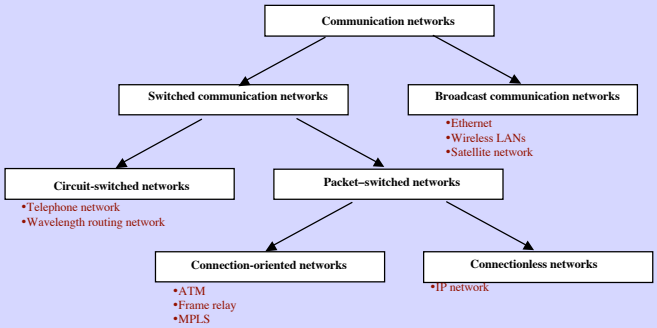
Communication Networks - An overview

Harry Perros

Topics

- Classification of communication systems
- Connectionless networks
  - IP networks
- Connection-oriented networks
  - ATM, MPLS
- Broadcast networks
  - Ethernet, packet radio, satellite systems
- Access networks
- Standards committees
- Issues of resource allocation and QoS

Classification of Communication Networks



Switched communication networks

- Circuit-switched networks:
  - The telephone network
  - Wavelength routing optical network.
- Packet-switched networks:
  - IP network
  - ATM
  - Frame Relay
  - MPLS networks

Broadcast communication networks

- Examples:
  - wireless LANs
  - satellite networks
  - multi-access Ethernet
  - Cable-based access networks
  - passive optical networks.

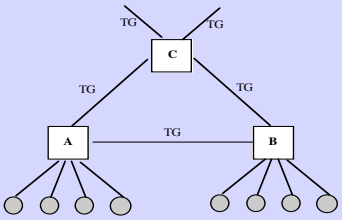
Circuit-switched networks

This technique is used in the telephone systems, and other transport technologies such as optical networks.

In order for two users to communicate a *circuit* or a *connection* has to be first established by the network. The following three phases are involved:

- *circuit establishment*,
- *data transfer*,
- *circuit disconnect*.

PSTN
(Public switched telephone network)



- A and B are known as *local exchanges*, or *central offices*, or *end offices*.
- C is known as an *intermediate* or *tandem*, or *toll*, or *transit exchange*.
- *Trunk:* is a circuit between two exchanges. It is nothing else but a channel associated with a time slot in a T1/E1 link or in a SONET/SDH link, which carries a single voice call.
- A group of trunks is known as a *trunk group* (TG).

Basic signaling

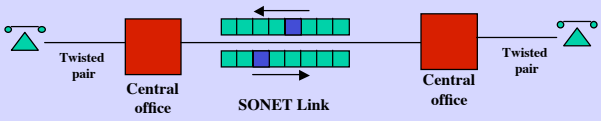
- Early telephones used *dial-pulse* to generate the digits.
- The dial-pulse system was replaced by the *dual-tone multi-frequency* (DTMF) system. When a subscriber presses a key on the keypad, an oscillator inside the telephone generates two simultaneous tones.
- The DTMF frequency combinations are distinct from naturally occurring sounds, voice and voiceband data

Signaling system No. 7 (SS7)

- In CAS, the signaling information for a trunk is carried in the trunk itself using the ABCD bits and the DTMF scheme.
- In *Common-Channel Signaling* (CCS), all signaling information, including dialed digits, is carried in messages over a separate packet-switched network.

Resource allocation

- When a connection is being setup, network resources are allocated specifically to the connection. These resources are de-allocated when the connection is terminated.



Cellular telephone networks

- These are the wireless extensions of the traditional PSTN networks.
- They allow roaming with the same mobile phone nation-wide and (in certain cases) worldwide
- They were specifically built for voice. Recently, they have evolved towards providing multi-media

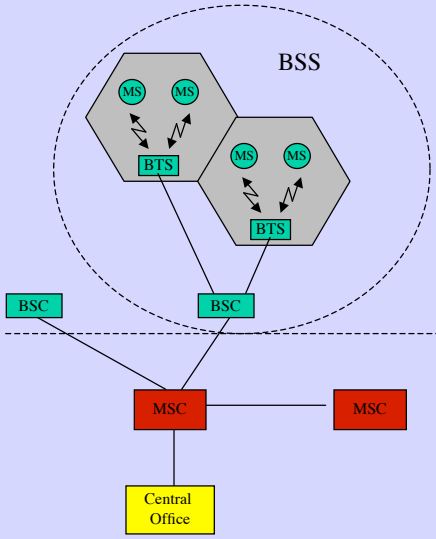
Cellular networks

- GSM
  - Digital TDM European system. 70% of the market.
- AMP
  - Analog system. Slowly been replaced by digital systems. 3% of the market.
- CDMA
  - A newer digital technology posed to replace TDM. 12% of the market
- TDM
  - Similar to GSM, but uses different frequencies. 10% of the market

Coverage

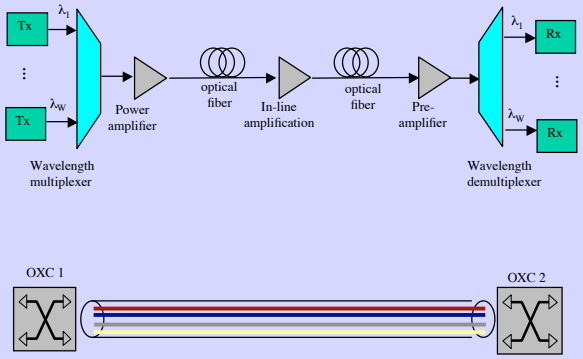
- Europe
  - GSM is the ubiquitous network
- USA and countries that adopted USA technologies (Canada, South Korea)
  - TDM
  - GSM
  - CDMA

Architecture



MS: mobile system (cell)
BTS: Base station system (tower)
BSS: Base station system
BSC: Base station controller
MSC: Mobile services switching center

Optical Networks - A point-to-point WDM link

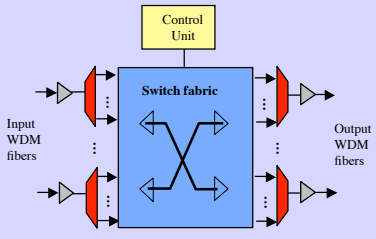


An optical cross node

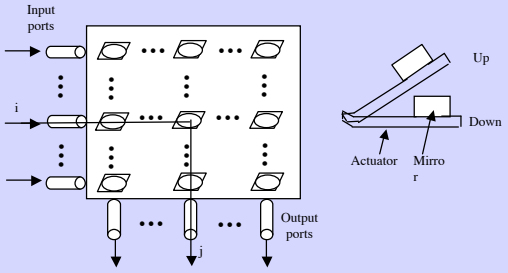
Switch fabric:

All optical: MEMS (a few msec), SOA (1 μsec)

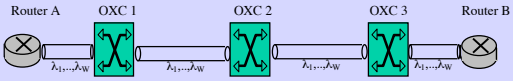
O-E-O: Large SONET switcher



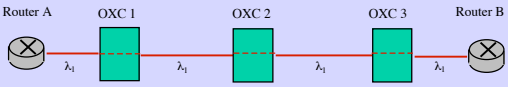
2D MEMS switching fabric



A wavelength routing optical network connection



A three-node wavelength routing network



A lightpath

- An important feature of a wavelength routing optical network is that it is a circuit-switched network.
- A connection is an optical path through the optical network (called a lightpath) and it is established using a wavelength on each hop along the connection's path.
- Connection is established using GMPLS

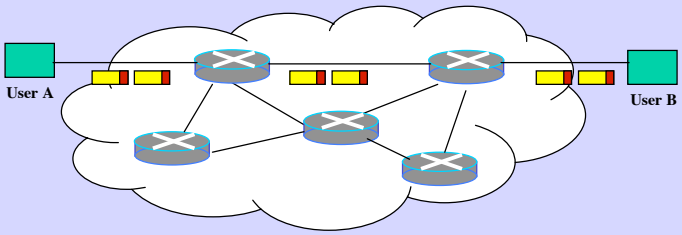
Packet-switched networks

- Connectionless networks
  - IP
- Connection-oriented networks
  - ATM
  - Frame Relay
  - MPLS

Connectionless packet-switched networks

- In an IP network, a user can send packets to a destination without having to set up a connection first, i.e., without informing the network prior to transmitting them.
- This simplifies the network, as there is no need for a special signaling protocol.

Routing in IP



The routing of a packet through the network is done on a hop-per-hop basis based on the destination IP address carried in the IP packet's header.

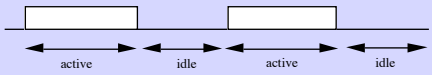
Quality of Service (QoS) in IP

- Typically, an IP router does not offer QoS.
- It cannot distinguish packets belonging to different service classes based on their destination address.
- IP is almost ubiquitous. There has been a lot of interest in introducing QoS in the IP network, and MPLS seems to be the architecture of choice for introducing QoS.

Connection-oriented packet-switched networks

- Circuit switching is a good solution for voice, since it involves exchanging a relatively continuous flow of data.
- However, it is not a good solution for the transmission of *bursty* data

An example of a bursty source



- Packets arrive only during each active period (on/off source).
- Arrival rate may vary from active period to active period (MMPP)

- Connection-oriented packet-switched networks imitate circuit-switched network.
- In order for two users to communicate a *virtual circuit* or a *connection* has to be first established by the network.
- Similarly to circuit-switched networks, the following three phases are involved:
  - *connection establishment*,
  - *data transfer*, and
  - *connection disconnect*.

Asynchronous Transfer Mode (ATM)

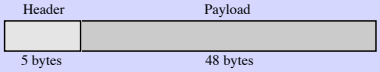
- ATM was standardized by ITU-T (old CCITT) in 1988 as the transfer mode of B-ISDN
- It can carry a variety of different types of traffic, such as
  - *Voice*
  - *Video*
  - *Data*

  At speeds varying from fractional T1 to 2.4 Gbps

- These different types of traffic have different Quality-of-Service (QoS) requirements, such as:
  - *Packet loss*
  - *End-to-end delay*
- ATM, unlike IP networks, can provide each traffic connection a different type of quality of service.

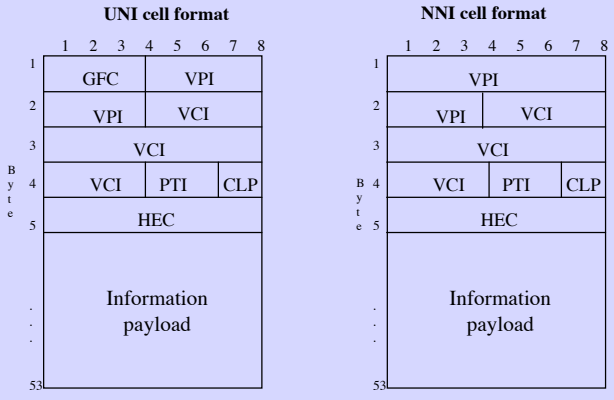
Some features of ATM

- Connection-oriented packet-switched network
- Fixed cell (packet) size of 48+5 bytes

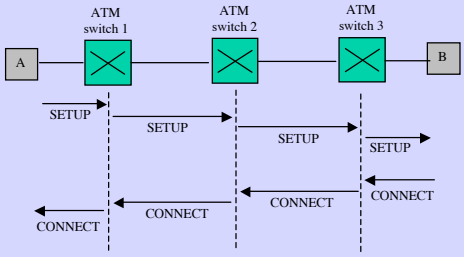


- No error protection on a link-by-link
- No flow control on a link-by-link
- Delivers cells in the order in which they were transmitted

The structure of the ATM cell

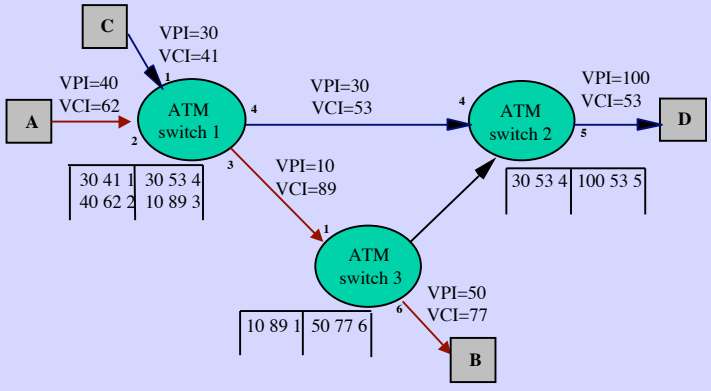


Establishment of an ATM connection



A bi-directional connection is established using signaling. The connection is associated with an id number.

Switching of cells is done using a connection ID number {VPI, VCI}.



Quality of Service

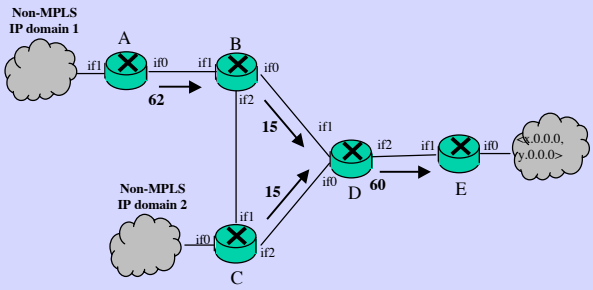
- A connection is associated with a specific class of service.
- An ATM switch can distinguish cells belonging to different service classes, and serve them accordingly so that to provide them with the requested QoS.

MPLS Networks

- MPLS introduces connection-oriented features to the IP network, in a manner similar to ATM.
- An MPLS-enabled IP router switches IP packets not on a hop-by-hop basis using the packet's IP address. Rather, it forwards them using a label which identifies the connection that the packet has to follow.

Label switched path (LSP)

The sequence of routers for a particular packet P, i.e., A,B, D, E, or C, D, E is known as an LSP.



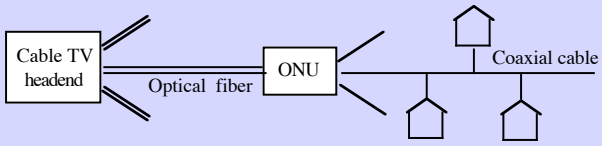
Broadcast communication networks

- In such system, a transmission will be received by all the users attached to the network.
- Different wired and wireless technologies
  - Ethernet
  - Cable-based access networks
  - Passive optical networks
  - Wireless LANs
  - Satellite networks

Ethernet

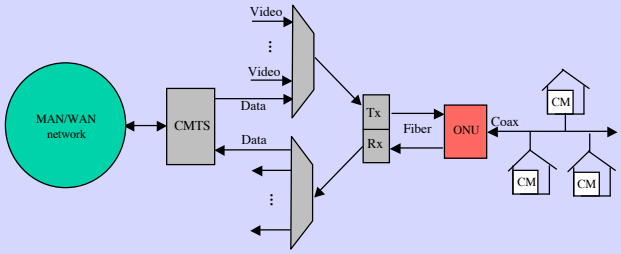
- It was defined and implemented for 10 Mbps around 1980. All users shared the same cable.
- In the early 1990s, it was defined to run at 100 Mbps.
- Towards the end of the 1990s, it was defined to run at 1 Gbps.
- Recently, it was standardized for 10 Gbps.
- *Ethernet is currently used for point-to-point communications. It is no longer used in broadcast mode*

Cable-based access networks



Due to the combination of fiber optics and coaxial cables, this cable network architecture is known as the *hybrid fiber coaxial* (HFC) architecture.

The DOCSIS reference architecture



Wireless LANs (WLANs)

- This is a fast-growing market: office, home, production environment
  - Nodes can communicate without cable restrictions
  - No wiring plans are required
  - Wireless networks permit the design of small independent devices
  - They can survive disasters, i.e earthquakes
  - After the initial layout for the wireless access, additional users can be added at no extra cost

IEEE 802.11

- This standard specifies the most popular family of WLANs.
- The original version of IEEE 802.11 released in 1997 specified two raw data rates: 1 and 2 Mbit/s to be transmitted via infra-red (IR) signals or in the 2.4 GHz radio frequency. IR remains a part of the standard but has no actual implementations.
- The original standard also defines CSMA/CD as the media access method.

IEEE 802.11b

- The 802.11b amendment to the original standard was ratified in 1999.
- It has a maximum raw data rate of 11 Mbit/s and uses the same CSMA/CA as in the original standard.
- Due to the CSMA/CA protocol overhead, in practice the maximum 802.11b throughput that an application can achieve is about 5.9 Mbit/s over TCP and 7.1 Mbit/s over UDP.

- 802.11b is usually used in a point-to-multipoint configuration, wherein an access point communicates via an omni-directional antenna with one or more clients that are located in a coverage area around the access point.
- Typical indoor range is 30 m at 11 Mbit/s and 90 m at 1 Mbit/s.
- With high-gain external antennas, the protocol can also be used in fixed point-to-point arrangements, typically at ranges up to eight km.

IEEE 802.11a

- 802.11a has 12 non-overlapping channels, 8 dedicated to indoor and 4 to point to point.
- It is not interoperable with 802.11b, except if using equipment that implements both standards.
- The 5 GHz band used restricts its use to almost line of sight, necessitating the use of more access points. It also cannot penetrate as far as 802.11b since it is absorbed more readily.

802.11a

- The 802.11a amendment to the original standard was ratified in 1999.
- It uses the same core protocol as the original standard, operates in 5 GHz band, and uses a 52-subcarrier (OFDM) with a maximum raw data rate of 54 Mbit/s, which yields realistic net achievable throughput in the mid-20 Mbit/s.
- The data rate is reduced to 48, 36, 24, 18, 12, 9 then 6 Mbit/s if required.

IEEE 802.11g

- 802.11g is a third modulation standard ratified in June 2003. This flavour works in the 2.4 GHz band (like 802.11b) but operates at a maximum raw data rate of 54 Mbit/s, or about 24.7 Mbit/s net throughput like 802.11a.
- 802.11g hardware will work with 802.11b hardware.

IEEE 802.11n

- This is a new Task Group fromed in January 2004 to develop a new amendment to the 802.11 standard for wireless local-area networks.
- The real data throughput is estimated to reach a theoretical 540 Mbit/s
- It is projected that 802.11n will also offer a better operating distance than current networks

Standards Committees

- ITU-T
- ISO
- ANSI
- IEEE
- ATM Forum
- MPLS and Frame Relay Alliance
- OIF
- IETF