Multimedia Systems

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Networks

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Outline

- Network basics for Multimedia Data
  - Network Types and Services
  - Switching
  - ISO/OSI Reference Model
  - Network QoS Mechanisms
- Network Technologies Considered for Multimedia
  - Ethernet
  - ISDN
  - ATM
  - Internet Access Technologies
- Protocols Considered for Multimedia
  - IP
  - Integrated Services
  - Resource Reservation Protocol
  - Differentiated Services
  - Multiprotocol Label Switching
  - Real-Time Transport Protocol

Network basics for Multimedia Data

- Network types
  - Switching concepts
- ISO/OSI model
  - Layer Description
  - Terminology
- Mechanisms for Network QoS

Network Types and Services (1)

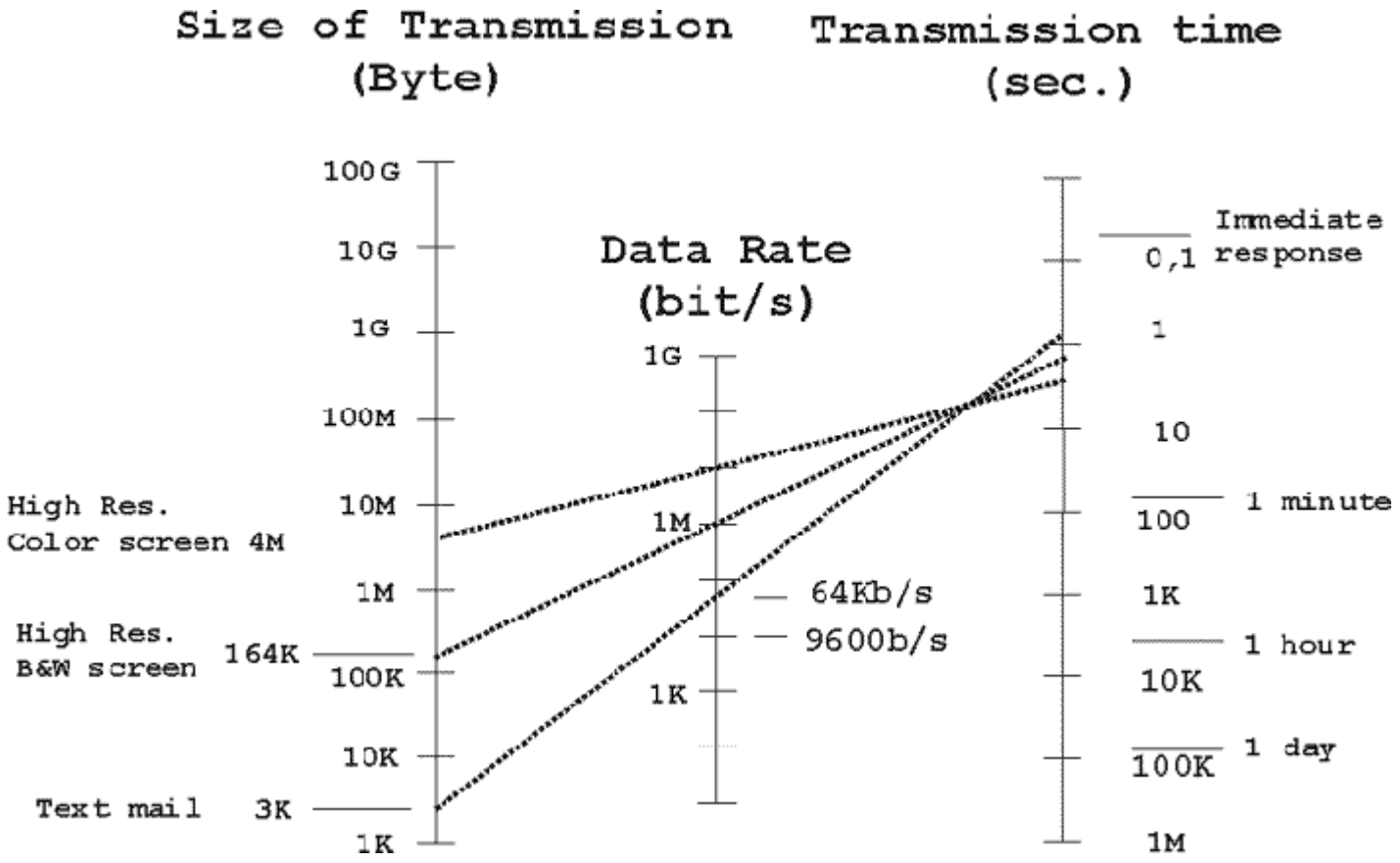
Network	Services	Physical Type
Telephone	Voice (1:1 and 1:n), Fax, Video, Text, Data, ...	cable (copper, fiber) wireless, satellite
Telephone (mobile)	Voice, Fax, Text, Data, ...	wireless + cable
Internet	Data, Text, Voice, Audio, Video, ...	cable (copper, fiber), wireless, satellite
Intranet	Data, Text, Voice, Audio, Video, ...	cable (copper, fiber), wireless
Cable TV	Video, Audio, Videotext, Data	cable (copper)
Satellite TV	Video, Audio, Videotext	satellite
Broadcast TV	Video, Audio, Videotext	wireless
Broadcast Radio	Audio, Text	wireless

Network Types and Services (2)

Additionally very specialized Networks:

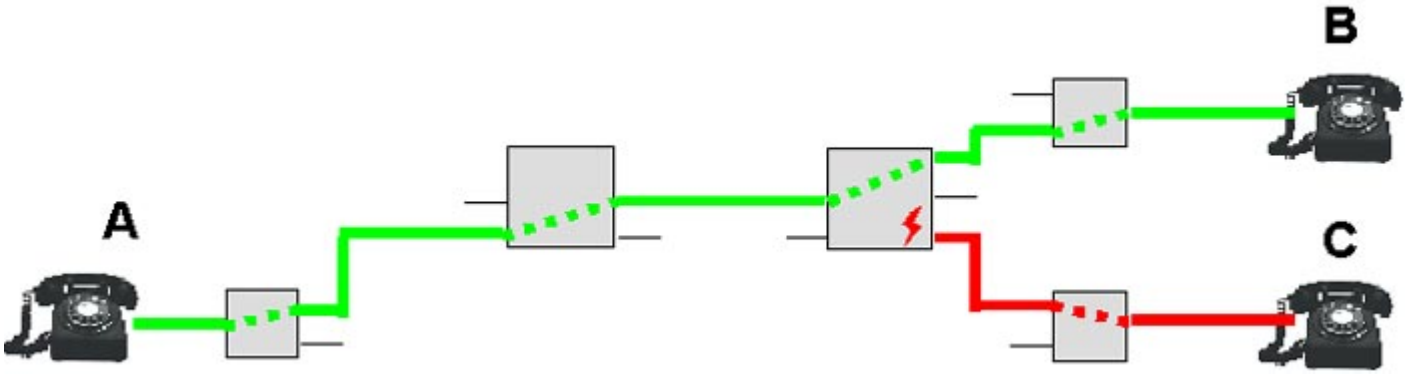
- Bank connections
- Controlling (traffic, machines, in house systems, ...)
- Supervising (alarm systems, gas pipes, street lights, ...)

Size versus Time of Transmission



Circuit Switching

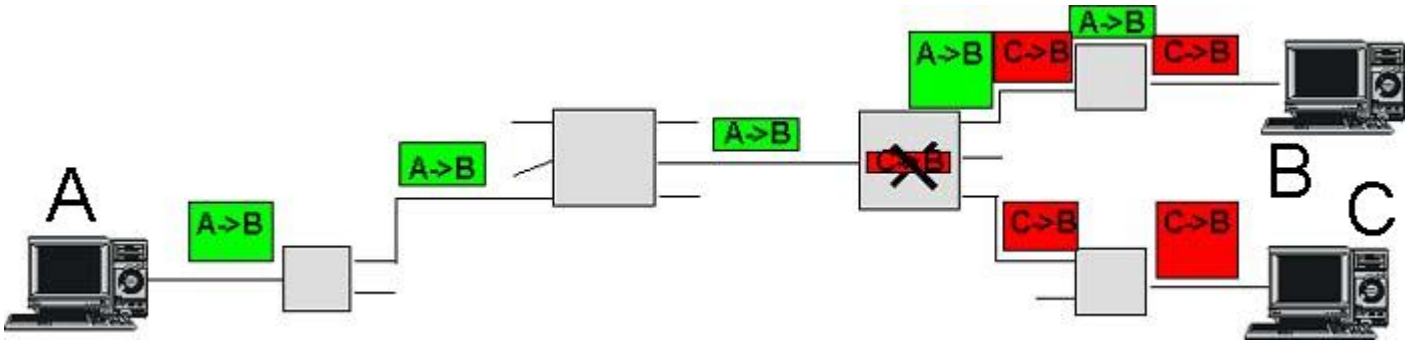
- Provide a "physical" link:
  - **connection A, B established**
  - **connection C, B blocked**



- **Advantages:**
  - guaranteed bandwidth and delay
  - worldwide available
- **Disadvantages:**
  - bandwidth not scalable
  - bad efficiency (bandwidth usage)

Packet Switching

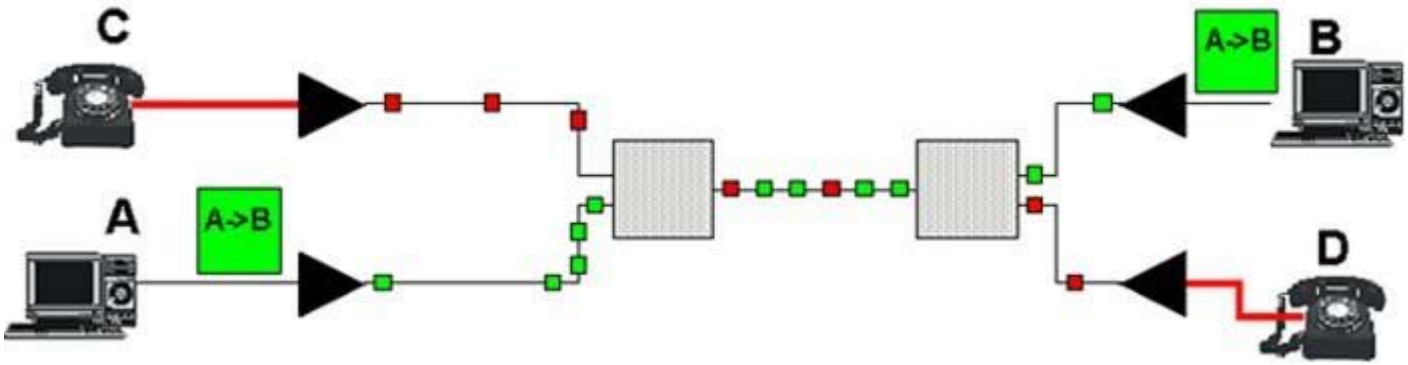
- Handle independent packages:
  - **A+C sending packages of different size to B**
  - **Packet may get lost because of congestion**



- **Advantages:**
  - high efficiency (bandwidth usage)
  - bandwidth is scalable
- **Disadvantages:**
  - no guaranteed delay (bandwidth)

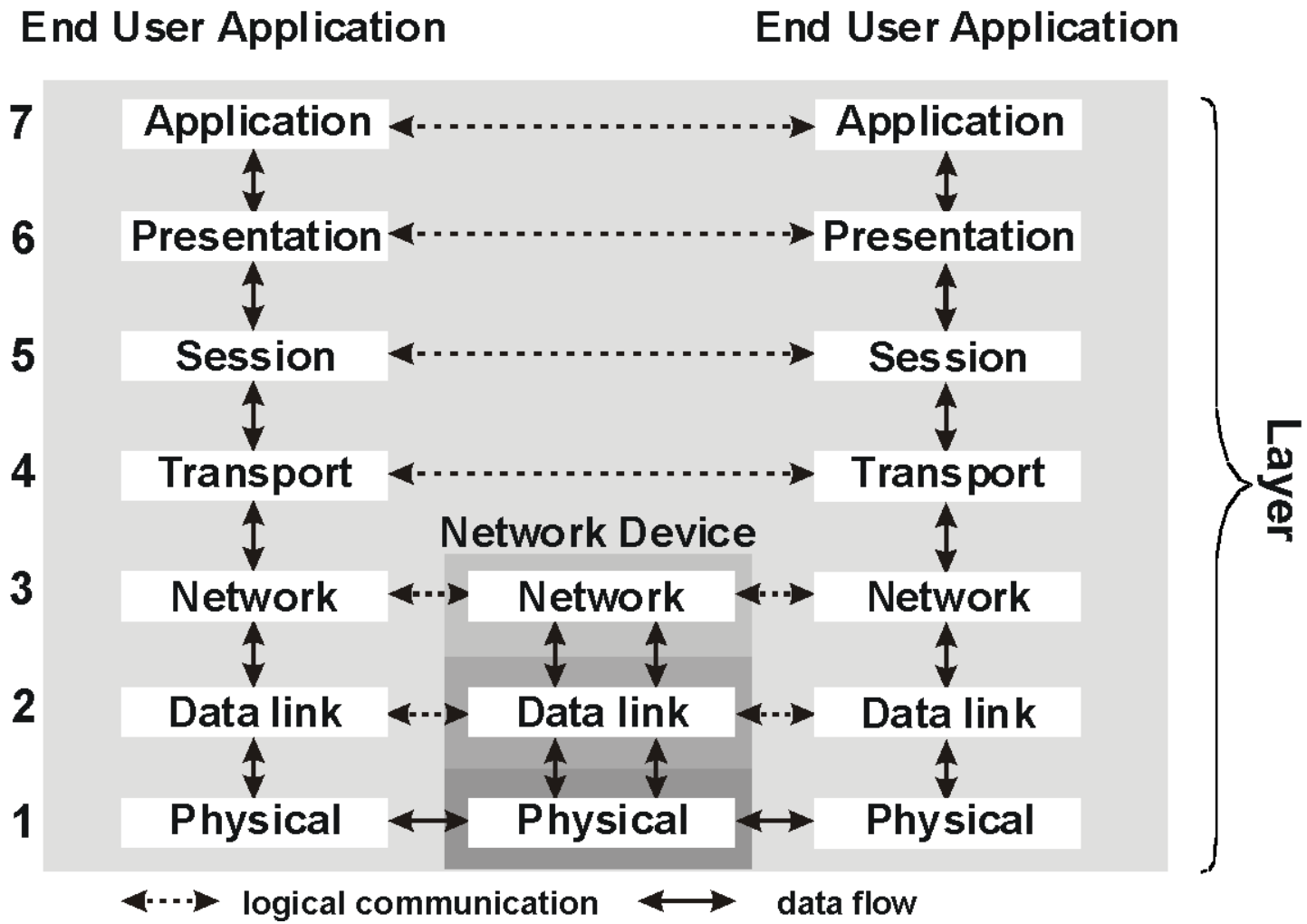
Cell Switching

- Promises to combine the best of circuit switching and packet switching.
  - **All data is segmented into small cells of fixed size. Cells are multiplexed as needed.**



- **Advantages:**
  - high efficiency (bandwidth usage)
  - bandwidth is scalable
  - guaranteed bandwidth and delay
- **Disadvantages:**
  - rare availability

ISO / OSI Reference Model (1)

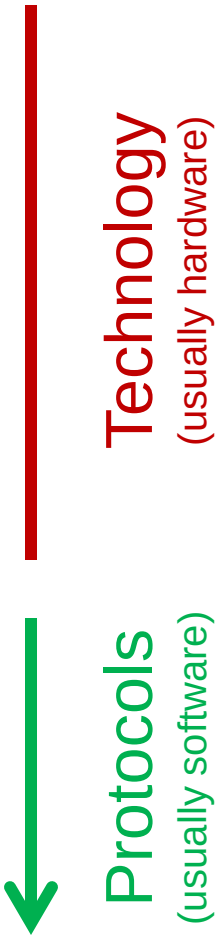


ISO / OSI Reference Model (2)

(1) The physical layer defines electric signaling on the transmission channel; how bits are converted into electric current, light pulses or any other physical form. Serial_line is an example of the physical layer. A network device for this layer is called a repeater.

(2) The data link layer defines how the network layer frames are transmitted as bits. An example of a data link layer protocol is Ethernet. A network device for this layer is called a bridge.

(3) The network layer defines how data from the transport layer is sent over networks and how different hosts are addressed. An example of a network layer protocol is the Internet Protocol. A network device for this layer is called a router.



ISO / OSI Reference Model (3)

(4) The transport layer takes care of data transfer, ensuring the integrity of data if desired by the upper layers. TCP and UDP are operating at this layer.

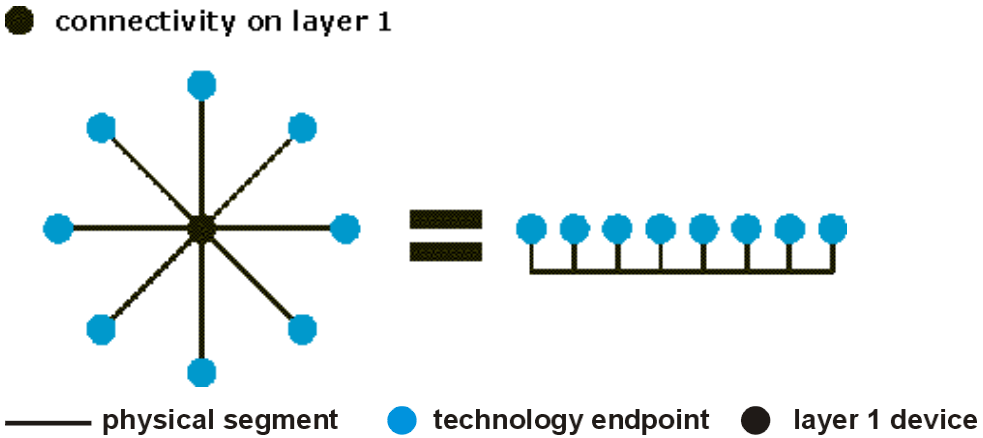
(5) The session layer establishes and terminates connections and arranges sessions to logical parts. TCP and RPC provide some functions at this layer.

(6) The presentation layer takes care of data type conversion. Protocols residing at this layer are used to provide interoperability between heterogeneous computer systems.

(7) The application layer defines the protocols to be used between the application programs. Examples of protocols at this layer are protocols for WWW (http) electronic mail (e.g. SMTP) and file transfer (e.g. FTP).

Layer 1

- **Data Types**
  - electrical or optical signals
- **Devices**
  - Repeater
    - extends physical segments to logical segments
    - boosts electrical or optical signals
  - Hub
    - is a multiport repeater
    - is a shared medium like a bus
- **Connectivity**

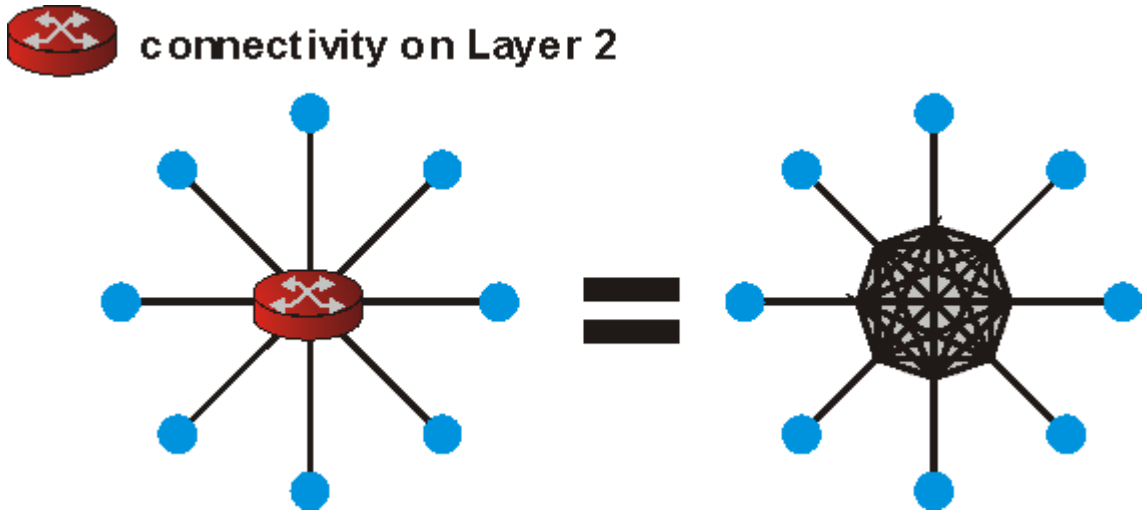


Layer 2 (1)

- **Data Types**
  - frames
- **Devices**
  - Bridge
    - connects logical segments to broadcast domains
    - provides connectivity on layer 2 by forwarding frames between two logical segments
    - a frame will be forwarded if
      - the receiver resides on the other segment
      - the receiver's location is unknown
      - the destination address is a broadcast address
    - needs information about directly connected network segments only
    - automatically collects layer 2 addresses to be able to make forwarding decision

Layer 2 (2)

- **Devices**
  - Switch
    - is a multi-port bridge
    - provides dedicated connections between all ports, i.e. does not realize a shared medium
- **Connectivity**

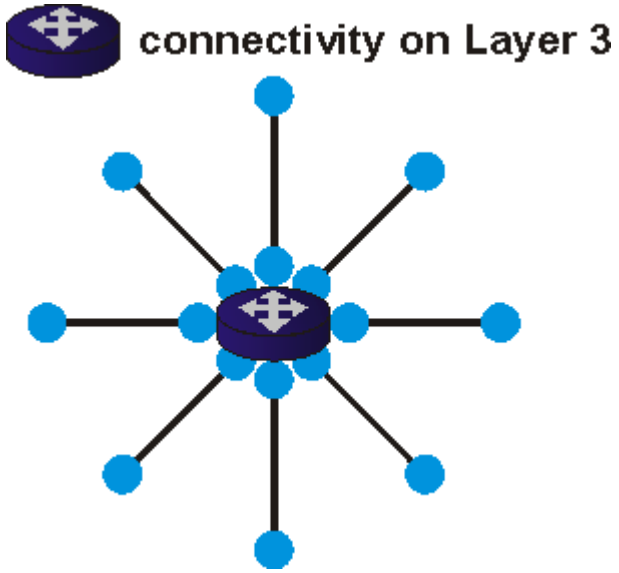


Layer 3 (1)

- **Data Types**
  - packets
- **Devices**
  - provides connectivity on layer 3, by interpreting packets and making routing decisions
  - a router port is an endpoint of a network segment
  - may connect different types of layer 2 networks
  - needs information about the whole network topology
    - receives external information to make a routing decision
    - static information may be configured by an administrator
    - dynamic information may be collected by routing protocols

Layer 3 (2)

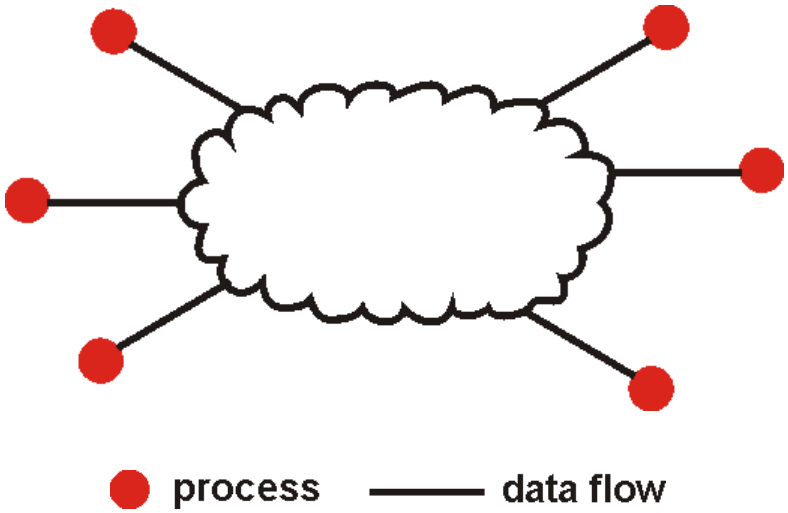
- **Connectivity**



Layer 4 - 7

- **Data Types**
  - protocol data
    - arbitrary application specific data
- **Applications**
  - Client Process
    - requests some information
    - receives payload
  - Server Process
    - waiting for information requests
    - sends payload
  - One process may be client and server
    - on different levels (e.g. FTP)
  - on the same levels (e.g. peer-to-peer protocols)

- **Connectivity**



Terminology (1)

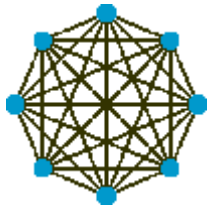
- **Data types:**
  - layer 1: signals
  - layer 2: frames
  - layer 3: packets
- **Repeating:**
  - boosting electrical or optical signals
- **Forwarding:**
  - is the task of moving a frame or packet from one interface (or port) to another interface
- **Bridging or switching:**
  - depending on layer 2 addresses deciding whether a frame needs to be forwarded, identifying the output port and performing the forwarding
  - bridging/switching is a layer 2 functionality

Terminology (2)

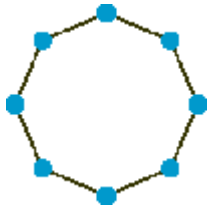
- **Routing:**
  - depending on layer 3 addresses and routing information deciding to which output port a packet needs to be forwarded and performing the forwarding
  - forwarding a packet includes the generation of a new frame
  - routing is a layer 3 functionality
- **Combined devices:**
  - switching-hubs oder route-switches denote combined devices

Topologies (1)

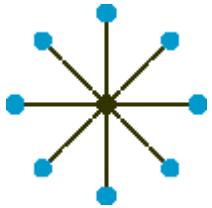
- **Complete mesh:**
  - ideal performance
  - high reliability
  - only for networks with small expansion
  - $\frac{n(n-1)}{2}$ connections



- **Ring:**
  - reliability
    - absorb drop out of one link
  - easier cabling
  - *n* connections

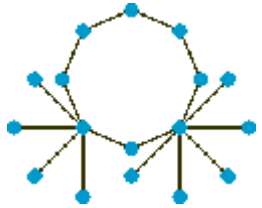


- **Star:**
  - reliability
    - drop out of one link affects a single endsystem only
    - node in the middle is single point of failure
  - complex cabling for large extent networks
  - *n* connections

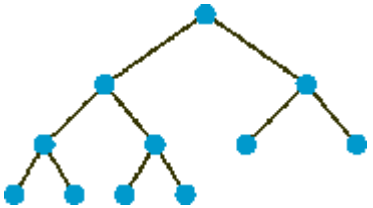


Topologies (2)

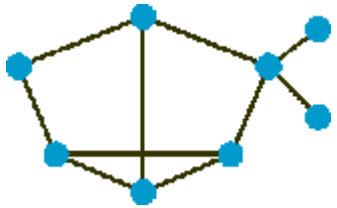
- **Combination:**
  - large networks often combine different topologies
  - Example: the B-WIN network of the DFN (Deutsches Forschungsnetz) uses a combination of ring and star topology



- **Tree:**
  - is a combination of star topologies



- **Irregular:**
  - some applications may require specialized topologies



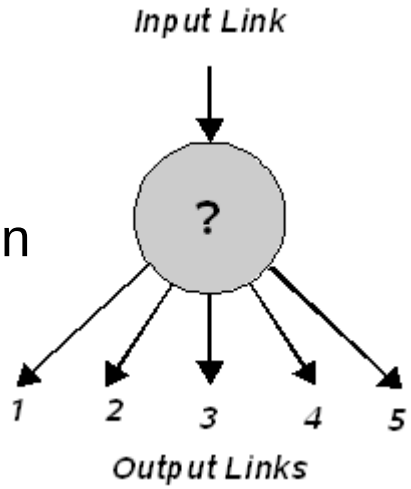
physical segment technology endpoint layer 1 device

Network QoS Mechanisms

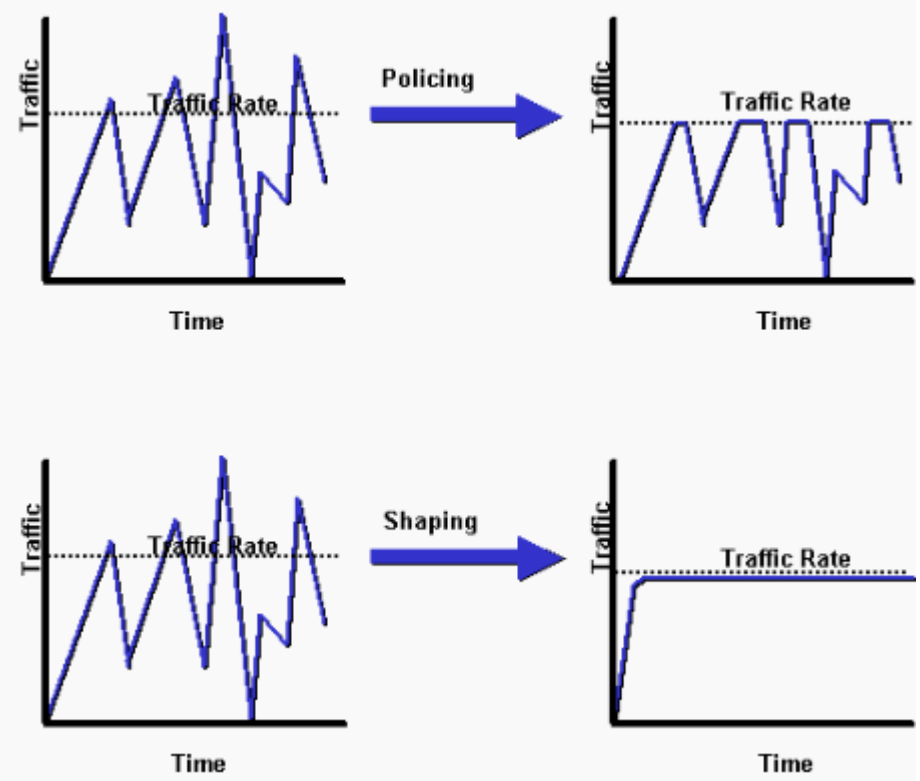
- Network Device QoS Mechanisms
  - Classification: type of incoming data
  - Shaping & Policy: keep / monitor traffic characteristic
  - Queueing: determine output schedule
- Network Mechanisms related to QoS
  - Congestion control / avoidance
  - Routing
  - SLA / QoS Signaling
  - Media transport & usage

Traffic Classification

- In order to provide QoS in a packet switched network, a network device has to classify each incoming packet
  - distinguish flows and aggregations (terms: flow-based vs class-based)
- Classification criteria
  - physical port of incoming data
  - frame/packet addresses (MAC, IP-Address, TCP/UDP Port-Number)
  - protocol interpretation
- Obtaining classification info
  - static: by (manual) configuration
  - dynamic: by signaling



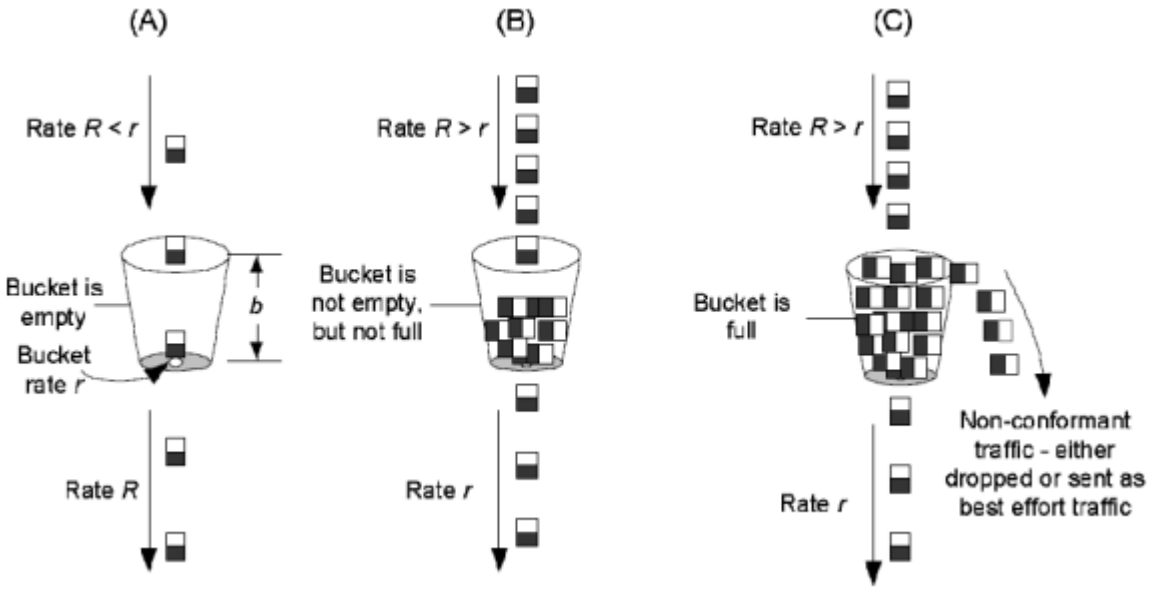
Shaping vs Policing



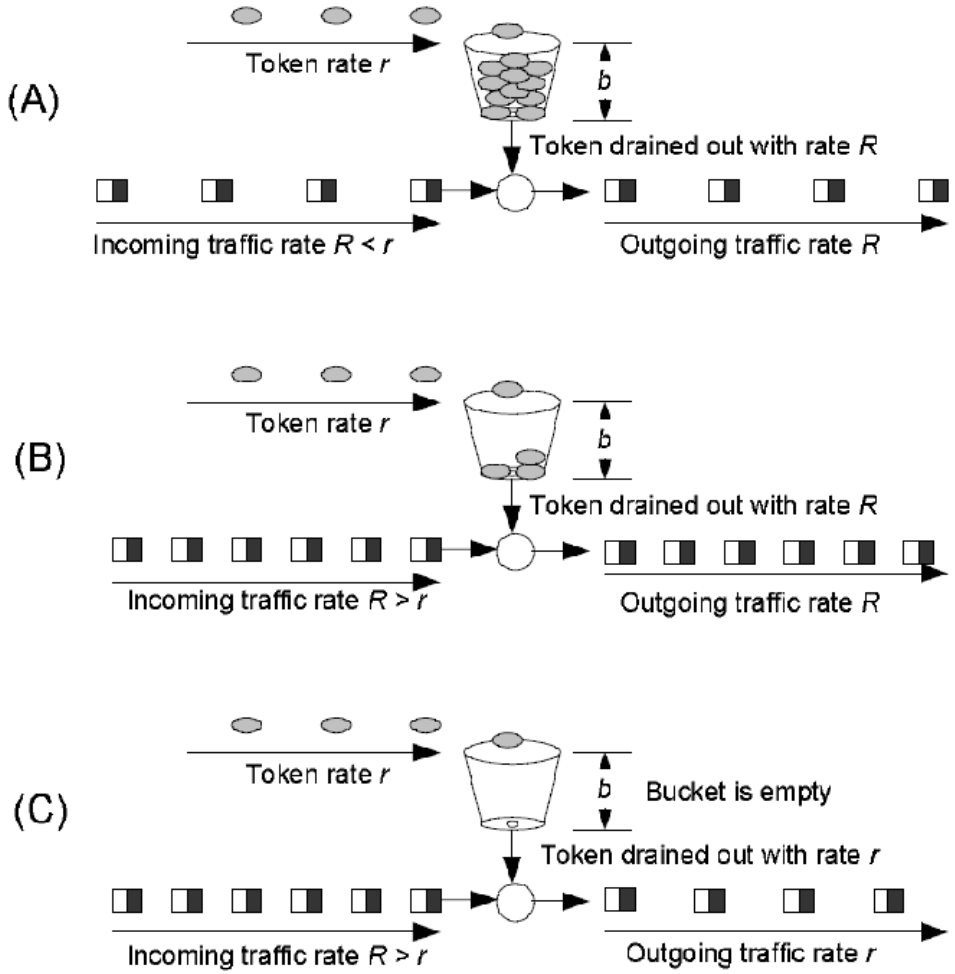
(image source: Cisco.com)

- shaping: keep a traffic characteristic, increases delay!
- policing: monitor the traffic characteristic, increases loss rate!

Leaky Bucket (Shaping)



Token Bucket (Policing)

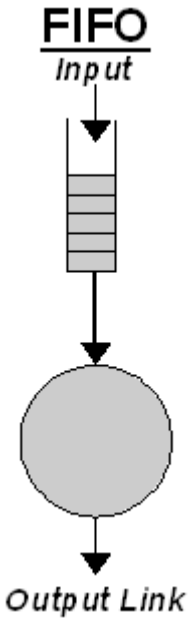


Shaping vs Policing

- ideal: shaping at client side, policing at provider side
  usually both done by provider
- Several instances enable control of multiple traffic parameters
  Example:
  1. Token Bucket: average rate
  2. Leaky Bucket: peak rate
- it's not necessary to drop non conforming packets, these may be
  - marked and dropped preferably in case of high load
  - assigned to a class with lower priority

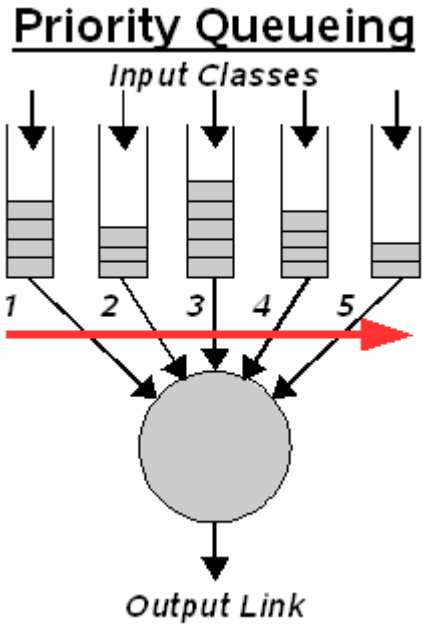
Packet Scheduling / Queueing 1

- FIFO
  - best effort service only
  - prior admission control and policing may improve fairness



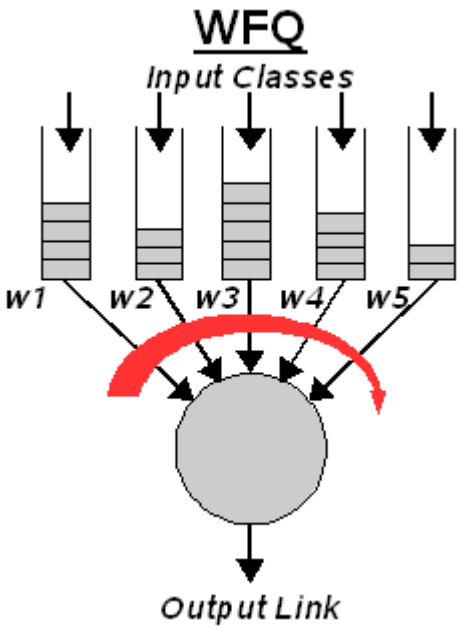
Packet Scheduling / Queueing 2

- (Strict) Priority Queueing
  - different services according to bandwidth and delay
  - unfair, because starvation of low priority flows possible



Packet Scheduling / Queueing 3

- Weighted Fair Queueing (WFQ)
  - each queue receives a portion of the available bandwidth resources
  - round robin according to weight of queues, guarantees fairness



Isochronism

An end-to-end network connection is called isochronous if the bit rate and the jitter over the connection life time is guaranteed and the jitter is also small.

- Isochronism therefore simply defines the requirements of continuous media streams.
- Remark:
  - The property of media like audio and video, that must be sampled and played in regular intervals is also called isochrony
  - Isochronism does not define quantitative values for jitter or probabilities refereed to by guaranteed.
  - If a jitter may be considered small depends on the application

Multicasting

Multicasting is the capability to replicate data at certain internal points. Replicated data is forwarded to endsystems which are part of a multicast group.

- multicast avoids or minimizes the multiple transport of the same data over the same network segments
- broadcast is a special case of multicast
- data duplication must be supported by forwarding engines in switches
- multicast types
  - one-to-many unidirectional
  - one-to-many bi-directional
  - many-to-many
- Note: The multicast or broadcast capability on OSI layer 2 is usually a prerequisite for the realization of multicast on layer 3.

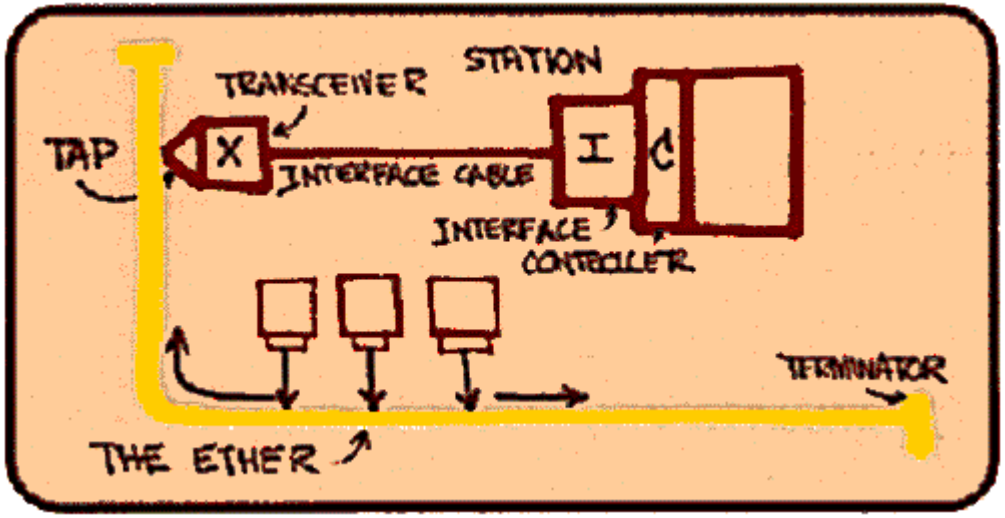
4.2. Networks

Different network characteristics lead to different usability for the transport of multimedia data:

- QoS guarantees:
  - bandwidth
  - delay
  - delay variation
- Isochronism
- Multicast capability
- Flexibility:
  - bandwidth
  - traffic types
  - distance (LAN, WAN)
  - physical media
- Efficiency/Utilization of physical media
- Costs

4.2.1. Ethernet

- **History:**
  - Xerox Corp.: R. Metcalfe (PHD at the M.I.T.) and D. Boggs
  - Standardized by IEEE 802.3
    - there are vendor specific Ethernet variants, e.g. Ethernet V2
  - The original article from Robert M. Metcalfe and David R. Boggs Xerox Palo Alto Research Center



Ethernet

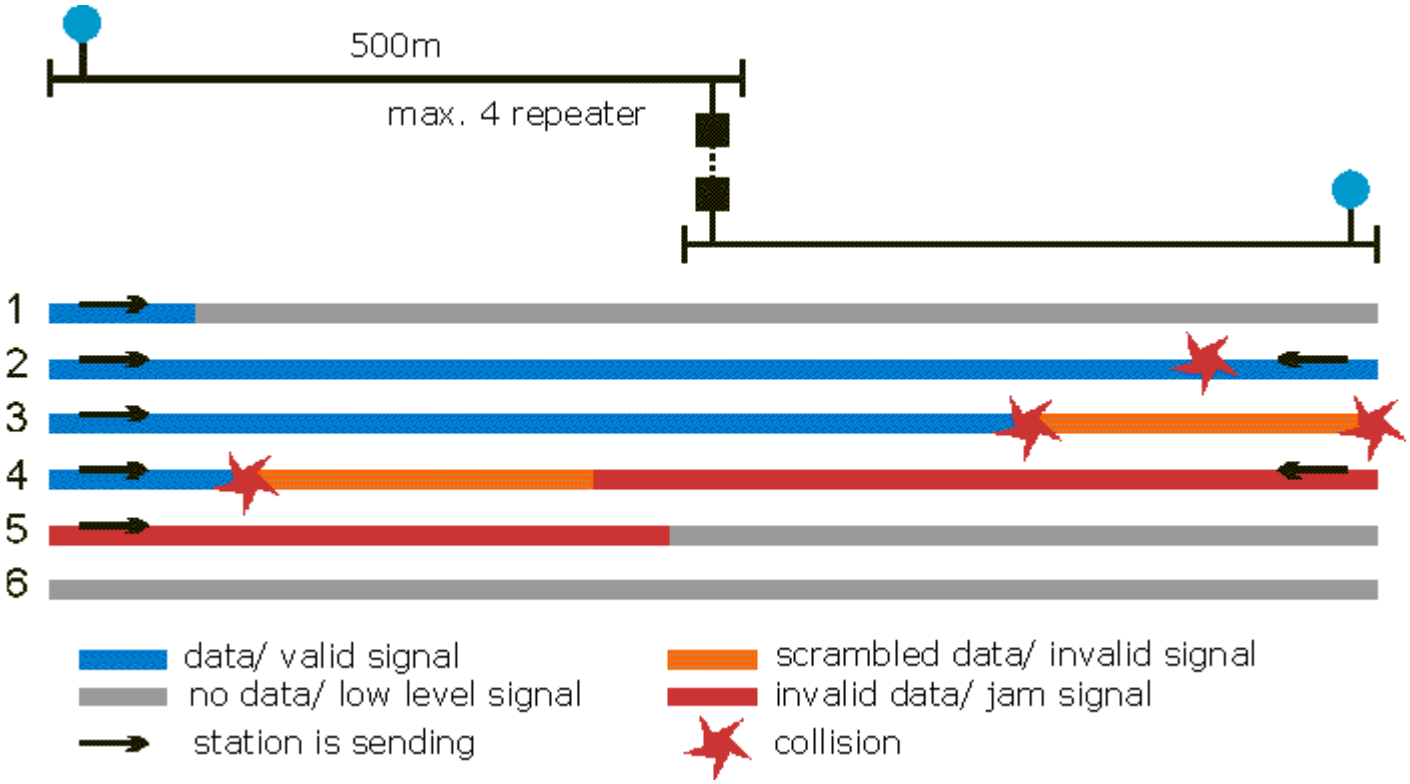
Characteristics:

- Bus topology
- Several physical media: coax cable, twisted-pair, fiber
- Bus characteristics:
  - max. segment size
  - min. distance between nodes
  - Repeater/Hub/Switches for longer distances
- access protocol CSMA/CD (Carrier Sense Multiple Access with Collision Detection)

Ethernet: CSMA/CD Protocol (1)

- Carrier Sense Multiple Access with Collision Detection:
  - Carrier sense: check if there is traffic on the net before sending
  - Multiple access: each station "listens" simultaneously to the net and tries to send
  - Collision detection: if multiple stations are sending, data will be corrupted, wait and try again
- CSMA/CD is a medium access (MAC) protocol
  - A shard medium provides half-duplex communication (HDX) only
  - Collisions are not errors, they are part of the distributed channel arbitration mechanism

Ethernet: CSMA/CD Protocol (2)



Ethernet: CSMA/CD Protocol (3)

1. Station A determines there is no data on the bus and starts sending data.
2. Before the data of A has arrived at station B, station B has determined there is no data on the bus and starts sending data also, leading to a collision.
3. The scrambled data spreads over the bus, station B recognizes the collision.
4. After recognizing the collision station B must send a jam signal with a length equal to 32 bits.
5. Station A recognizes the collision when the scrambled data arrives at station A or at least when the jam signal arrives, station A sends a jam signal also.
6. The bus is empty after some waiting time.

A station must continuously send data for at least twice the network transit delay of the signal in order to recognize a collision. Since the transmission speed is fixed the station must send a sufficient number of bits.

100 Mbit/s Ethernet

100 Mbit/s Ethernet

- New physical layers
  - 100 Base-TX (802.3u) max length 100 m
  - 100 Base-T4 (802.3u) max. length 100 m
  - 100 Base-T2 (802.3y) max. length 100 m (no fullduplex mode)
  - 100 Base-FX (802.3u) max. length 150m - 10km
- The slot time is still 64 bytes
  - the physical network must be much smaller, e.g. max of 205m for coax cable
  - no problem when using star topology with switches and 100m twisted pair cables

New Features (1)

- **full duplex mode (FDX)**
  - peer-to-peer only
  - no CSMA/CD
  - lower delay and jitter
- **auto-negotiation of bandwidth and HDX/FDX mode**
  - by modified and backward compatible link integrity pulses
  - 100 Mbit/s device changes to 10 Mbit/s if receiving „old“ integrity pulses
- **flow control**
  - with CSMA/CD a switch could send jam signals reducing traffic at an ingress port
  - with FDX a PAUSE frame is defined
    - the receiver of a PAUSE frame has to slow down
    - uses a special multicast address
    - is not forwarded by the receiver

Gigabit Ethernet

1 Gbit/s Ethernet

- 1 Gbit/s over category 5 cables is specified
  - problems with crosstalk may still occur
  - special testing is required
- several new physical layers
  - with single mode fiber distances of up to 5 km are possible
- slot time is extended to 512 bytes for HDX mode (which requires CSMA/CD)
  - if necessary a frame extension (null-data) is added after the CRC
  - with 64 byte packets a throughput of only around 100 Mbit/s could be achieved
- frame bursting defines the concatenation of frames for HDX Gigabit Ethernet to improve performance
  - a burst must not exceed 65536 bit
  - frames are separated by special signals

Ethernet: Usability for Multimedia Data

QoS parameters:	No end-to-end guarantees possible No priorities supported
Isochronism:	not available
Multicast capability:	Multicast group addressing supported Broadcast group addressing supported
Flexibility:	formerly fixed bandwidth of 10 Mbit/s, Ethernet derivatives up to 10 GBit/s
Efficiency:	with CSMA/CD: low throughput at high utilization because of collisions bad efficiency for small frames because padding is required to ensure the necessary minimum frame size
Costs:	Low cost technology enables dedicate connected systems 10/100 Mbit/s guaranteed bandwidth per host in small LANs

4.2.2. ISDN: Integrated Services Digital Network

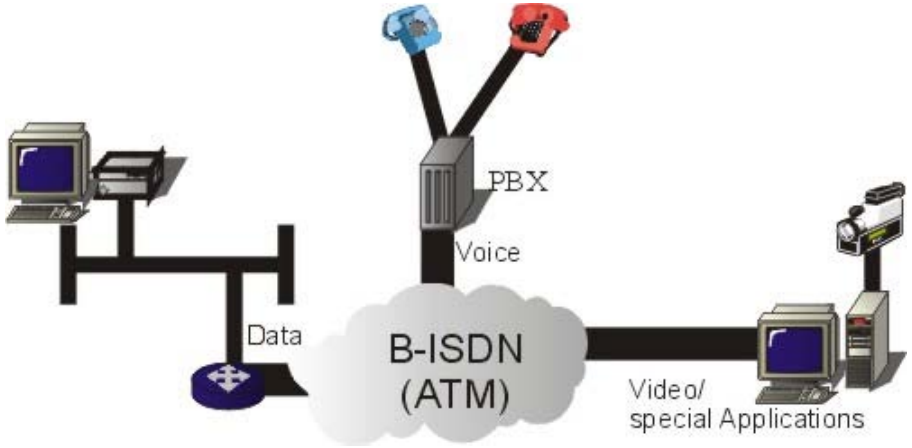
- **Standardization:**
  - ITU recommendations (former CCITT)
  - ETSI and ANSI standards
- **Characteristics:**
  - Public, digital, end-to-end network
  - Implements digital bit pipe
    - Based on 64 Kbit/s data rate
    - Multiple full duplex data channels
  - Support for multiple media and services within one network:
    - Voice, low quality video, image data, text data,
    - supplementary services
  - Common signaling channel with common set of signaling protocols
- **Technology:**
  - Circuit switching
  - Fixed bandwidth channel assignment

ISDN: Interfaces

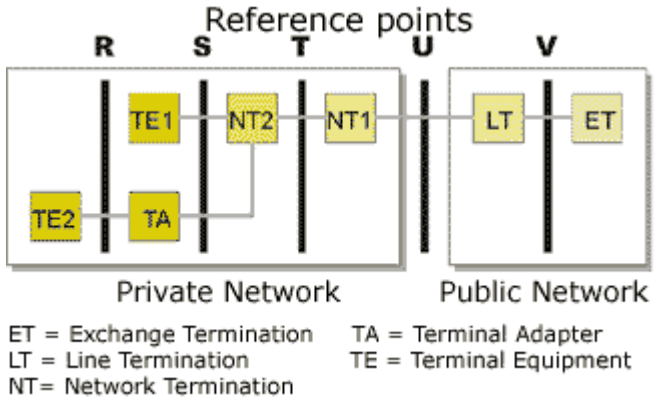
- ISDN User Interfaces
  - Basic Rate Interface
    - 2 data channels (B channel) with 64 Kbit/s
    - 1 signaling channel (D channel) with 16 Kbit/s
  - Primary Rate Interface:
    - 30 data channels (B channel) with each 64 Kbit/s in Europe
    - 1 signaling channel (D channel) with 64 Kbit/s
- ISDN Protocol Reference Model
  - Extensions to ISO/OSI:
  - User plane: for user data
  - Control plane: for connection management
  - Packet oriented D channel signaling
- Channels:
  - A - 4kHz analog
  - B - 64 Kbps digital PCM
  - C - 8 or 16 Kbps digital
  - D - 16 or 64 Kbps digital signaling
  - E - 64 Kbps digital internal signaling
  - H - 384, 1536 or 1920 Kbps digital

ISDN: Topology + Interfaces

- **Star topology, different technologies in LAN and WAN**



- **Formats are defined for Interfaces only**
  - Interfaces are described as reference points



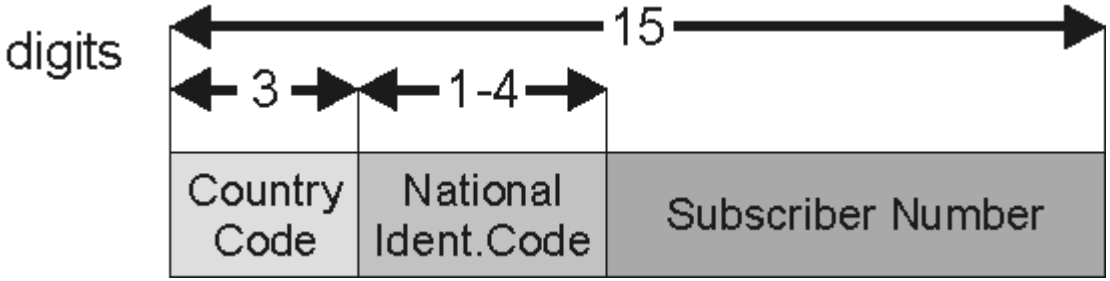
ISDN: Network Access

- **Time Division Multiplexing maps several 64 Kbps channels to one faster channel**
  - A frame consists of a header and a fixed number of slots

  - A frame is generated each 125 micro-sec
  - The slot size is 8 bit
  - During signaling a fixed mapping between channels and slot numbers is defined; this is called Synchronous Time Division Multiplexing (STDM)
    - The mapping is valid for two adjacent devices only
    - Technology: Synchronous Digital Hierarchy (SDH) or SONET

ISDN: Addresses

- **Defined by the ITU in E.164 Format:**



  - Prefixes are not part of the number (the prefix in Germany is ‚0‘)
  - Digits are represented as binary coded decimals (BCD)
  - 8 bytes are used to represent 15 digits
  - Example: 0049 631 205 2263
    - 00 is used in Germany to identify an international number
    - 49 is the country code for Germany
    - 631 is the area code for Kaiserslautern
    - 205 is the subscriber number of the university
    - 2263 is a sub address (called "extension"), it is used within a private network only

ISDN: Usability for Multimedia Data

QoS parameters:	guaranteed bandwidth low delay and low delay variation (not guaranteed, e.g. Satellite links with significantly higher delay)
Isochronism:	guaranteed by design principles
Multicast capability:	no multicast capabilities
Flexibility:	fixed bandwidth although ISDN is used for end-to-end communications, it is mainly a WAN technology independent of physical media
Efficiency:	low bandwidth utilization
Costs:	expensive bandwidth (Telecom ports include WAN connectivity)

4.2.3. B-ISDN (Broadband ISDN) / ATM

- **Standardization:**
  - ITU recommendations (former CCITT)
  - ATM Forum (organization of vendors, specifications only
- **Characteristics:**
  - For LAN and WAN networks
  - For private and public networks
  - Support of fine granular Quality of Service
    - Suitable for all media types
  - Low and high bandwidth is supported
  - Connection oriented
- **Technology:**
  - Cell Switching
  - ATM – Asynchronous Transfer Mode