purposes to provide a range of additional services such as home shopping and games playing.
- The subscriber accesses the cable distribution network through a *set-top box*.

Figure 1.3 Broadcast television networks: (a) cable networks; (b) satellite/terrestrial broadcast networks.



1.3.4 Integrated services digital networks

- Designed to provide PSTN users with the capability of having additional services.
- This was achieved by
  (i) converting the access circuits that connect user equipment to the network into an all-digital form, and
  (ii) providing 2 separate communication channels over these circuits.
- This all-digital access circuit is known as a *digital subscriber line* (DSL)
- The digitization of a toll-quality analog speech produces a constant bit rate bitstream of 64kbps. (64kbps is hence used as a basic unit.)
- Options of service:
  - *Basic rate access*(BRA) : supports 2 independent 64kbps channels or 1 128kbps channel (with an aggregation unit to synchronize 2 64kbps channels)
  - *Primary rate access* (PRA) : supports 1 1.5/2.0Mbps channel
  - It can also support a single switched channel of px64kbps, where p=1,2...30.

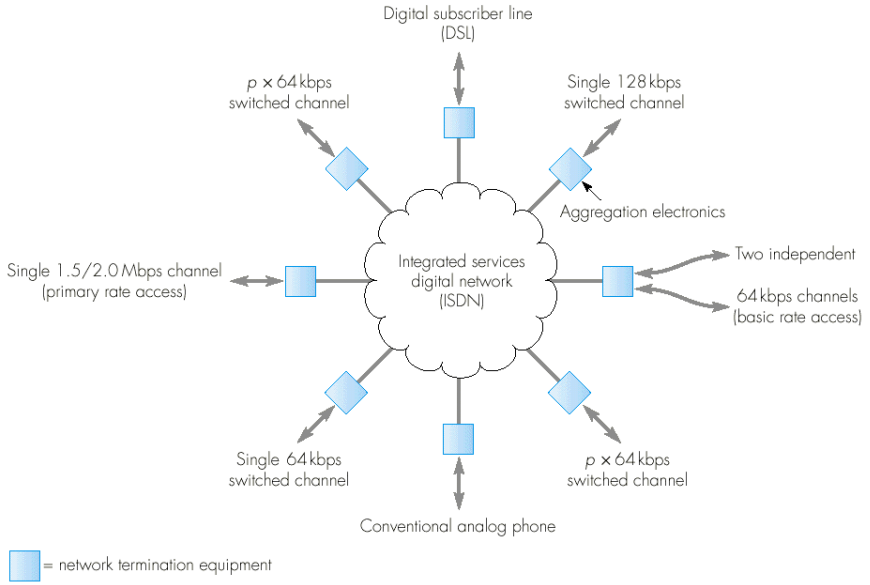


Fig 1.4 Alternative services provided by an ISDN

1.3.5 Broadband multiservice networks

- Designed in mid-80s for use as public switched networks to support a wide range of multimedia communication applications.
- "*Broadband*" means it can support a bit rate higher than that an ISDN can support (>2Mbps).
- This type of network is also known as *broadband ISDN* (B-ISDN) while ISDN is known as *narrowband ISDN* (N-ISDN).
- Switching and transmission methods that are used in these networks must be more flexible as they are designed to support multiple services.

- All media types are converted into digital form and integrated together, and the resulting stream is divided into fixed-sized packets known as *cells*.
- Switching fixed-sized cells can be carried out much faster than switching variable-length packets.
- Different multimedia applications generate cell streams of different rates and hence the rate of transfer of cells through the network varies. This mode of transmission is known as *asynchronous transfer mode* (ATM).
- This type of network is also known as *ATM network* or *cell-switching network*.

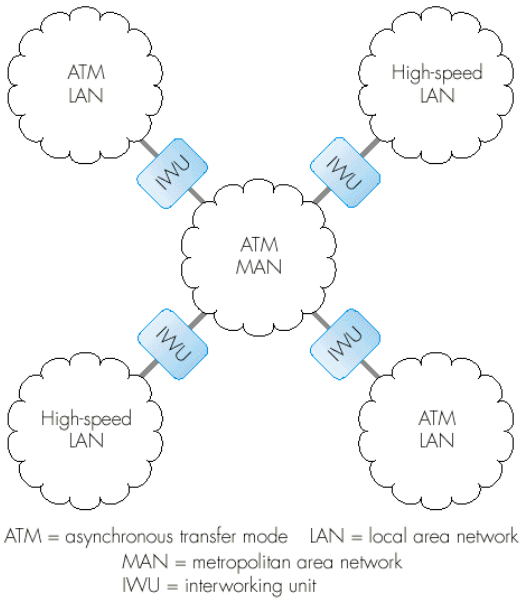


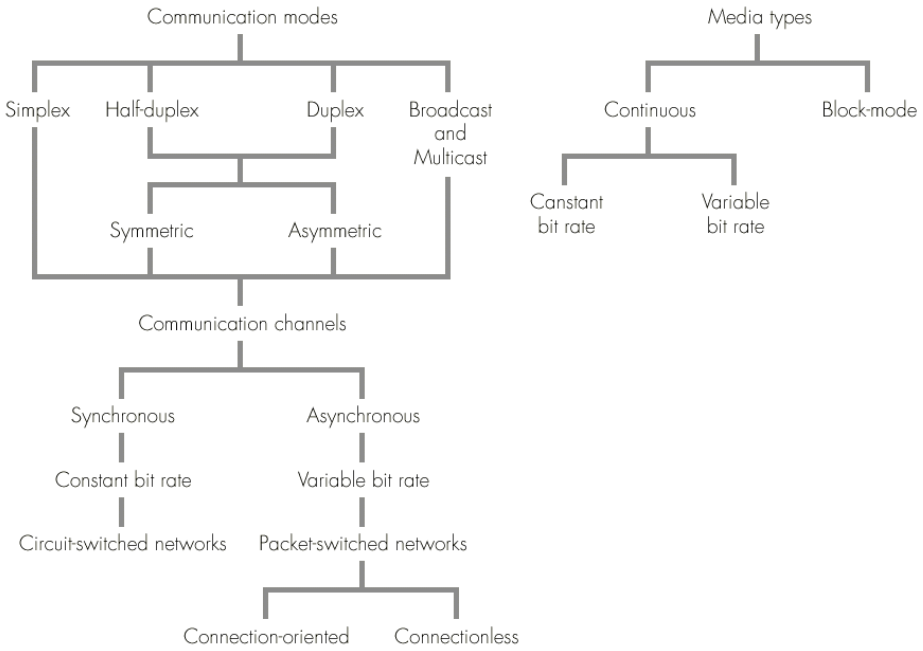
Fig 1.5 Example of an ATM boardband multiservice network

1.4 Multimedia application

Category	Media	Application descriptions
Interpersonal communications	Speech	Telephony, voice-mail, teleconferencing
	Image	Facsimile
	Text	Electronic mail
	Text and images	Computer-supported cooperative working
	Speech and video	Video telephoney, video mail, videoconferencing
	Text, image, audio and video	Multimedia electronic mail, multiparty video games etc.
Interactive applications over the Internet	Text, image, audio and video	Information retrievaal (news, weather, books, magazines, video games, product literature etc.) Electronic commerce
Entertainment services	Text, image, audio and video	Audio/CD-on-demand
		Movie/video-on-demand
		Analog and digital television broadcasts
		Interactive television

1.5 Application and network terminology

Fig. 1.17 A selection of the terms used with multimedia



- We review
  - some of the terminology used in relation to the different media types and
  - the terminology and operational characteristics of the different type of communication channels provided by different networks.

1.5.1 Media types

- The information flow associated with the different applications can be either continuous or block mode.

- In the case of continuous media:
  - Mode of operation : *streaming*
  - The information stream is generated by the source continuously in a timely-dependent way and played out directly as it is received at the destination.
  - e.g. audio, video
  - The continuous media is called *real-time media* as it's generated in a time-dependent way.
  - The source stream can be generated at a constant bit rate (CBR) or a variable bit rate (VBR).

- In the case of block-mode media:
  - Mode of operation: *downloading*
  - The source information comprises a single block of information that is created in a time-independent way.
  - E.g. text, image
  - The delay between the request being made and the contents of the block being outputted at the destination is called *round-trip delay*. (should be <few seconds)

1.5.2 communication modes

- The transfer of the information streams associated with an application can be 1 of the 5 modes:
  - Simplex: 1 direction only
  - Half-duplex: flows in both directions but alternately
  - Full-duplex: flows in both directions simultaneously (1-to-1 transmission)
  - Broadcast: 1-to-all transmission
  - Multicast: 1-to-many transmission

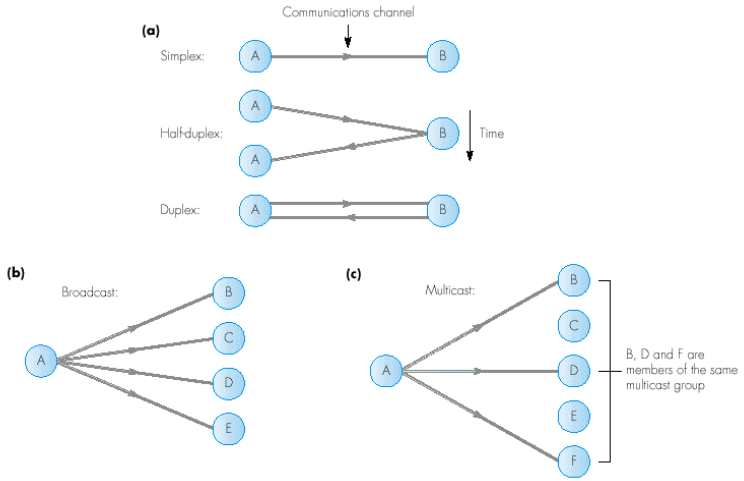


Fig. 1.18 Communication modes: (a) unicast; (b) broadcast; (c) multicast.

- In duplex communications, if the flows in the 2 directions are equal, the information flow is *symmetric*. Otherwise, it's *asymmetric*.

1.5.3 Network types

- There are 2 types of communications channel associated with the various network types: *circuit-mode & packet-mode*.
- Channels in circuit-mode:
  - Operates in a time-dependent way
  - Also known as a *synchronous communications channel* since it provides a constant bit rate service.
- Channels in packet-mode:
  - Operates in a time-varying way
  - Also known as an *asynchronous communications channel* since it provides a variable bit rate service.

<u>Circuit-mode:</u>

- This type of network is also known as a *circuit-switched network*.
- A circuit-mode network comprises an interconnected set of switching offices/exchanges to which the subscribers/computers are connected.
- Prior to sending any information, the source must first set up a connection through the network.
- The bit rate associated with the connection is fixed.
- The messages associated with the setting up and clearing of a connection are known as *signaling messages*.
- There is a call/connection setup delay.

- Examples: PSTN and ISDN

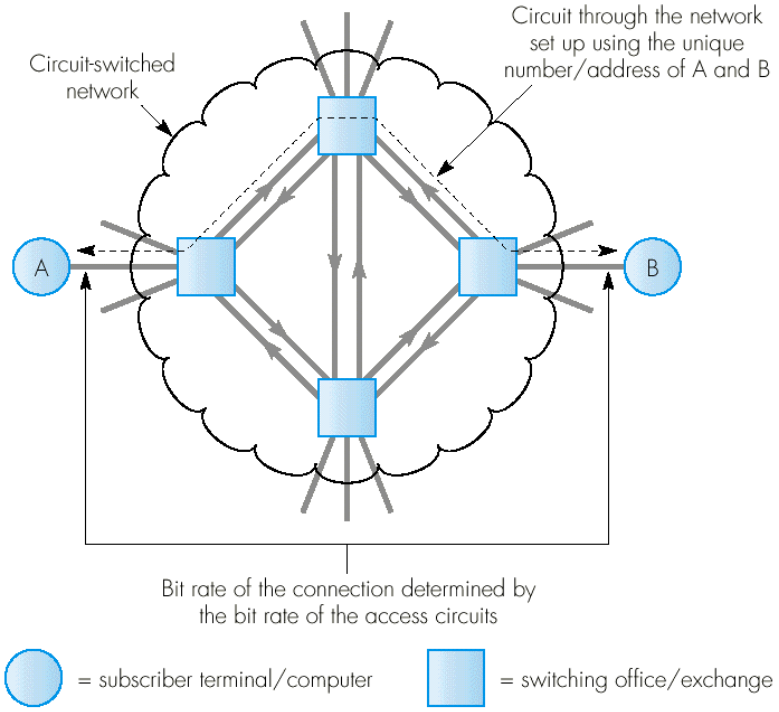


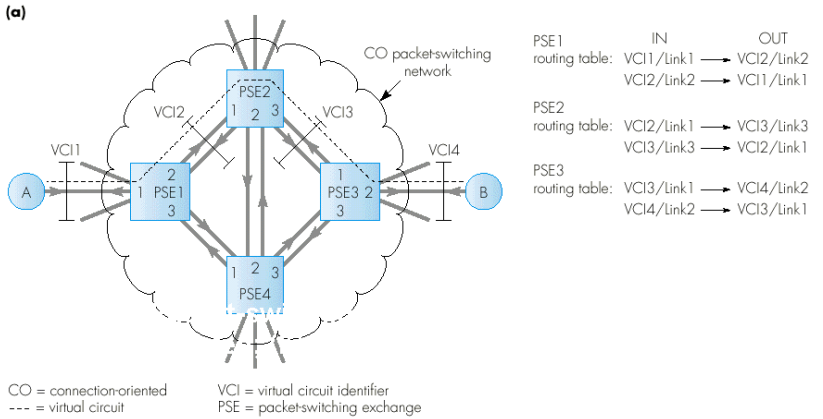
Fig 1.19 Circuit-switched network schematic

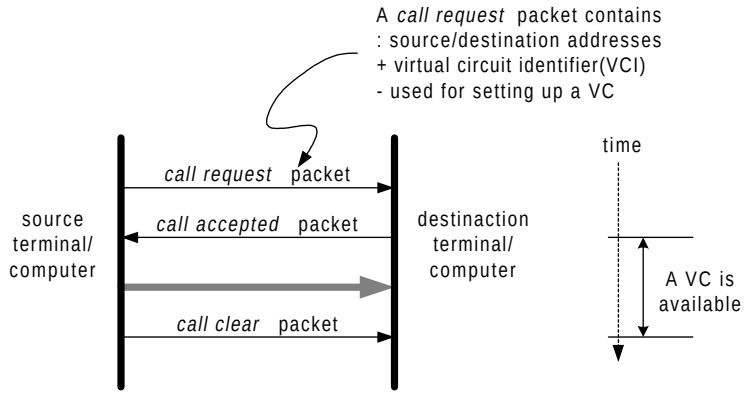
Packet-mode:

- There are 2 types of packet-mode networks: connection-oriented (CO) and connectionless (CL)
- This type of network is also known as a *packet-switched network*.

- A connection-oriented network:
  - A connection-oriented network comprises an interconnected set of *packet-switching exchanges* (PSEs).
  - Prior to sending any information, a connection is first set up through the network.
  - The connection utilizes only a variable portion of the bandwidth of each link and hence it's known as a virtual connection or a *virtual circuit* (VC).

Fig 1.20 Packet-switching network principles : (a) connection-oriented; (b) connectionless.



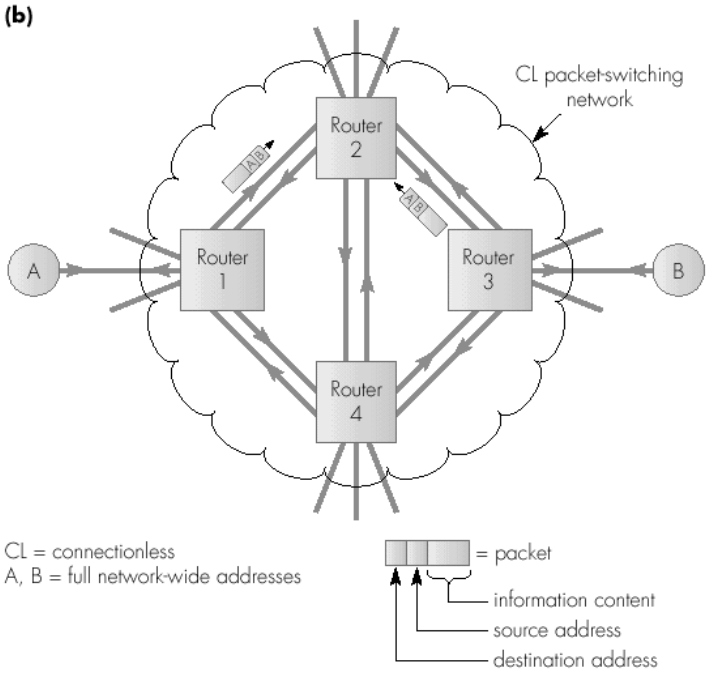


How to set up a VC

- Each PSE has a *routing table* which defines a packet coming from which input link will be delivered to which output link.
- Examples: X.25, ATM network

- Connectionless network:
  - The establishment of a connection is not required and the two communicating terminals/computers can communicate and exchange information as and when they wish.
  - Each packet must carry the full source and destination addresses in its header in order for each PSE to route the packet onto the appropriate outgoing link.
  - The term router is normally used rather than PSE.

- Example: Internet



- Basic mode of operation (Common to PS networks):
  - When a packet is forwarded to a PSE/router, it's stored in a buffer, checked, discarded if there is any problem (due to congestion or error), or else forwarded to next PSE/router if the outgoing link is available.
  - Each PSE/router has a routing table and it's used to determine the outgoing link to which a packet from a particular incoming link should forward.

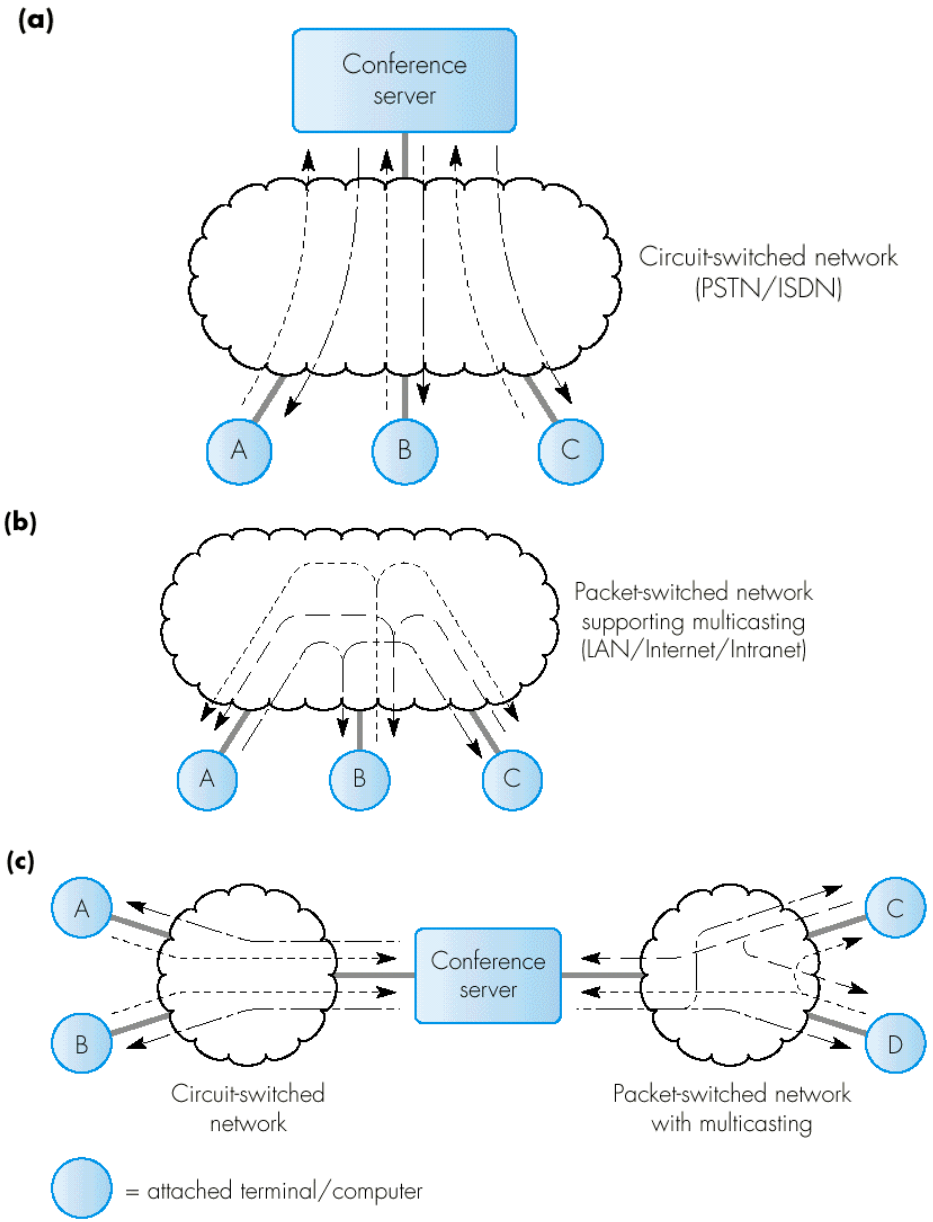
- This mode of operation is called *store-and-forward* as a packet has to wait in a PSE/router until the outgoing link is available.

- The service offered by a packet-switched network is said to be a *best-effort service* as the transmission of a packet is not guaranteed to be successful.
- *Mean packet transfer delay*: The mean of overall transfer delay of a packet across the network
- *Delay variation* or *jitter* : the variation about the mean packet transfer delay

1.5.4 Multipoint conferencing

- It's implemented in one of the 2 ways: centralized and decentralized.
- The centralized mode is used with circuit-switched networks such as a PSTN or an ISDN.
- The decentralized mode is used with packet-switched networks which support multicast communications. (e.g. LAN, intranet and the Internet)
- A third mode known as the hybrid mode can be used.

Fig. 2.21 Multipoint conferencing modes of operation: (a) centralized; (b) decentralized; (c) hybrid.



1.5.5 Network QoS

- the *network Quality of Service* (QoS) parameters
  - are the operational parameters associated with a communications channel through a network, and
  - collectively determine the suitability of the channel in relation to its use for a particular application.

- Circuit-switched network: (CBR network)
  - The QoS associated with a CBR channel that is set up through a circuit-switched network include:
    - The bit rate
    - The mean bit error rate
    - The transmission delay

  - The *mean bit error rate* (BER) of a channel is the probability of a bit being corrupted during its transmission across the channel in a defined time interval.

Example 1.1

Derive the maximum block size that should be used over a channel which has a mean BER probability of 10^{-4} if the probability of a block containing an error – and hence being discarded – is to be 10^{-1}.

Answer:

$$P_B = 1 - (1 - P)^N$$

Hence $0.1 = 1 - (1 - 10^{-4})^N$ and $N = 950$ bits

Alternatively, $P_B = N \times P$

Hence $0.1 = N \times 10^{-4}$ and $N = 1000$ bits

- Issue of the block size:
  - In practice, most networks provide an *unreliable service* (best-effort service).
  - Information is partitioned into blocks during its transmission so as to minimize the propagation of error.
  - Any blocks containing bit errors will be discarded.
  - A *reliable service* can be offered by using error detection and block retransmission, which results in high transmission overheads and additional delay.
  - The choice of the block size is a compromise between the delay and the overhead in this case.

- The *transmission delay* associated with a channel is determined by the bit rate, the *codec delay* and the *propagation delay*.
- The *propagation delay* is determined by (i) the physical separation of the 2 communicating devices and (ii) the velocity of propagation of a signal across the transmission medium.

- Packet-switched network
  - The QoS parameters associated with a packet-switched network include:
    - The maximum packet size
    - The mean packet transfer rate
    - The mean packet error rate
    - The mean packet transfer delay
    - The worst-case jitter
    - The transmission delay

Example 1.2

Determine the propagation delay associated with the following communication channels:

(i) a connection through a private telephone network of 1 km,

(ii) a connection through a PSTN of 200 km,

(iii) a connection over a satellite channel of 50 000 km.

Assume that the velocity of propagation of a signal in the case of (i) and (ii) is 2×10^8 ms^{-1} and in the case of (iii) 3×10^8 ms^{-1}.

Answer:

Propagation delay T_p = physical separation/velocity of propagation

(i) $T_p = \frac{10^3}{2 \times 10^8} = 5 \times 10^{-6}$ s

(ii) $T_p = \frac{200 \times 10^3}{2 \times 10^8} = 10^{-3}$ s

(iii) $T_p = \frac{5 \times 10^7}{3 \times 10^8} = 1.67 \times 10^{-1}$ s

- *Mean packet transfer rate* is a measure of the average number of packets that are transferred across the network per second

- *Mean bit rate* of the channel = mean packet transfer rate x mean packet size

- *Mean packet error rate* (PER) is the probability of a received packet containing bit errors.

- *Mean packet transfer delay* is the summation of the store-and-forward delay that a packet experiences when it travels along the route.

- The transmission delay
  - includes the codec delay and the signal propagation delay
  - is the same whether the network operates in a packet mode or a circuit mode

1.5.6 Application QoS

- The application QoS parameters that relate to the network include:
  - The required bit rate or mean packet transfer rate
  - The maximum startup delay
  - Maximum delay variation/jitter
  - Maximum round-trip delay

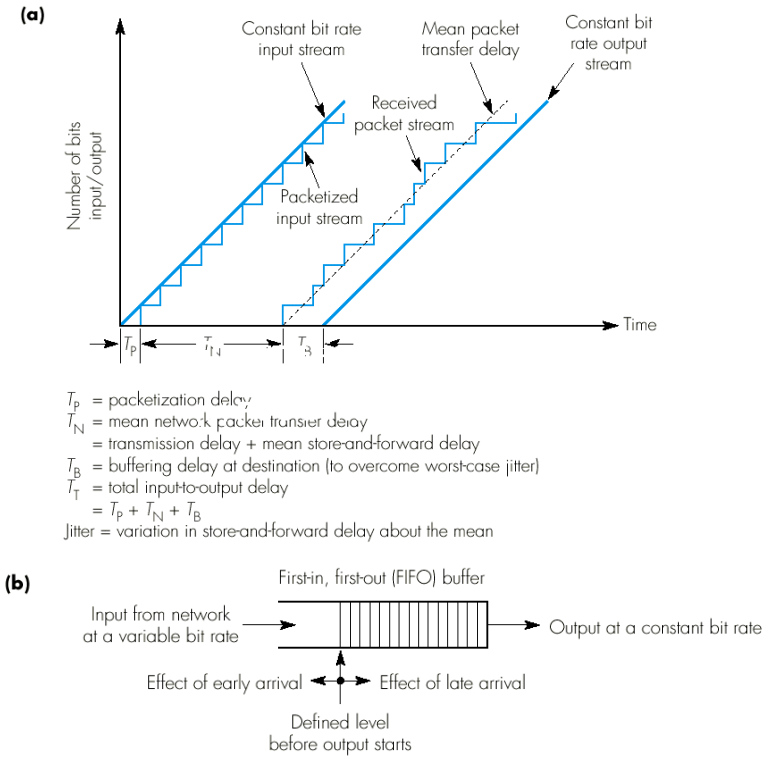
- *Startup delay* defines the amount of time that elapses between an application making a request to start a session and the confirmation being received from the application at the destination.

- A circuit-switched network would be most appropriate for applications that involve the transfer of a constant bit rate stream.
  - Why?
  1. The call setup delay is not important.
  2. The channel provides a constant bit rate service of a known rate.

- A connectionless packet-switched network would be more appropriate for interactive applications.
  - Why?
  1. There is no network call setup delay
  2. Any variations in the packet delay are not important.

- When packet-switched network is used:
  - A technique known as *buffering* is used to overcome the effect of jitter in a packet-switched network.
  - The effect of jitter is overcome by retaining a defined number of packets in a memory buffer at the destination before playout of the information bitstrem is started.
  - Buffering delay plus the time for playing a packet must be larger than the worst-case jitter.

Fig. 2.22 Transmission of a constant bit rate tream over a packet-switched network (a) timing schematic; (b) FIFO buffer operation



  - *Packetization delay* is the delay incurred at the source to packetize the information.
  - The larger the size of a packet, the larger the packetization delay is.
  - Some other concerns when determining the packet size:
    - Is retransmission required?
    - Is the destination buffer larger enough to handle the worst-case jitter?

- How to use QoS in multimedia communication?
  - In order to simplify the process of determining whether a particular network can meet the QoS requirements of an application, a number of standard application service classes have been defined.
  - A specific set of QoS parameters is associated with each class.
  - In order to ensure the QoS parameters associated with each class are met, the packets relating to each class are given a different priority in a network that supports a number of different service classes.

Revision

Figure 1.23 Alternative types of media used in multimedia applications.

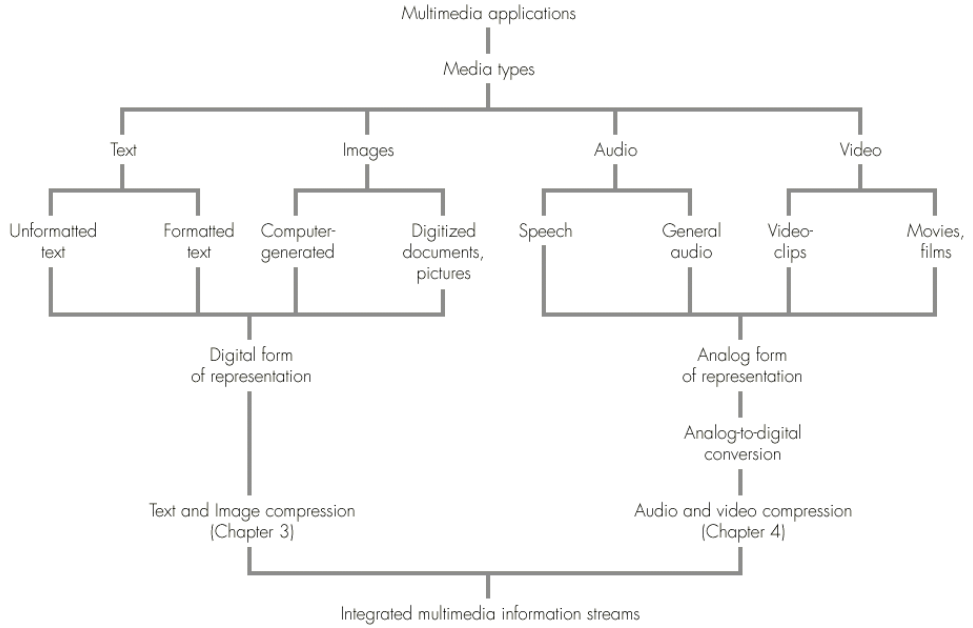


Figure 1.24 Multimedia communication networks.

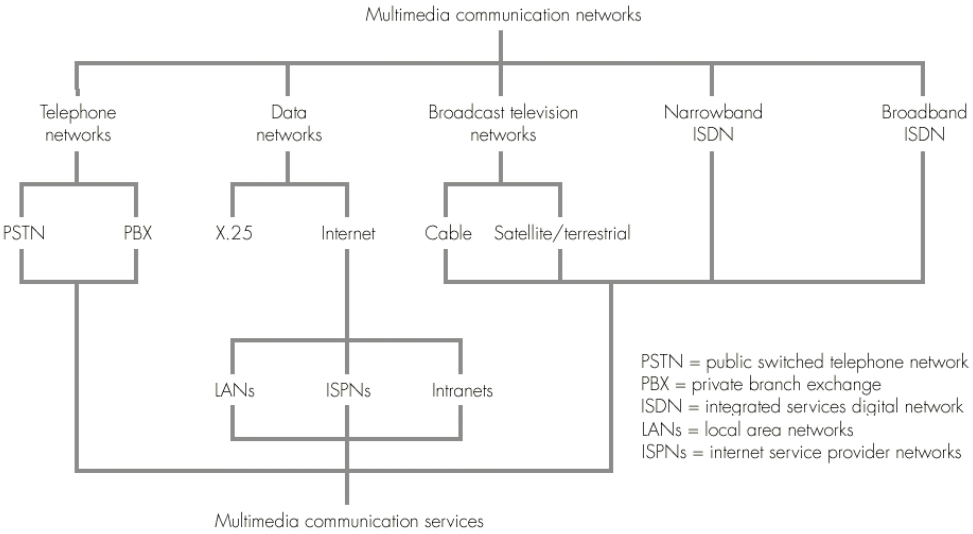


Figure 1.25 Multimedia communication networks and their services.