Communication Networks

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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)

| Header | Payload | Trailer |

• 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

- 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)
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*  

(Transmission system)
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