Communication Networks

MAP-TELE

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Network basic mechanisms

Introduction to Communications Networks

Communications networks

- Communications networks are used to transport information (data) exchanged between *end-systems* with the ultimate goal of supporting a variety of services and distributed applications
- Networks were initially designed and optimized for a specific service
  - The telephone network for the voice service
  - Broadcast networks for distribution of radio and TV programmes
  - Computer networks for exchange of data among computers to support applications like remote access, file transfer, e-mail, etc.
- The current trend is towards carrying traffic (flows) of different applications or services in the same network infrastructure
  - The concept of service integration in public networks started with ISDN (*Integrated Services Digital Network*), which was an evolution of the digital telephone network IDN (*Integrated Digital Network*), and was extended to support BISDN (*Broadband ISDN*), which was the driving force behind the development of ATM (*Asynchronous Transfer Mode*)
  - The Internet was designed for carrying data traffic (on a *best effort* basis) but is becoming the universal infrastructure for carrying any type of traffic, such as VoIP (Voice over IP), video streaming, etc.

Resource sharing

- At present, the two most ubiquitous networks are the telephone network and the Internet
- Both the telephone network and computer networks rely on a *transmission* and *switching* infrastructure
- A key issue in networks is the way resources are shared
  - Sharing may be static or dynamic
- A network is characterized by the multiplexing and switching techniques (*transfer mode*) it adopts and these are tightly related
  - Sharing of transmission resources is accomplished by means of *multiplexing* techniques
- The telephone and computer networks use two different switching techniques – *Circuit Switching* and *Packet Switching*, respectively, which are based on rather different paradigms of resource sharing (driven by the type of service they were designed for)
  - Circuit Switching is based on static sharing of resources
  - Packet Switching is based on dynamic sharing of resources

Telephone network

- In the telephone network, multiplexing and switching techniques evolved from analogue to digital
- The telephone network provides *circuits* to end-users
  - A circuit is a dedicated resource provided between two end-points
  - A circuit is a concatenation of *channels* established between network nodes (switches) along a path
- Multiple telephone channels may share a transmission link by means of multiplexing – this sharing is static
  - FDM (*Frequency Division Multiplexing*) is used in analogue systems (a telephone analogue channel has a nominal bandwidth of 4 kHz)
  - STDM (*Synchronous Time Division Multiplexing*) is used in digital systems (the basic telephone digital channel has a capacity of 64 kbit/s)
- The telephone network adopts the Circuit Switching paradigm
- Data networks may use circuits to build their own infrastructure based on a different paradigm (Packet Switching)

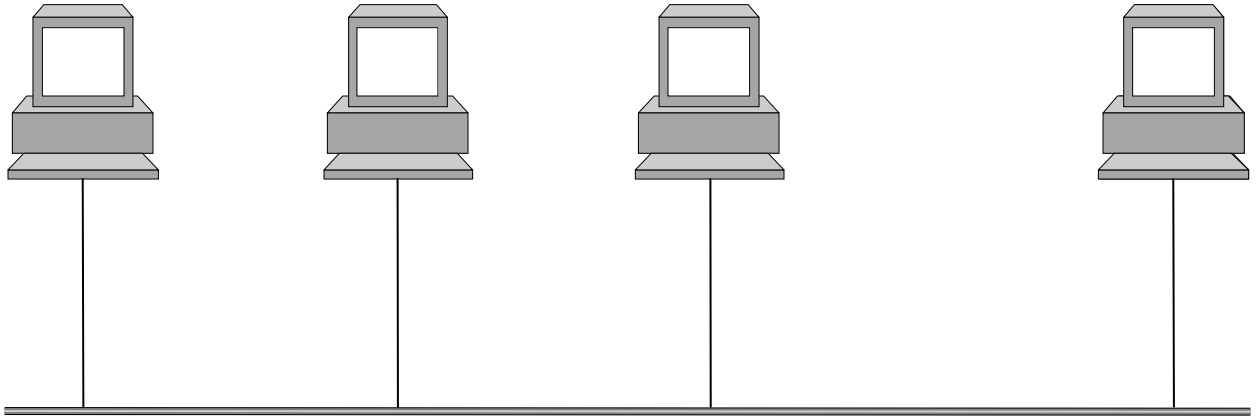
Computer networks

- Computers store and process information (digital data), which may have to be exchanged with other computers (*end-systems*) for many purposes
  - This exchange may require a number of *intermediate systems*
- In the first place a transmission system is necessary to move bits between systems (bits are represented by means of signals)
  - *Point-to-point links* between two systems (e.g., a telephone circuit)
  - *Multipoint links* shared by multiple systems (that listen and broadcast to the medium)
- Different media may be used for transmission links
  - Guided: copper pairs, coaxial cable, optical fibers
  - Unguided: free space (radio frequencies, microwaves, infrared)
- Computer networks may cover geographical areas of different sizes
  - WAN – *Wide Area Network*
  - MAN – *Metropolitan Area Network*
  - LAN – *Local Area Network*
  - PAN – *Personal Area Network*

Transmission links

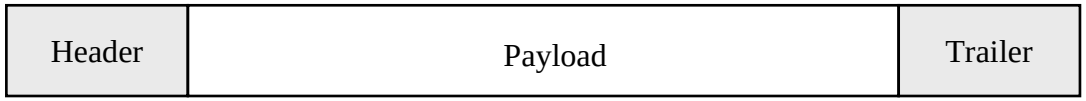
- Point-to-point

- Multipoint (multiple access)



Data communications

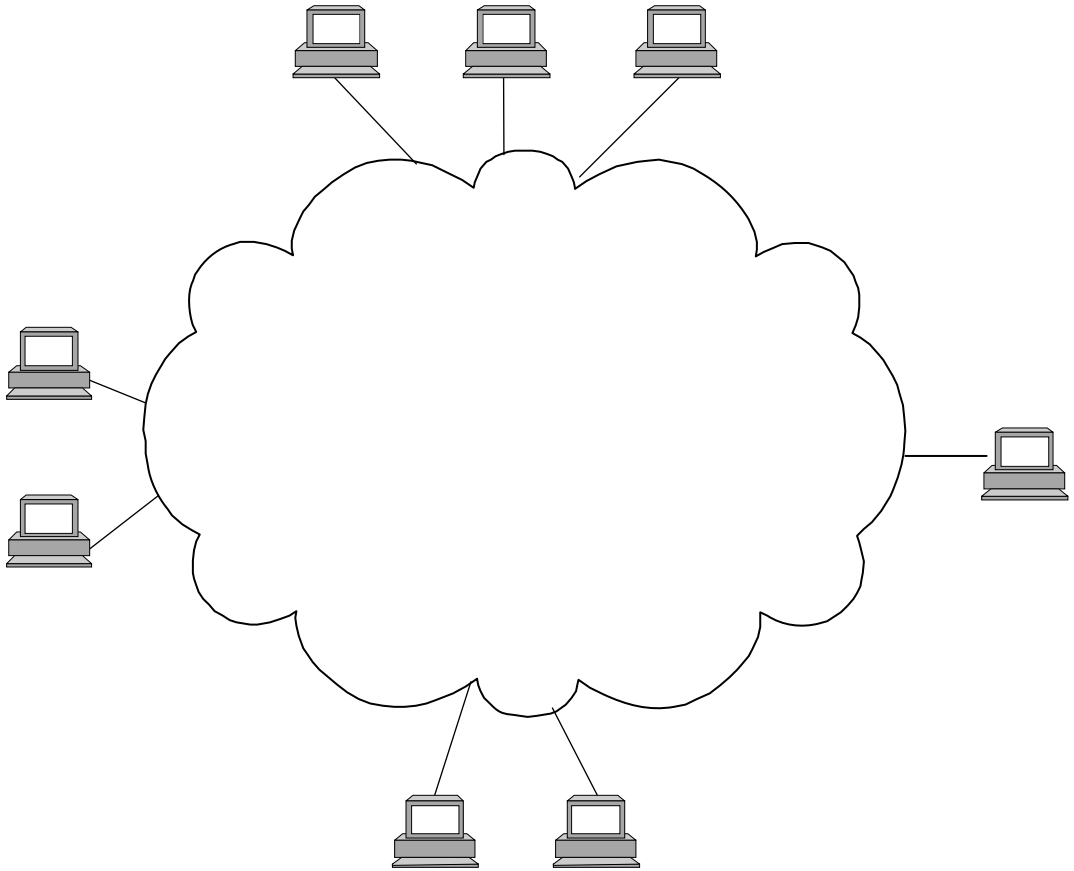
- Data communications require organizing and structuring the raw sequence of bits handled by the transmission system (this is called *framing*) as well as other functions (e.g., error and flow control)
  - The unit of data communications exchanged between systems (over a point-to-point or a multipoint link) is called a *frame*
  - Frames are exchanged on a *data link* (a logical entity different from a physical link)
  - Data is carried in the frame payload that is enveloped with a *header* and a *trailer*, which support data link functions (to be discussed)



- In simple cases computers may be directly connected by point-to-point links, using dedicated resources for this purpose, but to allow general and unrestricted connectivity among a large number of computers a network is necessary (and thus some form of switching)

Abstract view of a computer network

- A computer network is used to transport data between end-systems, with some level of service assurance
- A cloud is usually used to represent any type of network that provides connectivity between systems attached to it

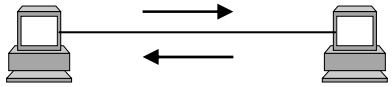


Need for switching

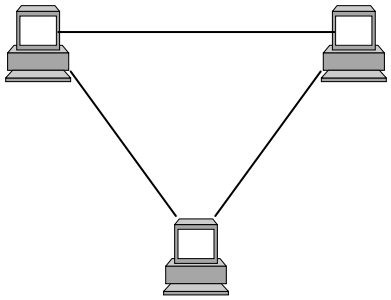
- Establishing direct (dedicated) links between pairs of computers is not practical nor feasible when:
  - The number of computers is high, since the number of links necessary to fully interconnect the computers grows with the square of its number
  - Computers are geographically distributed over a wide area (due to the high communications costs)
  - Connectivity requirements are not known in advance, but connectivity should not be restricted (any to any)
  - Traffic is bursty and asynchronous (typical of computer data), which may lead to underutilization of resources (or even no utilization at all)
- In general, computers must communicate through a switched network
  - In a shared medium (multipoint link), systems are directly connected, but an arbitration mechanism is required to access the medium without conflicts (the medium provides an inherent form of distributed switching)
  - When a network is made up of switching nodes (intermediate systems), they are connected by point-to-point links, typically in a mesh topology

Connectivity – direct links

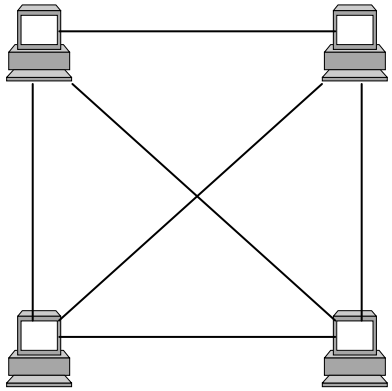
- Total number of links: L = n*(n – 1), assuming that there are two unidirectional links between each pair of systems



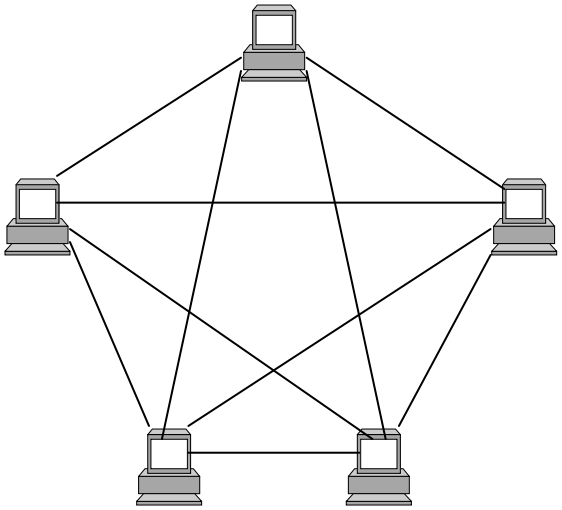
n = 2
L = 2



n = 3
L = 6

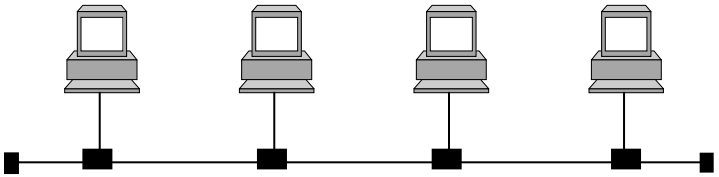


n = 4
L = 12

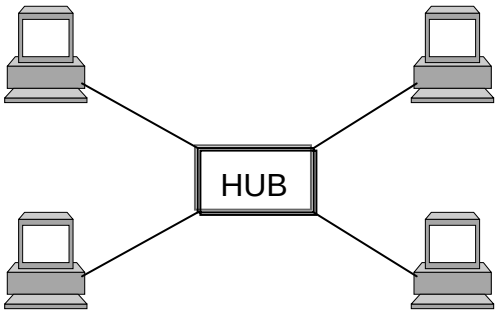


n = 5
L = 20

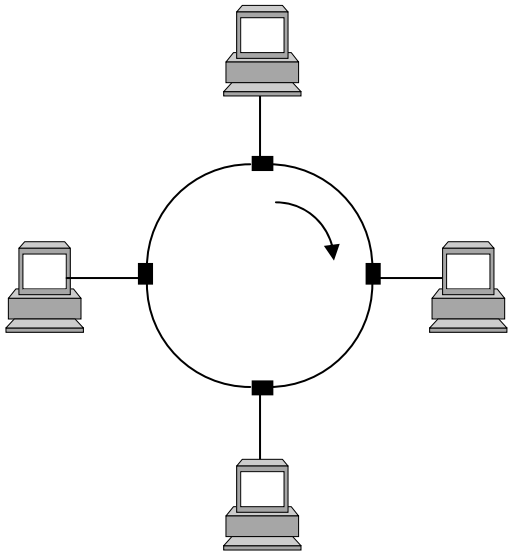
Connectivity – shared media



Bus



Star

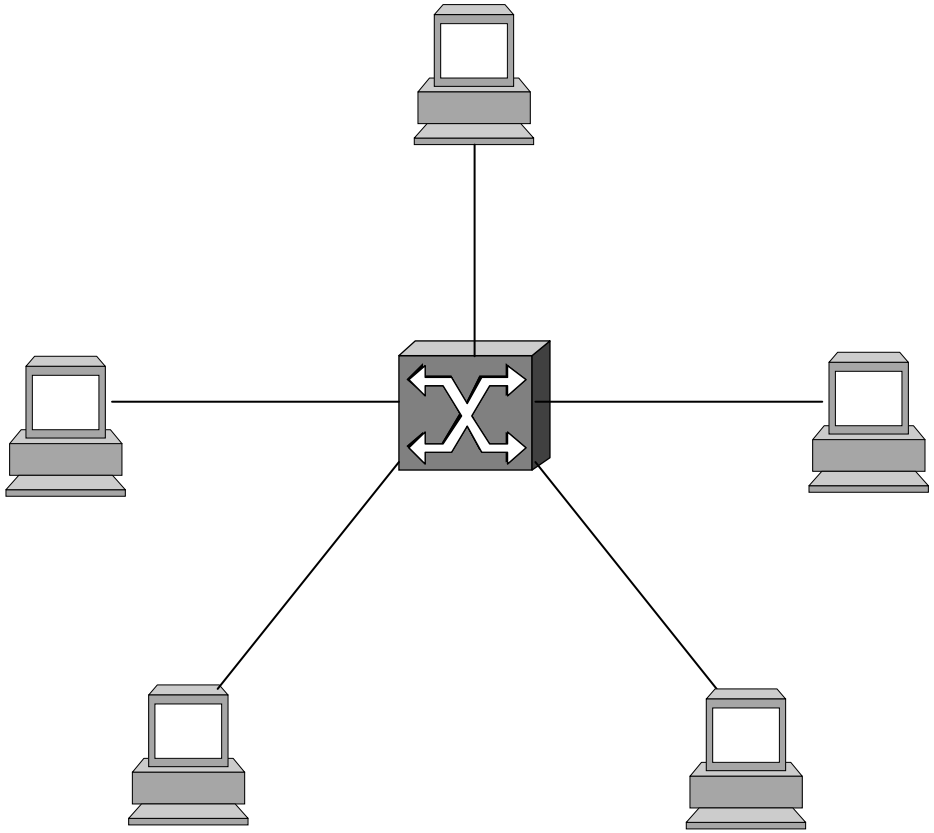


Ring

- Hub (multiport repeater) – broadcasts signals received on each input port (this is logically equivalent to a shared bus and should not be confused with a switch)

Connectivity – single switch

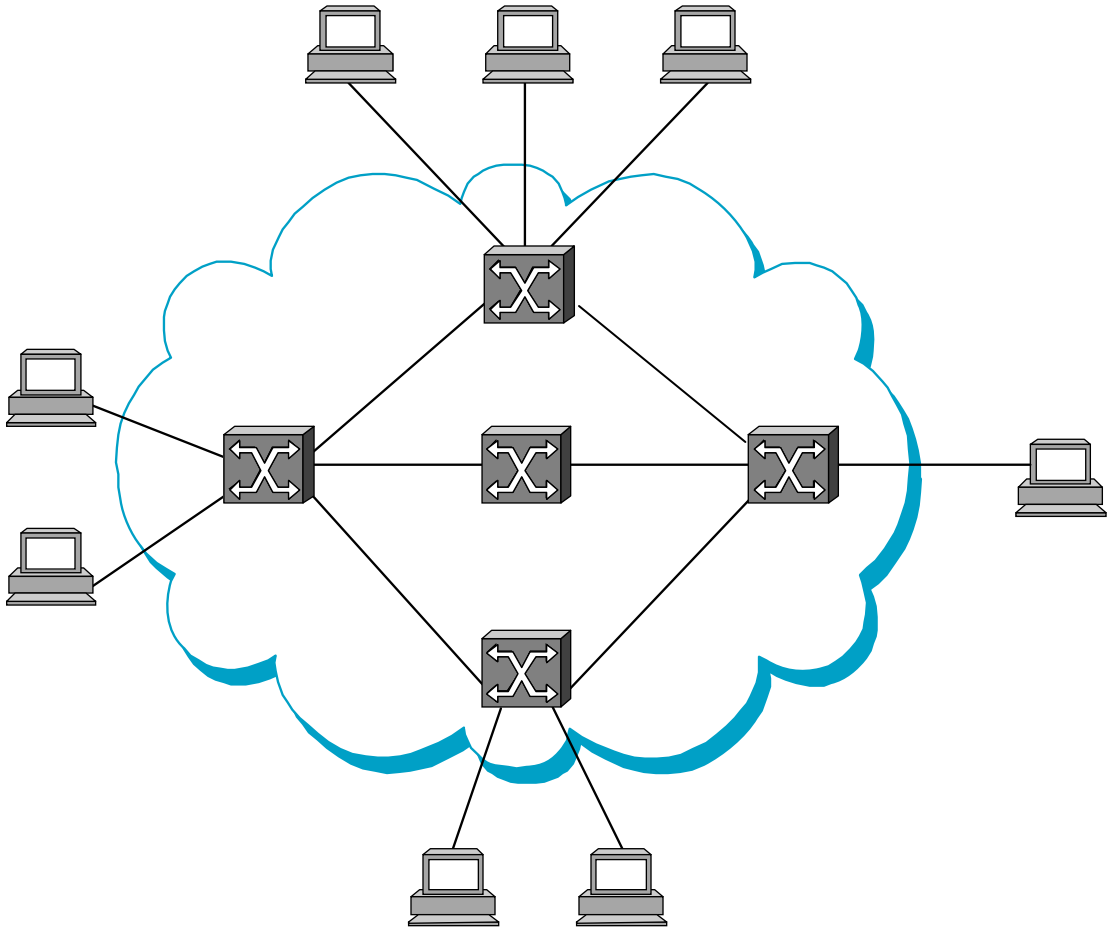
- Central switching node (star topology) – traffic is switched between input and output ports (a switch may be designed to support multicast or broadcast)



Star

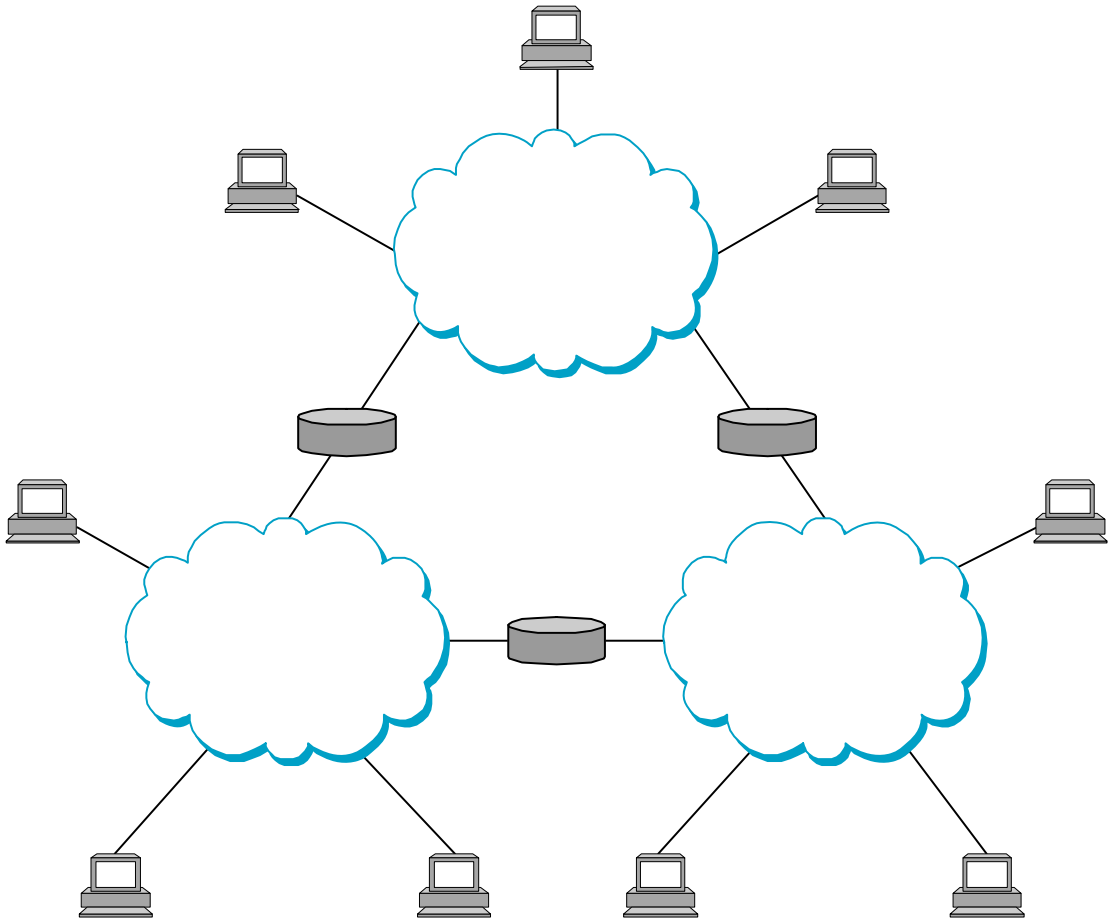
Connectivity – mesh network

- Multiple switches interconnected in a mesh topology, which provides alternative paths between network edge nodes



A network of networks

- Networks are interconnected by *routers* to form an internet
- The Internet is a worldwide internet based on the TCP/IP protocol family

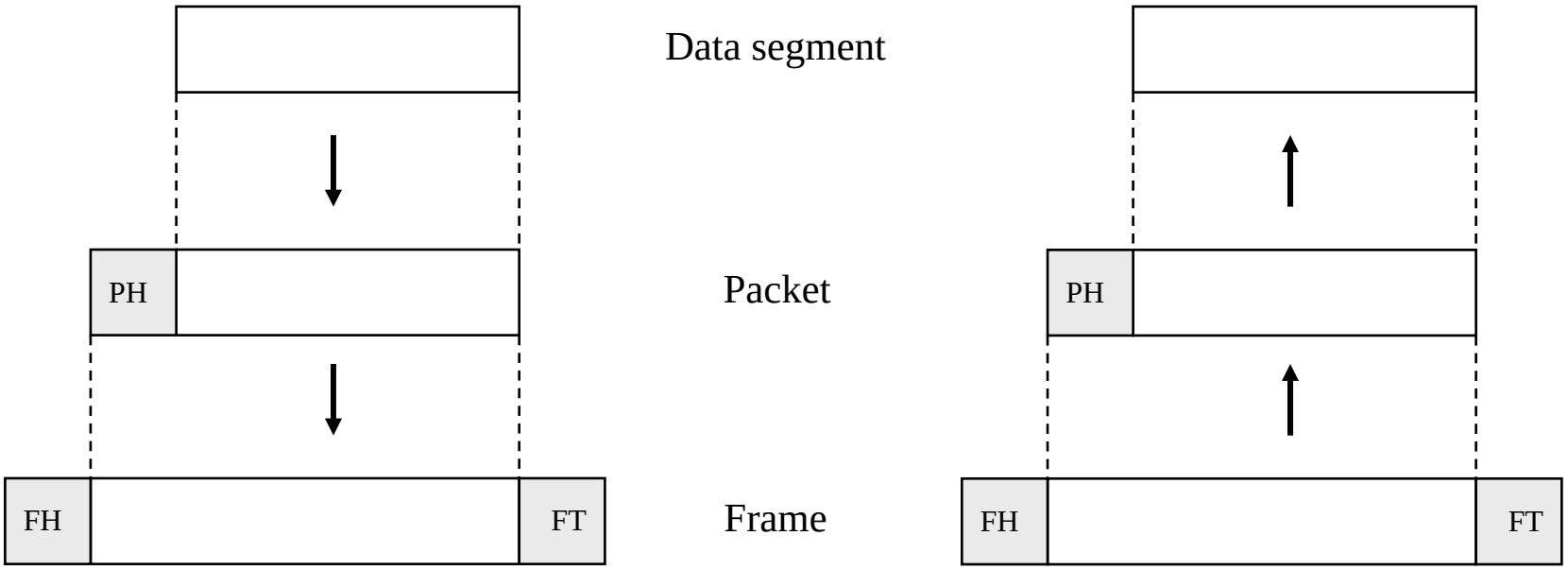


Packet Switching

- A computer network allows the attached computers (*end-systems* / *hosts*) to exchange data and share their resources
- Traffic generated by computers is inherently asynchronous (bursty and unpredictable) and therefore it is not efficient to reserve and dedicate transmission resources (circuits) to carry such individual traffic flows
- It is possible and desirable to exploit *statistical multiplexing* to dynamically share network resources (transmission and switching facilities) among many independent traffic flows and thus improve the utilization of resources
- This was the driving force behind the adoption of Packet Switching in computer networks
- Packet Switching is based on *Asynchronous Time Division Multiplexing* (ATDM), which is more efficient and flexible than Synchronous Time Division Multiplexing (STDM) for carrying data traffic or traffic mixes
- When a network carries traffic of different classes, the degree of statistical multiplexing depends on a trade-off between efficiency and the Quality of Service (QoS) guarantees required by each class

Frames and packets

- The unit of data transported by a network is called a *packet*
- Packets are carried in the payload of data frames on each hop (between adjacent nodes) along a path
- Packets also have a header and a payload – the latter carries user data, which may have to be fragmented to suit the payload size



PH – *Packet Header*
FH – *Frame Header*
FT – *Frame Trailer*

Topics to cover

- We shall start by studying the basic technologies that are used in the core of networks (in particular, in computer networks)
  - Multiplexing
  - Switching
- Then we discuss how to organize the many functions that must be performed by end-systems and intermediate systems (network nodes) in support of the communication process
  - Network architectures and protocols – protocol layering
- Finally we shall address a number of specific functions that give support to data communications and networking
  - Framing
  - Error control (error detection and recovery)
  - Multiple access
  - Flow, congestion and admission control
  - Scheduling
  - Routing