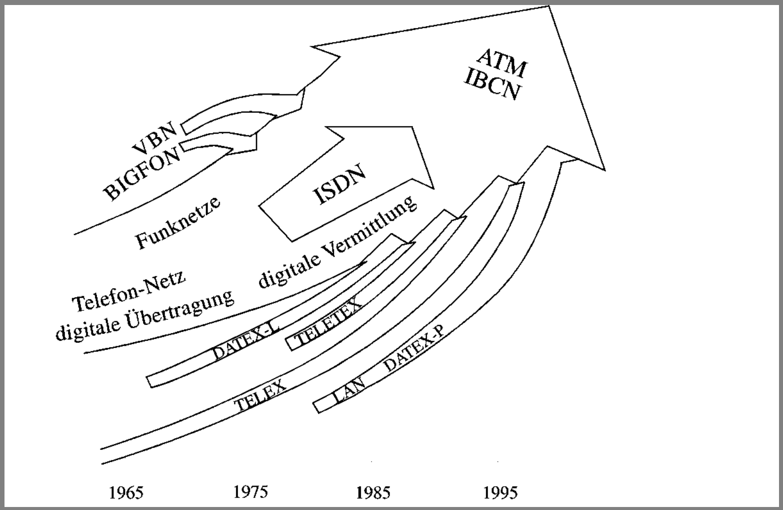
Integrated Communication Systems

ICSY

Multimediale Visualisierungssysteme WS 2000/2001

4. Networks



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AG: Integrierte Kommunikationssysteme

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Literatur

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Site Map

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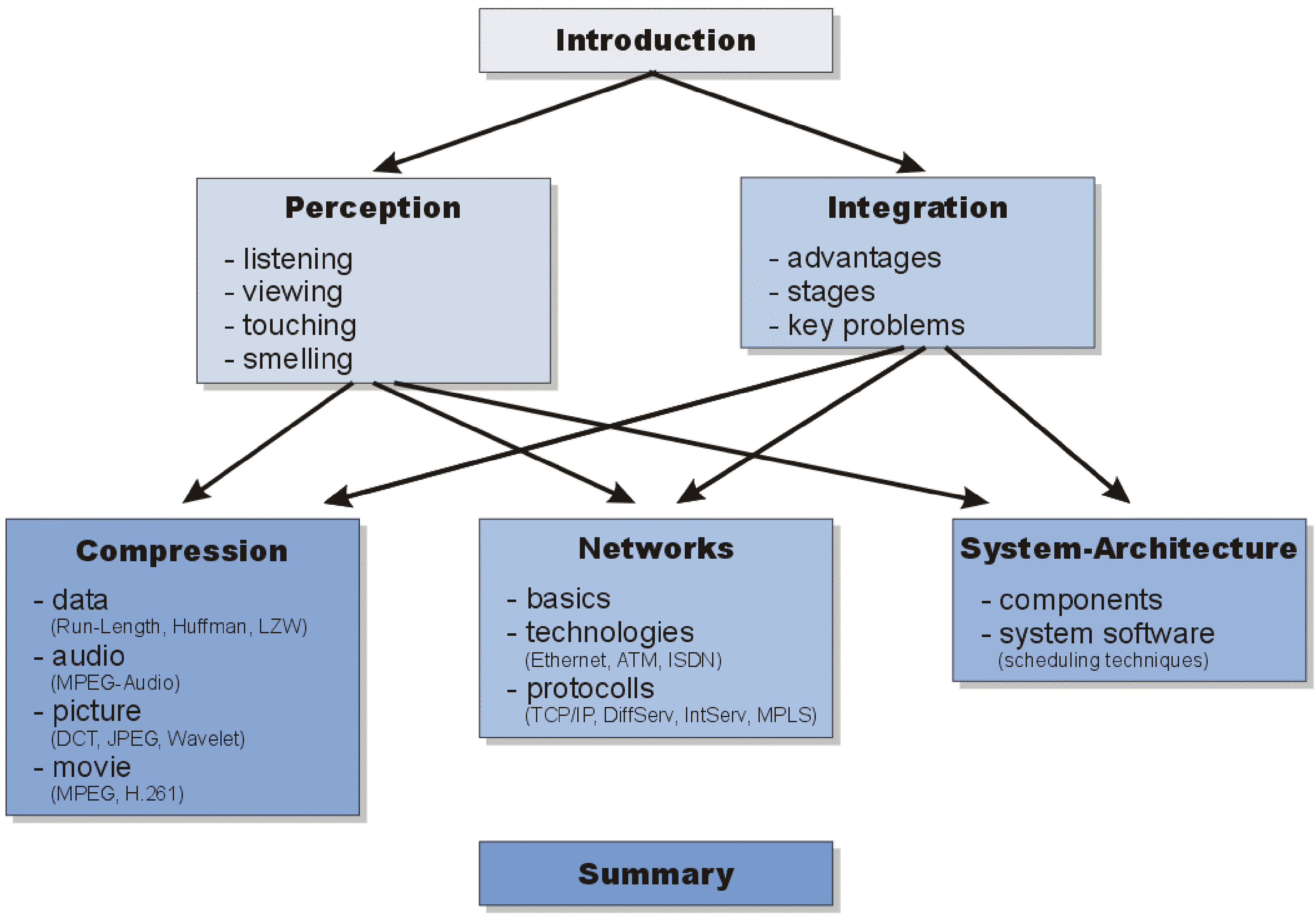
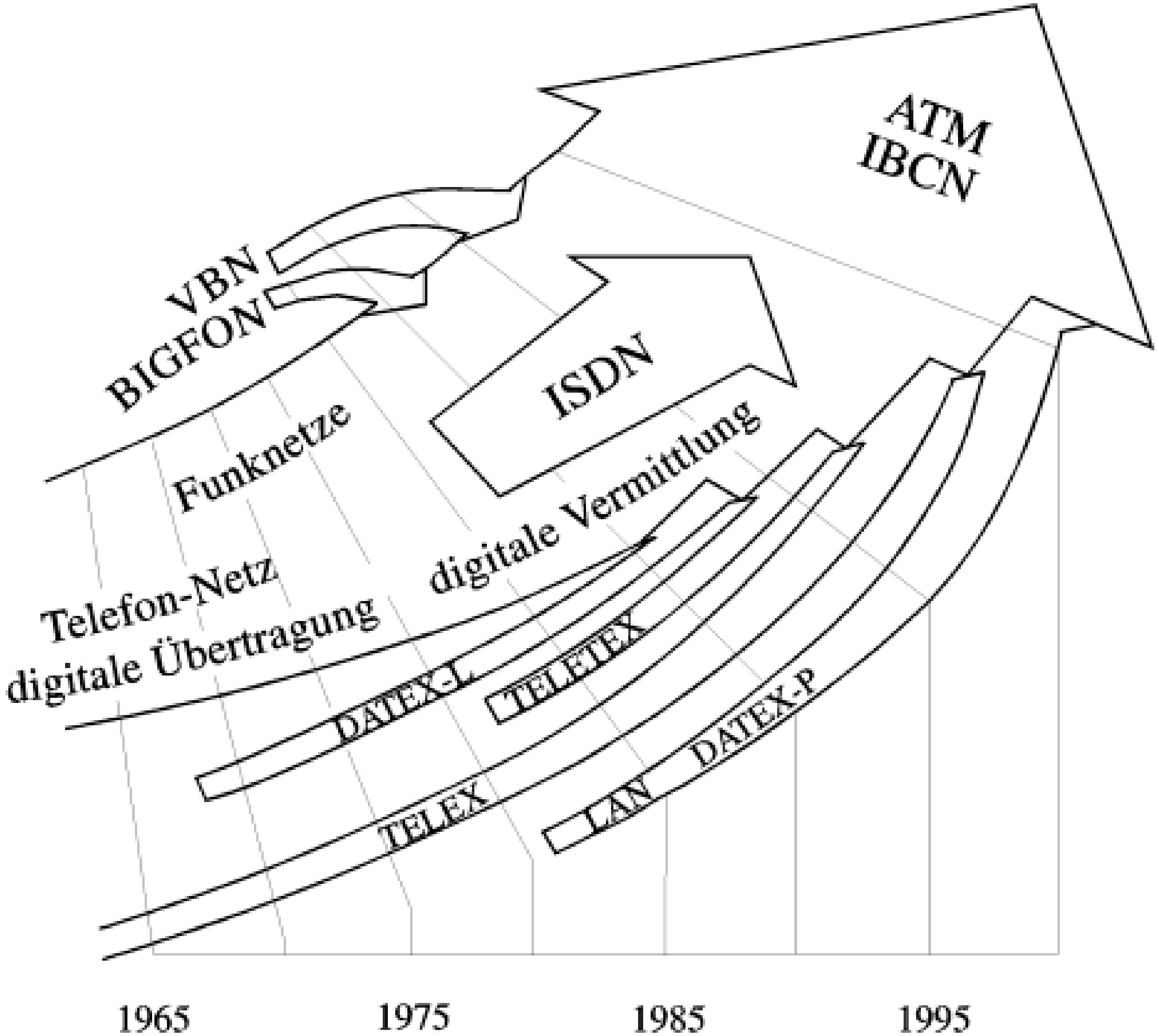


Networks


ATM
IBCN
VBN
BIGFON
ISDN
Funknetze
digitale Vermittlung
Telefon-Netz
digitale Übertragung
DATEX-L
TELETEX
TELEX
LAN
DATEX-P
1965
1975
1985
1995

Network Types and Services

Network	Services	Physical Type
Telefon	Voice (1:1 and 1:n), Fax, Video, Text, Data, ...	cable (copper, glass), wireless, satellite
Telephone (mobile)	Voice, Fax, Text, Data,...	wireless + cable
Internet	Data, Text, Voice, Audio, Video, ...	cable (copper glass), wireless
Intranet	Data, Text, Voice, Audio, Video, ...	cable (copper, glass), wireless, satellite
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

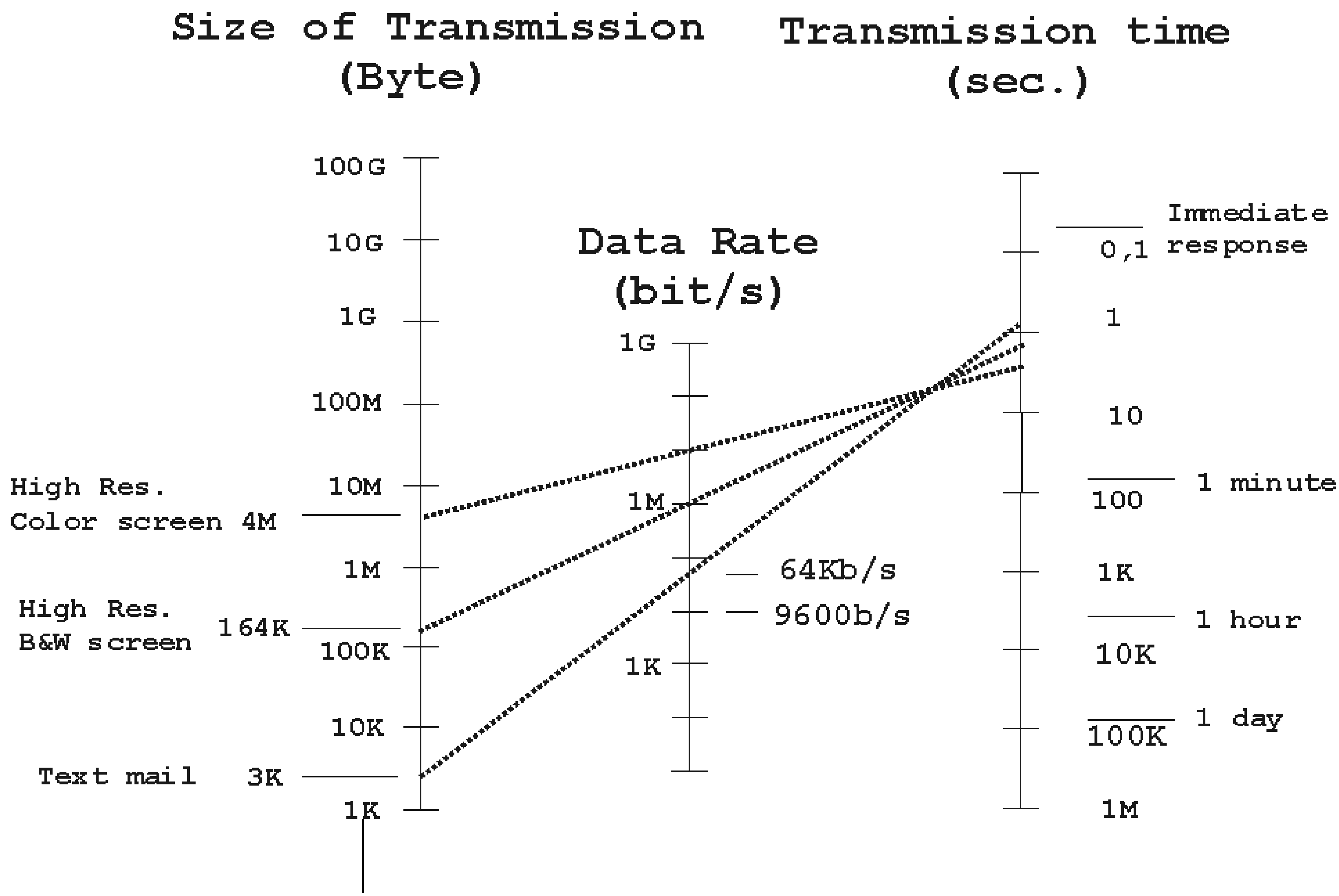
Additionally very specialized Networks:

– Bank connections

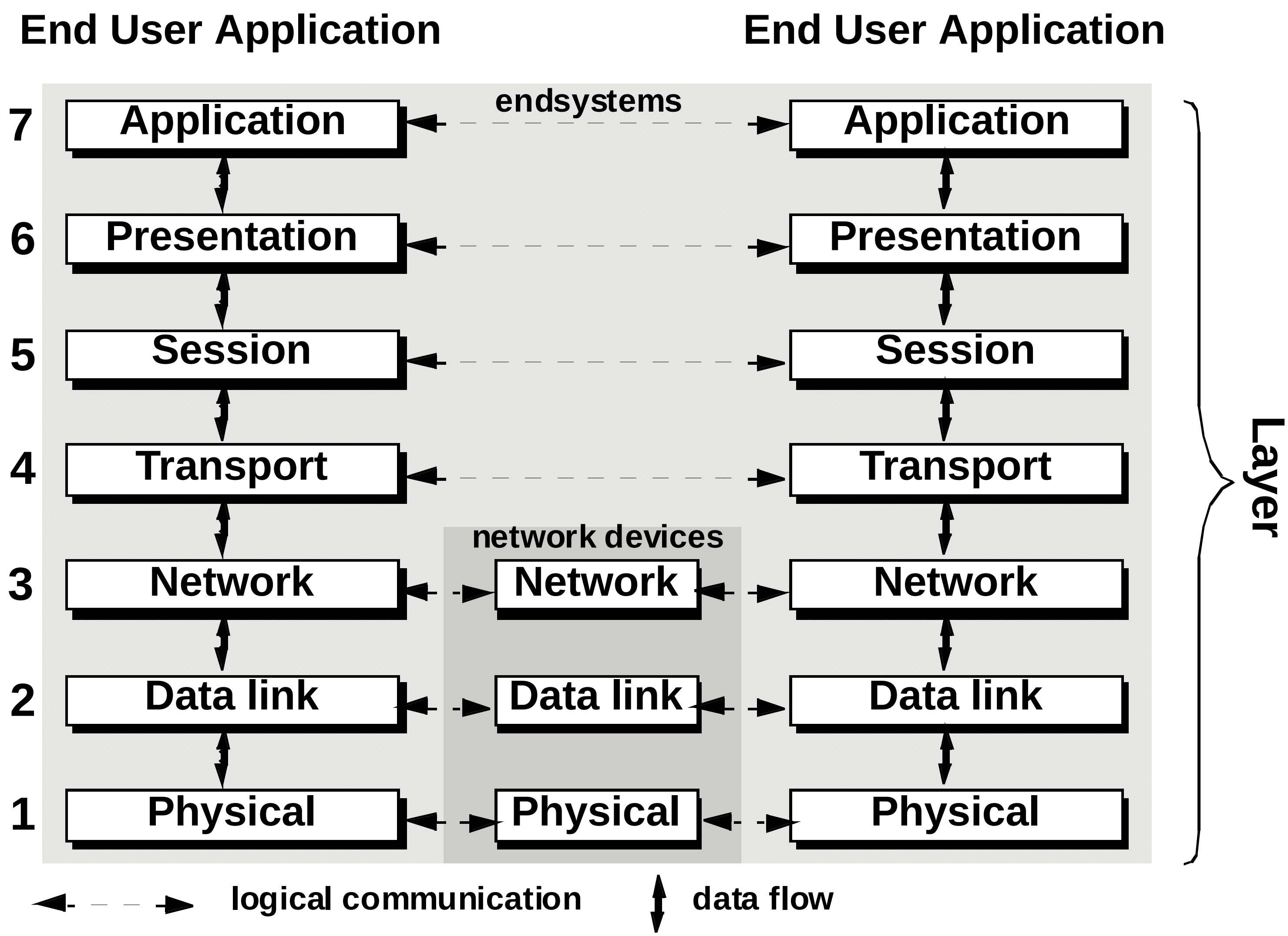
– Controlling (traffic, machines, in house systems, ...)

– Supervising (alarm systems, gas pipes, street lights, ...)

Size versus time of transmission



ISO / OSI Reference Model



ISO / OSI Reference Model

1 The physical layer defines electrical signaling on the transmission channel; how bits are converted into electrical 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 packets are transmitted as bits. An example of a data link layer protocol is Ethernet. A network device for this layer is called a bridge.

Technology (usually hardware)

Protocolls (usually software)

3 The network layer defines how information 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

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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.

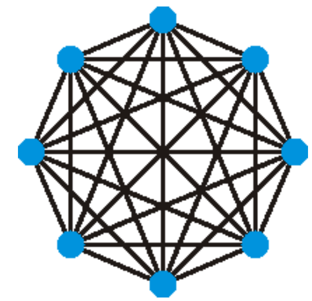
5 The session layer establishes and terminates connections and arranges sessions to logical parts. TCP and RPC provide some functions at this layer.

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).

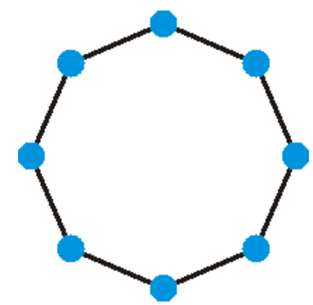
Network Topologies 1

Complete mesh



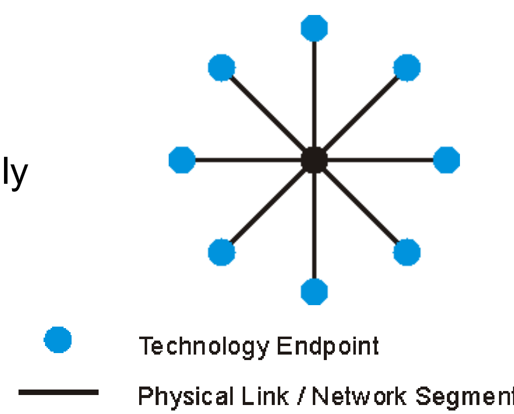
- ideal performance
- high reliability
- only for networks with small expanse
- $\frac{n(n-1)}{2}$ connections

Ring



- reliability
  - absorb drop out of one link
- easier cabeling
- $n-1$ connections

Star

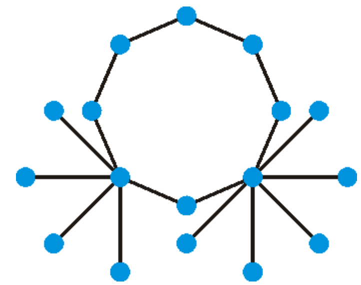


- reliability
  - drop out of one link affects one endsystem only
  - node in the middel is single point of failure
- complex cabling for large expanse networks
- n connections

Network Topologies 2

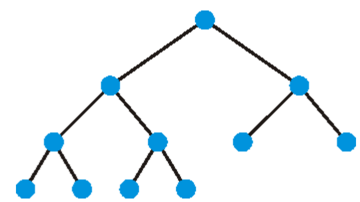
Combination

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



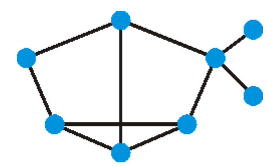
Tree

- is a combination of star topologies



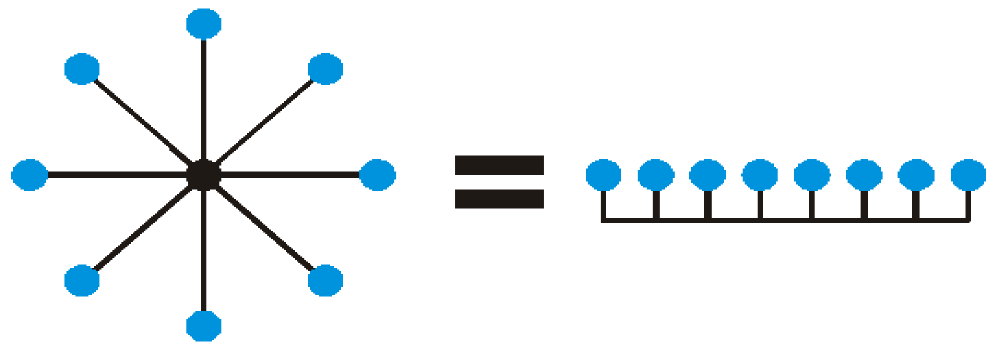
Irregular

- some applications may require specialized topologies



Connectivity on layer 1

- connectivity on Layer 1



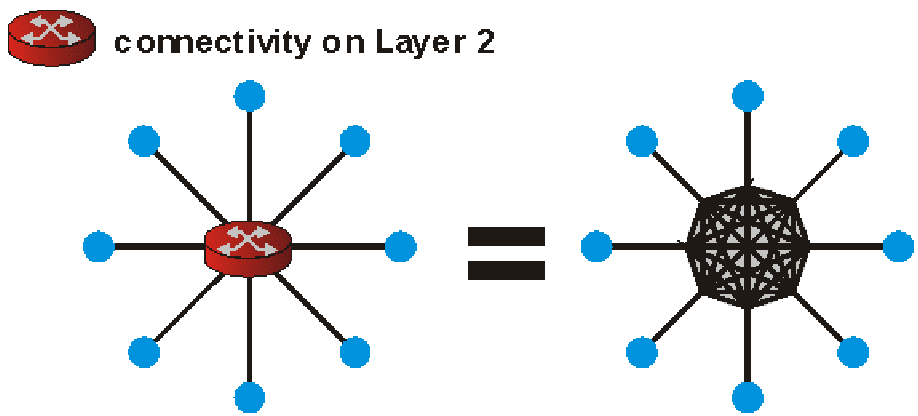
Repeater

- provides connectivity on Layer 1, by boosting electrical signals
- network segments are expanded with repeaters, the result is still one segment

Hub

- is a multi-port repeater
- is a shared medium like a bus

Connectivity on layer 2



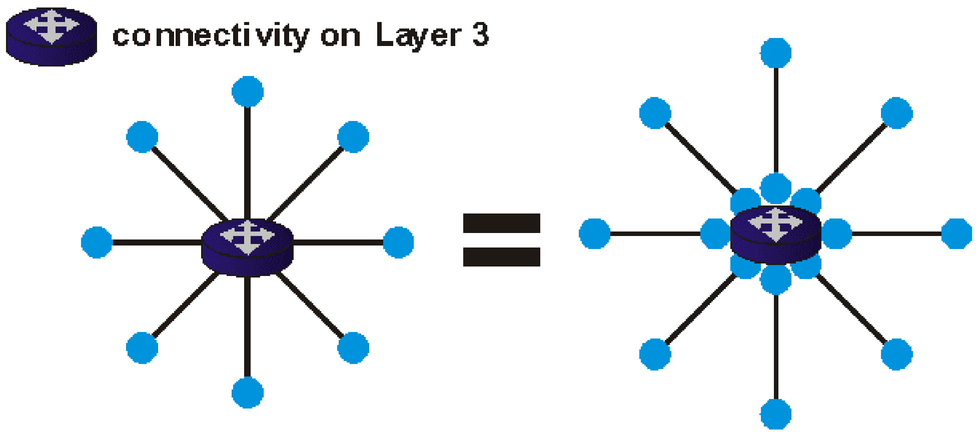
Bridge

- provides connectivity on Layer 2, by forwarding frames between two segments
  - if the receiver resides on the other segment
  - if the receivers location is unknown
  - if 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

Switch

- is a mutli-port bridge
- provides dedicated connections between all ports, i.e. does not realize a shared medium

Connectivity on layer 3



Router

- 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
  - must be simplified to be managable
- receives external information to make a routing decision
  - static information may be configured by an administrator
  - dynamic information may be collected by routing protocolls

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 if a frame must be forwareded, identifying the output port and perform 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 must be forwareded and perform the forwarding
- forwarding a packet includes the generation of a new frame
- routing is a layer 3 functionality

Combined devices

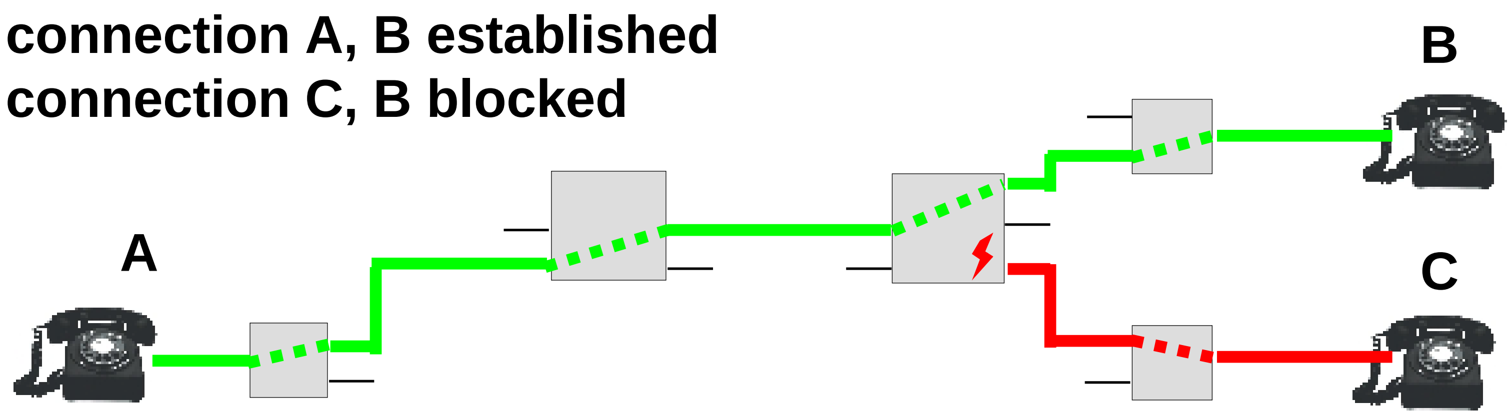
- switching-hubs oder route-switches denote combined device

Switching concepts

- denote different network philosophies
- are made for different media types
  - circuit switching, emulating a physical link
  - packet switching, handle packets or frames
  - cell switching, handle cells which are packets of constant length

Circuit switching

Provide a “physical” link:



Advantages:

- guaranteed bandwidth and delay
- worldwide available

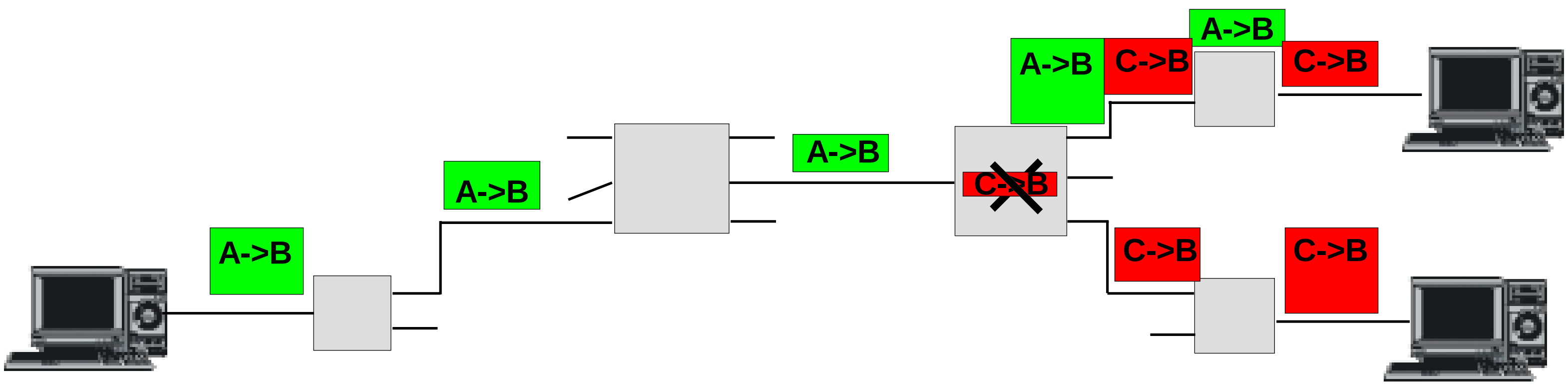
Disadvantages:

- bandwidth not scalable
- bad efficiency (bandwidth usage)

Packet switching

Handle independent packages

A + C sending packages of different size to B
Packet may be lost because of congestion



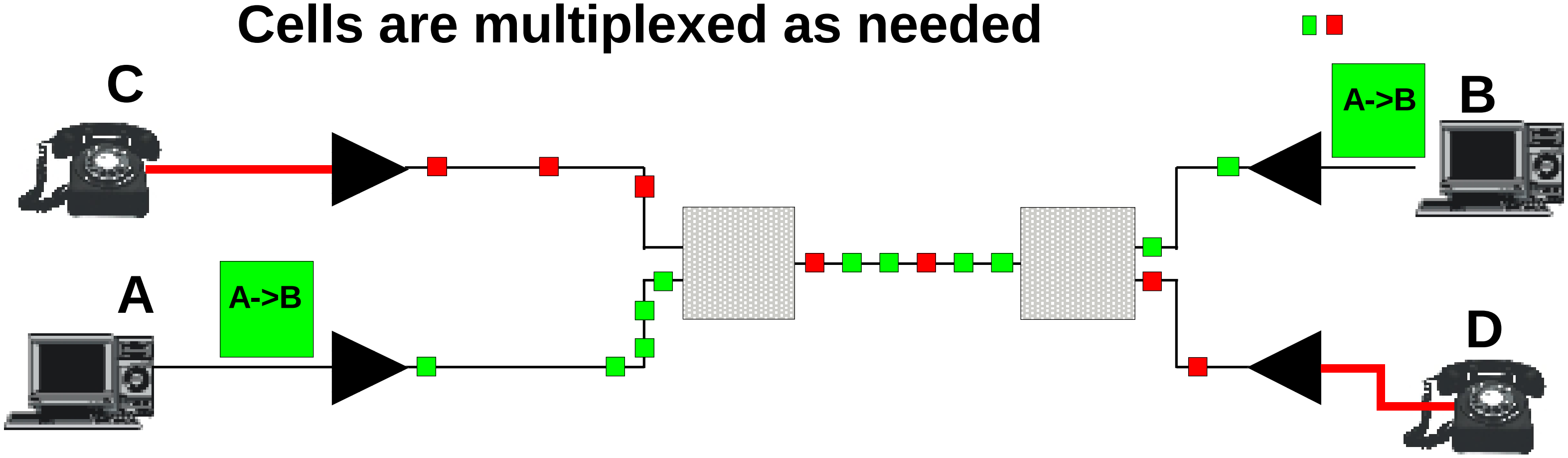
Advantages:
- high efficiency (bandwidth usage)
- bandwidth is scalable

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 (fixed size)
Cells are multiplexed as needed



Advantages:

- high efficiency (bandwidth usage)
- bandwidth is scalable
- guaranteed bandwidth and delay

Disadvantages:

- small availability

Speed versus Distance

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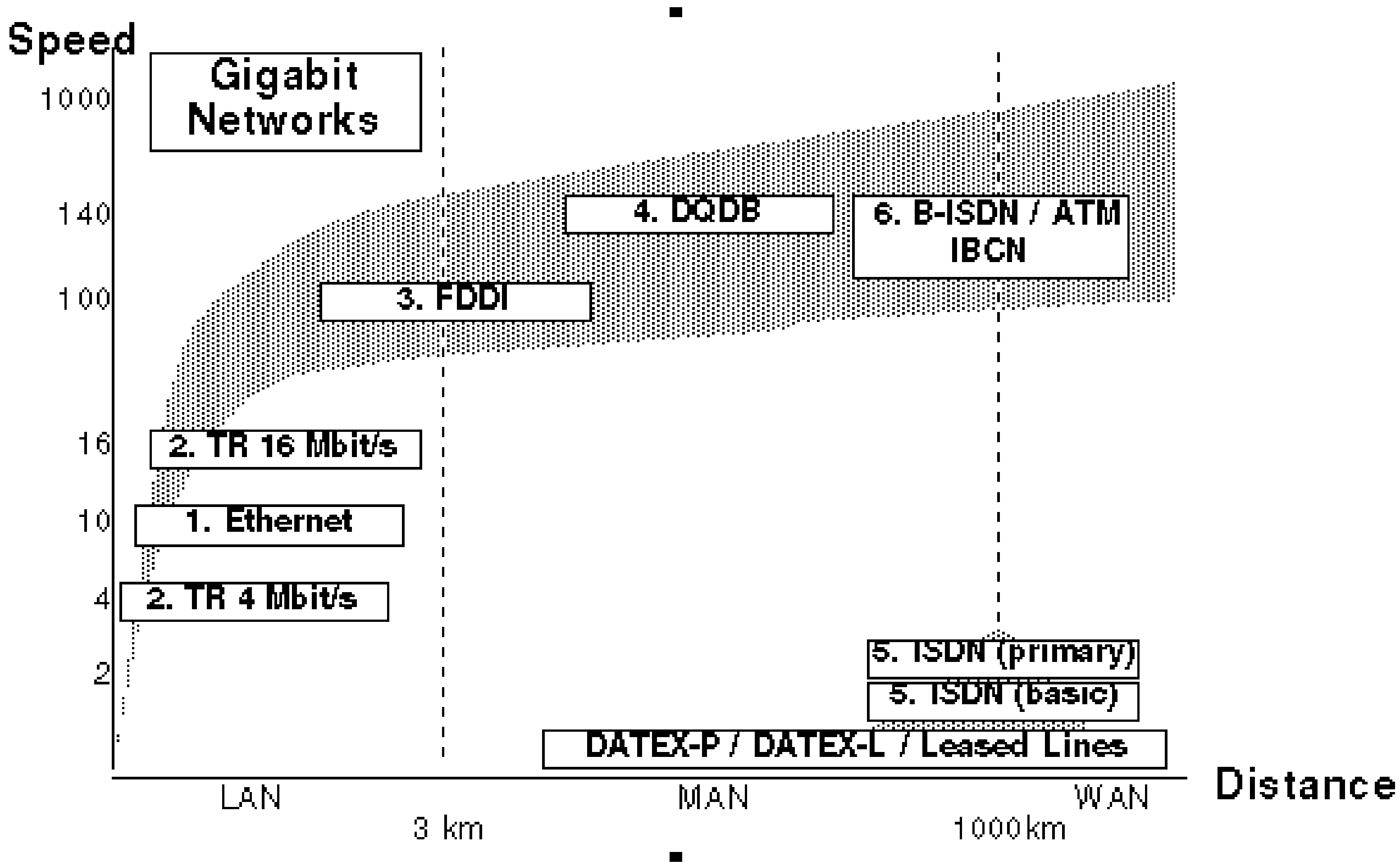


Networks

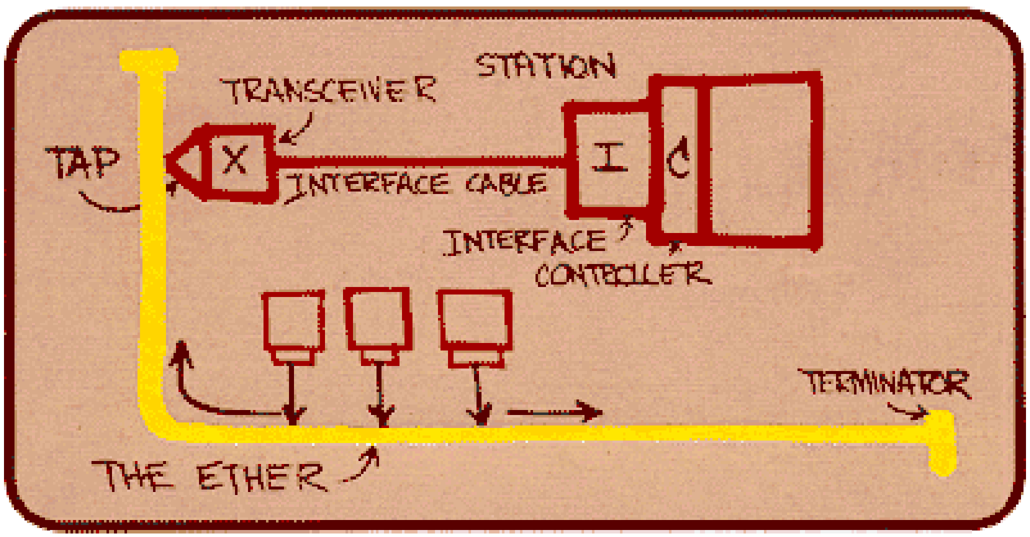
Different network characteristics lead to different usability for the transport of multimedia data:

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

4.1 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



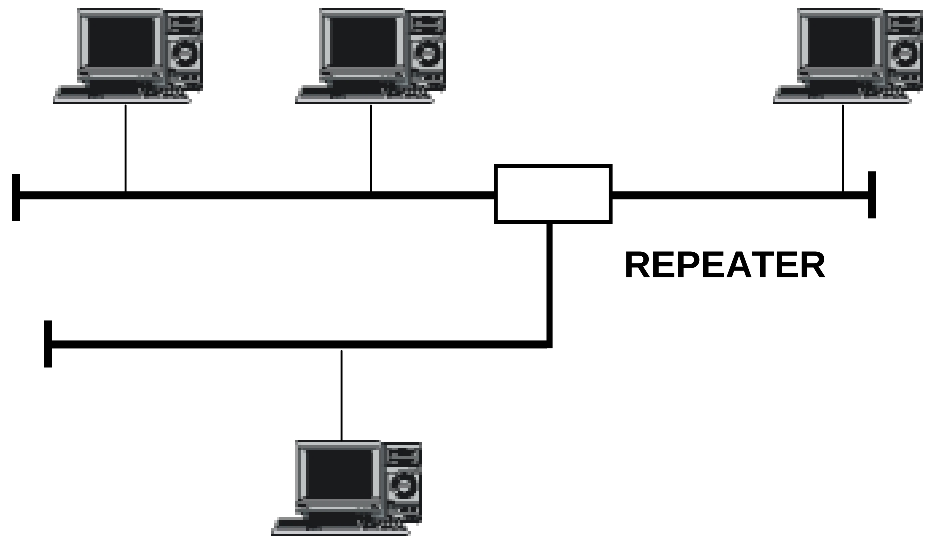
Ethernet

Characteristics:

- Bus topology
- Coax cable at 10 MBit/s
- Bus characteristics:
  - max. segment size
  - min. distance between nodes
  - Repeater for longer distances
- CSMA/CD access protocol

Name	Cable	max. segment	nodes/seg
10Base5	Thick coax	500 m	100
10Base2	Thin coax	200 m	30
10Base-T	Twisted pair	100 m	1024
10Base-F	Fiber optics	2000 m	1024

Ethernet Structure: Topology



Bus structure

- flexible configuration

No special bus stations

Repeater to connect different busses

Ethernet: CSMA/CD Protocol 1

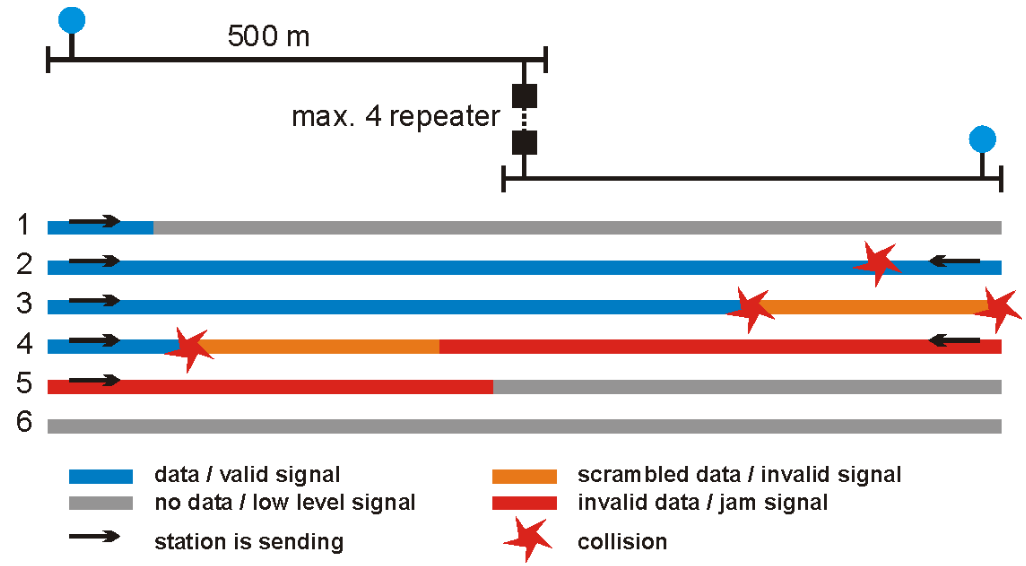
Carrier Sense Multiple Access with Collision Detection:

- 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



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 sent a jam signal with a length equal to 32 bits.
5. Station A recognizes the collision when the scrambled data arrive at station A or at least when the jam signal arrives, station A sents a jam signal also.
6. The bus is empty after some waiting time.

⇨ A Station must continuously send data for at least the round-trip time of the signal in order to recognize a collision. Since the transmission speed is fixed the station must sent a sufficient number of bits.

Ethernet: Minimum Frame Length

Minimum frame length

- the minimum frame length is defined to be 64 bytes
- data rate of 10 MHz ⇨ 64 bytes are sent in 51,2 µS (slot time)
- a collision must be detected at least 51,2 µS after beginning of data transmission

Propagation delays

- for coax cable a signal propagation of 0,77 * C is assumed
  - the propagation delay of a 500m coax cable is $\frac{500m}{0{,}77 * 300000000m/s} = 2{,}165\mu S$

Limited physical configurations

- depends on propagation delays
- large scale configuration, e.g.
  - 3 * 500m coax cable
  - 2 * 500m point-to-point link cable
  - 4 repeater
  - transceivers for repeaters and endsystems

propagation delays (generallized)	
Element	Delay
Encoder	0,60 µS
Decoder	1,80 µS
Transceiver cable (300m)	3,08 µS
Transceiver	0,50 µS
Point-to-point link cable (1000m)	10,26 µS
Repeater	1,00 µS

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Ethernet: Back-off

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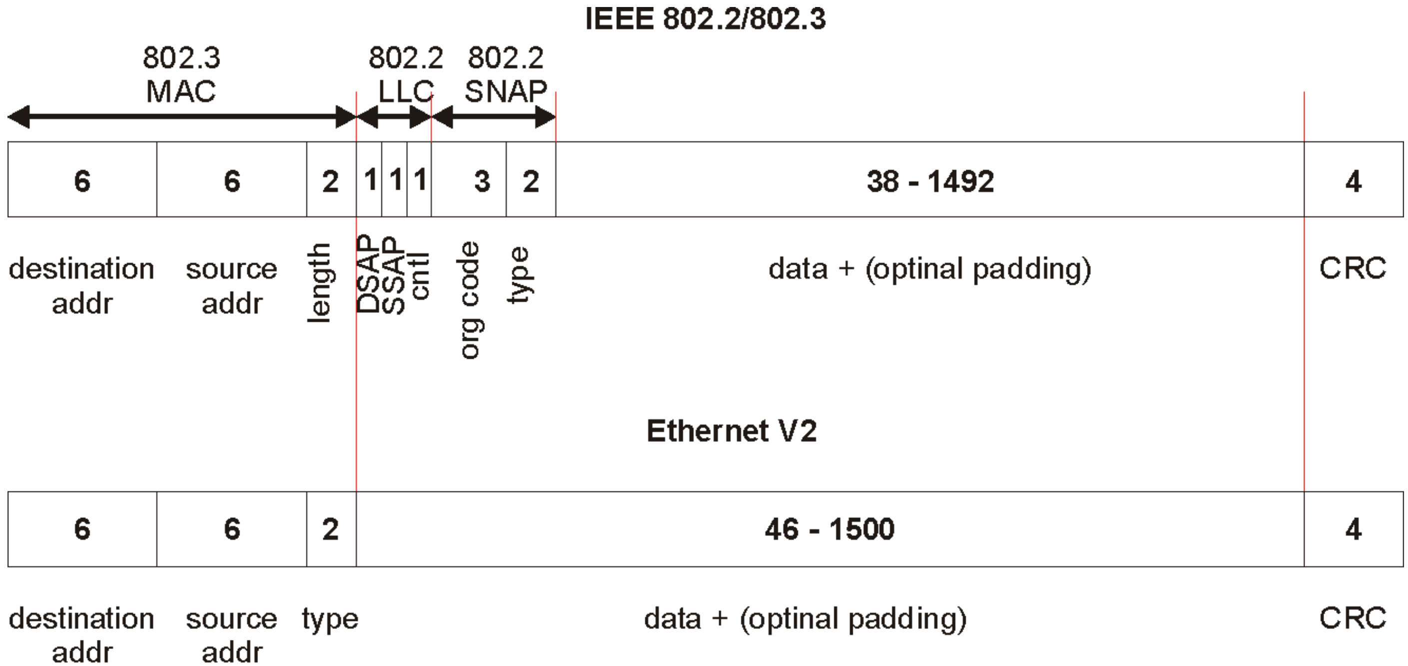
After a collision it must be avoided that two stations simultaneously start sending data again

- after sending the jam signal each stations waits for a random time

Binary Exponential Back-off Algorithm:

- 1st collision: wait 1 or 2 slot times with probability 0.5
- 2nd collision: wait 1 to 4 slot times with probability 0.25
- ...
- nth collision: wait 1 to 2^n slot times with probability 1/(2^^{10})

Ethernet Frame



MAC	= Medium Access Control	LLC	= Logical Link control
SNAP	= Sub-network Access Protocol	DSAP	= Destination Service Access Point
SSAP	= Source Service Access Point	cntl	= control
org code	= organization code	CRC	= Cyclic Redundancy Check

two frame formats for Ethernet

- IEEE defines a length field + technology independent type description
  - LLC defines upper layer protocoll types for sender and receiver
  - SNAP is an extension to LLC since protocoll identification with SAP was insufficient
- vendor defined Ethernet V2 uses a simple type field only
- since length < 0x0600 ≤ type; frame types could be recognized automatically

Ethernet: Usability for Multimedia Data

Performance:

- No end-to-end guarantees possible
- No priorities supported

Flexibility:

- fixed bandwidth of 10 Mbit/s
- short distances

Multicast capability:

- Multicast group addressing supported

Efficiency:

- Low throughput at high utilization because of collisions

Costs:

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 dealy and jitter

auto-negotiation of bandwidth and HDX/FDX mode

- by modified and backward compatible link integrety 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
- is faster than „old“ 32 bit and 33 Mhz PCI busses
- slot time is extended to 512 bytes for HDX mode (which requires CSMA/CD)
  - if neccessary 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

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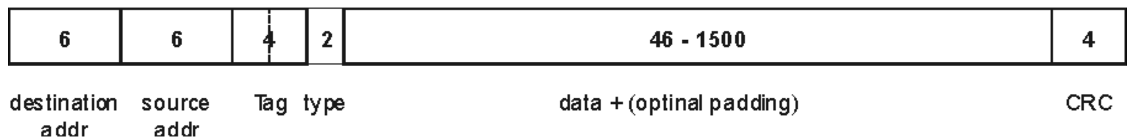
New Features 2

IEEE 802.3Q / VLAN tagging

– defines a new header field for VLAN tagging



- the VLAN tags are inserted only by network devices
- the first 2 byte of the tag are equal to an undefined type, endsystems discard those frames
- the maximum frame length is increased

IEEE 802.3p / priority switching

– defines a new header priority field in order to support Quality of Service at layer 2

– defines new management protocolls to support VLAN and QoS capabilities

IEEE 802.3ad / link aggregation

– allows the aggregation of several layer 2 links to one logical link

10 Gigabit Ethernet

10 Gbit/s Ethernet

- definition of last features expected for end of 2000
- standard expected in march 2002
- should be used as WAN technology also
  - distances of more than 50 km must be possible
  - new management functionalities are required, e.g. definition of virtual circuits/links

Interesting links

Gigabit Ethernet

http://www.gigabit-ethernet.org

10 Gigabit Ethernet

http://www.10gea.org

4.2 Token Ring

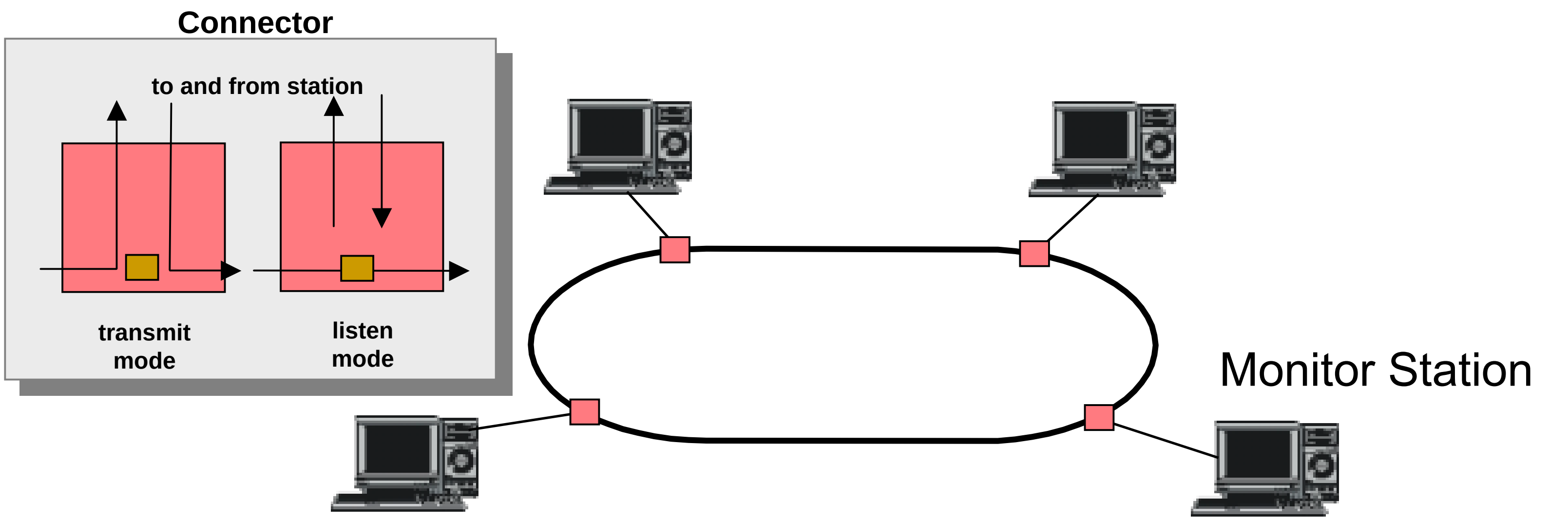
History:

- Introduced by IBM 1985
- Standardized by IEEE 802.5 (ECMA 89, ISO 8802/5)

Characteristics:

- Ring topology
- Shielded coax cable (double) at 4 or 16 MBit/s
- Ring characteristics:
  - Maximal 260 stations per ring
  - Bridges to connect several rings
- Token controld media access:
  - Rotates on ring
  - Owner of token may send data
  - Priority fields

Token Ring Structure: Topology



Ring Structure (logical):

- Build of several point-to-point links, not a shared medium
- The physical topology may differ
- The ring must have a sufficient delay to contain a complete token

One station is the data source and data sink

- This station is in transmit mode
- All other stations are in listen mode

A monitor station is responsible for the ring maintenance

Drop out of a station

- Requires the rearrangement of the ring (automatically)
- Connector must interconnect the ring in case of power down

Token ring: MAC protocol

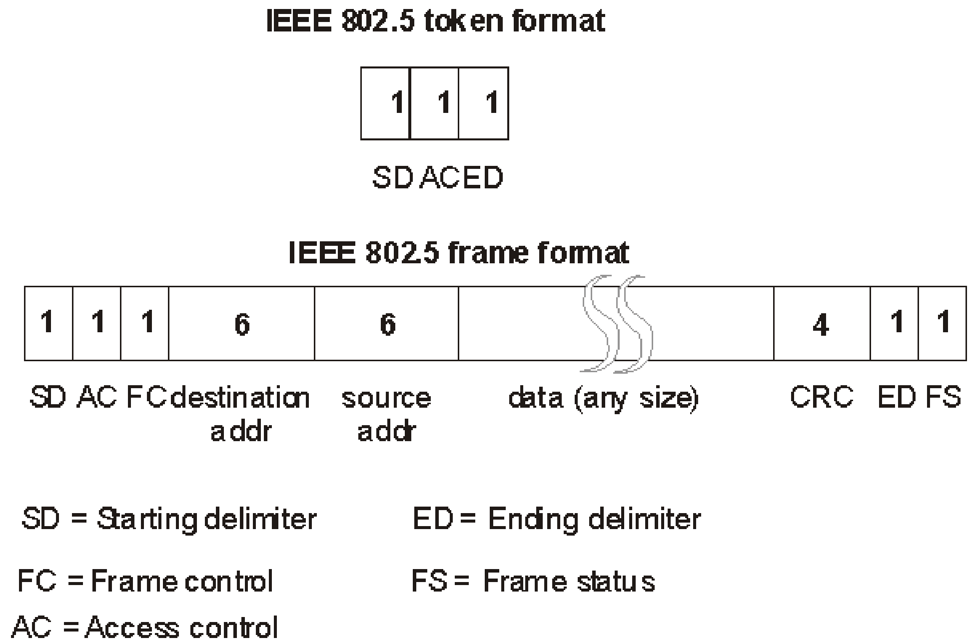
Ring access rules

- a station is allowed to send data if it is the owner of the token
- a station must not hold the token for longer than 10 msec
- receiver set flags in the data stream
  - receiver is present (accepted)
  - data copied (copied)
- only the sender removes data from the ring
  - inherent acknowledgement for correct data delivering

Priorities

- Each token has a priority, a station may use the token only if it has a packet of that or an higher priority
- All stations may request a token with a certain priority within the header of a passing frame (reservation)
- The next token is generated with the last requested priority or with the lowest priority if there was no reservation

Token Ring Frame



A token becomes the beginning of a frame by changing one bit

The address and CRC checksum fields are the same than for IEEE 802.3

The data size is technically not limited

FS contains the accepted and copied flags

- The flags are exists twice since they are not protected by the CRC

Token Ring: Ring Maintenance

One station functions as monitor station

- Dynamically assignment of the monitor station at configuration time
- Controls the token, verify proper functioning
  - Generate new token if lost
- Remove orphan frame or destroyed frames
- Introduction of 24-bit delay for token, if necessary

Token Ring: Bitlength Calculation

Length of a packet in km:

- Propagation delay: pd = 5 ms/km
- Bit delay per station: d_s = 2 bit
- Bit delay of monitor station: d_m = 24 bit
- Number of stations: assume n=10
- Bandwidth bw = 16 Mbit/s
- Packet length: n_p = 64*8 bit + 168 bit

$L = (n_p + n*d_s + d_m) / (pd * bw)$

= (64 * 8 + 10 * 2 bit + 24 bit) / (5 µs/km * 16 Mbit/s)

= 6.95 km

- 1 bit ~ 12.5 m

Token Ring Usability for Multimedia Data

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Performance:

- Bounded delay because of:
  - Token Holding Time
  - Deterministic access
- No bandwidth guarantees, but “reservation” possible by use of 4 priorities classes, e.g. high priority for continuous-media data traffic
- Priority Classes

Priority	Use
0	normal data transfer
1 – 3	available for data transfer
4	bridges
5 – 6	reserved
7	station management

Token Ring Usability for Multimedia Data

Flexibility:

- bandwidth of 4 or 16 Mbit/s
- short distances

Multicast:

- Multicast group addressing supported

Efficiency:

- High throughput at high utilization

Costs:

- complex protocol ⇨ “expensive” hardware

4.3 Token Bus

The Token Bus protocol was developed to meat the requirements of factory automation

Characteristics:

- Specified in IEEE 802.4
- Bus topology
- Shielded coax cable
- Defines a logical ring of stations
  - The order depends on MAC addresses
  - The MAC protocol is even more complex than for Token Ring
- Frame format is nearly the same than for IEEE 802.5
- Priorities are used to sort frames before sending only

4.4 FDDI
(Fiber Distributed Data Interface)

History:

- Based on IEEE 802.5 (Token Protocol)
- Standardized (ANSI X3T9.5, ISO 9314)

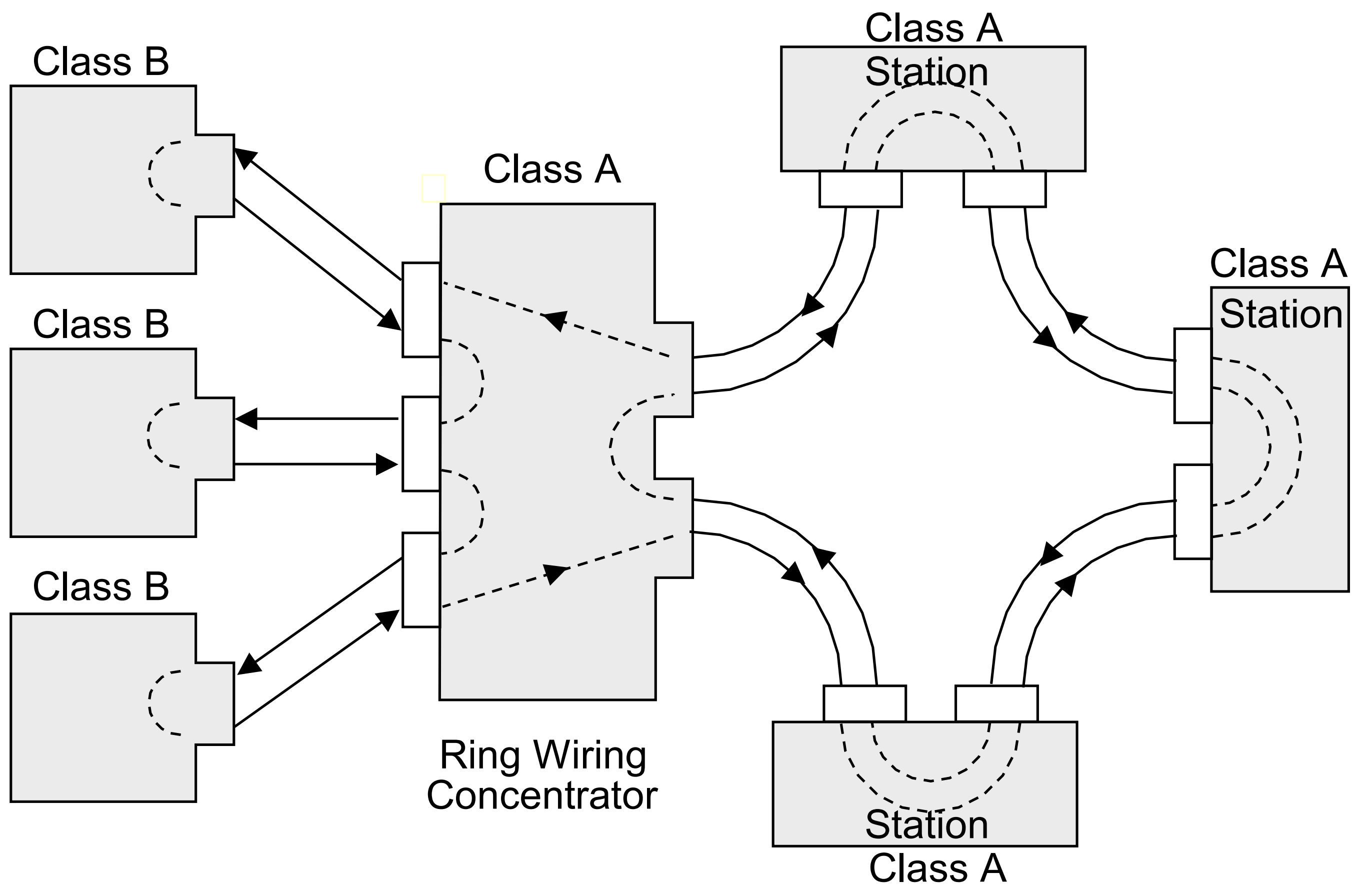
Ring Characteristics:

- Optical LAN at 100 MBit/s
- Up to 200 km in length with up to 2 km distance between two stations
- Up to 500 stations

Protocol Characteristics:

- Timer controlled token protocol
- Bidding process at (re-)configuration time
- Early token release option

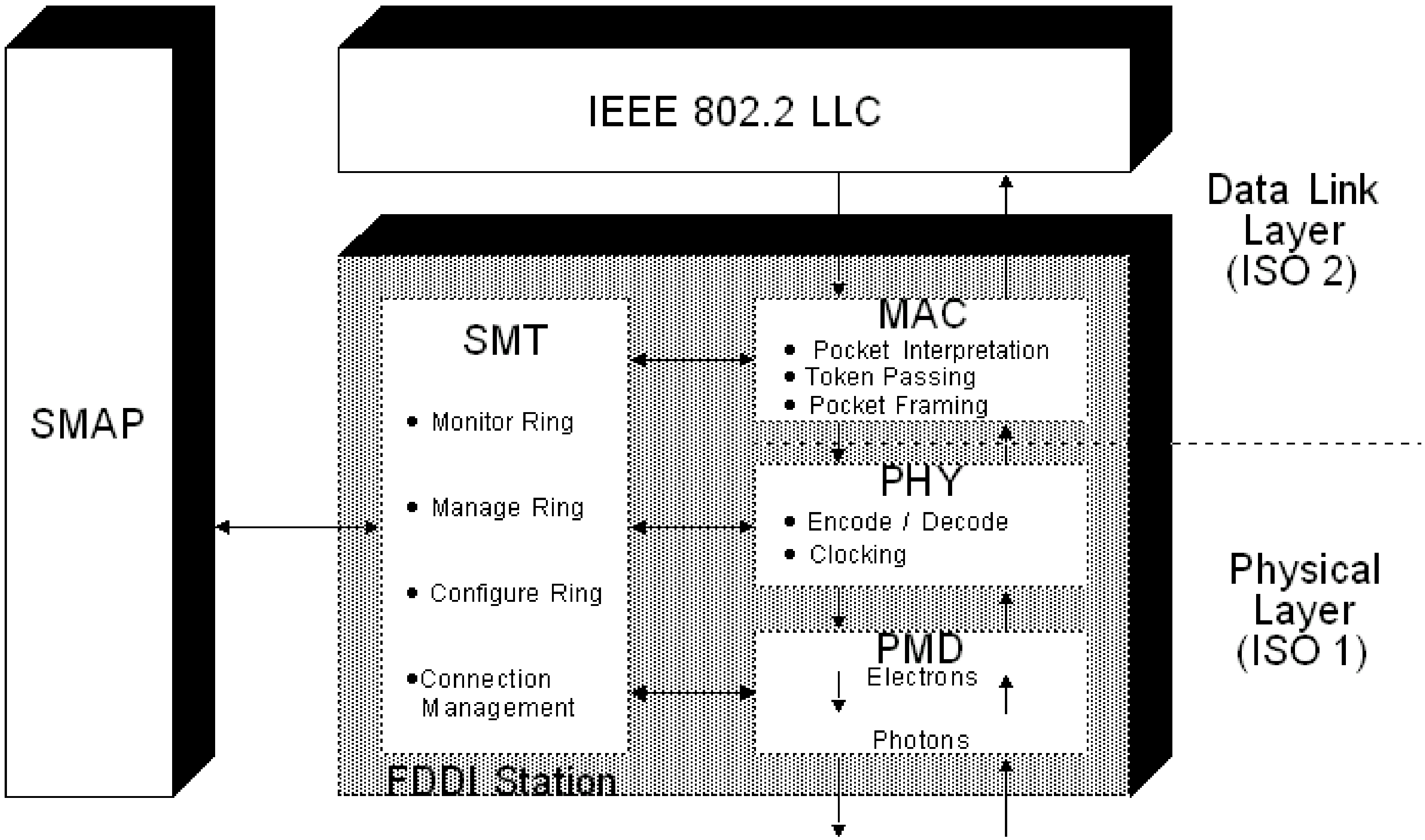
FDDI: Topology



2 rings with opposite direction:

- Primary ring: for data transmission
- Secondary ring: fault tolerance

FDDI: Components



FDDI: Components

Use of tokens to determine the station which will send next

Maintain timers

Generate and verify frame check sequence

PHY = Physical Layer Protocol:

- ISO 9341-1 Information Processing Systems FDDI - Part 1: Token Ring Physical Protocol
- Access to the ring for MAC
- Clocking, synchronization and buffering
- Code conversion

PMD = Physical Layer Medium

FDDI: Usability for Multimedia Data

Performance guarantees in asynchronous mode:

- Similar to Token Ring, but longer latency (20 bit per station instead of 2 bit)
- No guarantees if synchronous and asynchronous traffic on the ring
- Restricted mode for two stations:
  - Low delay
  - No other asynchronous traffic on the ring allowed

Performance guarantees in synchronous mode:

- Guaranteed bandwidth with maximum delay (variation up to 100 ms)
- Time for reservation of synchronous bandwidth relatively high
- Buffering for packets coming too early: buffer space for TTRT duration, isochronous mode in FDDI II

FDDI: Usability for Multimedia Data

Integrated Communication Systems

I C S Y

Flexibility:

- fixed bandwidth of 100 Mbit/s
- suitable for short and long distances

Multicast:

- Multicast group addressing supported

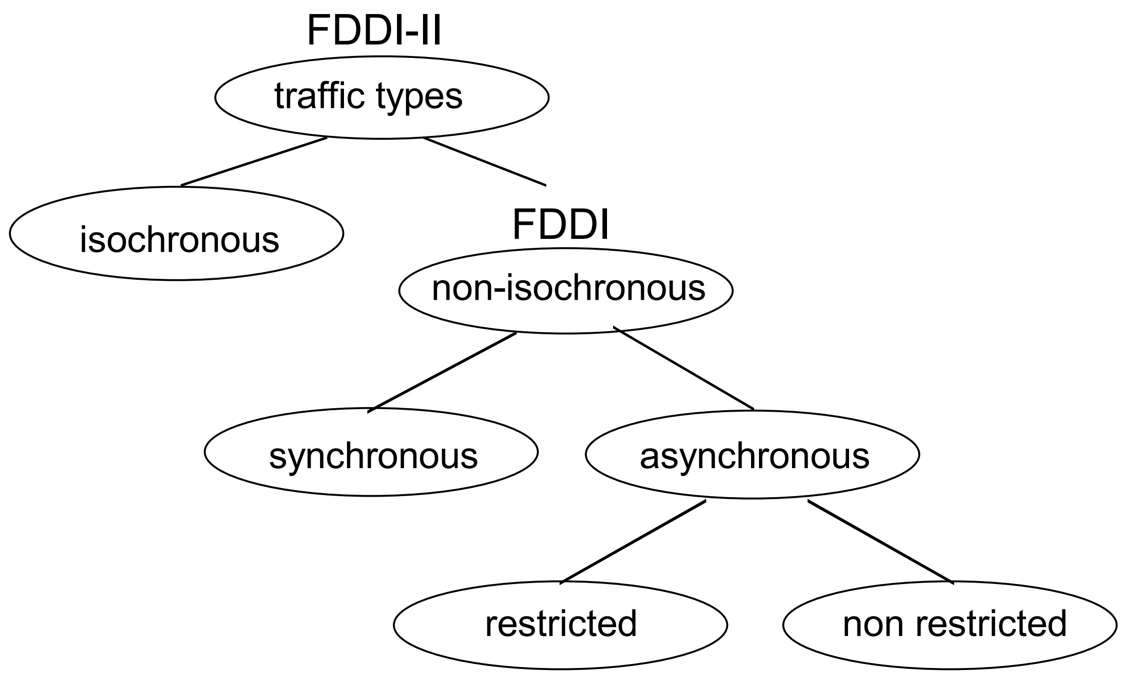
Efficiency:

- High throughput at high utilization

Costs:

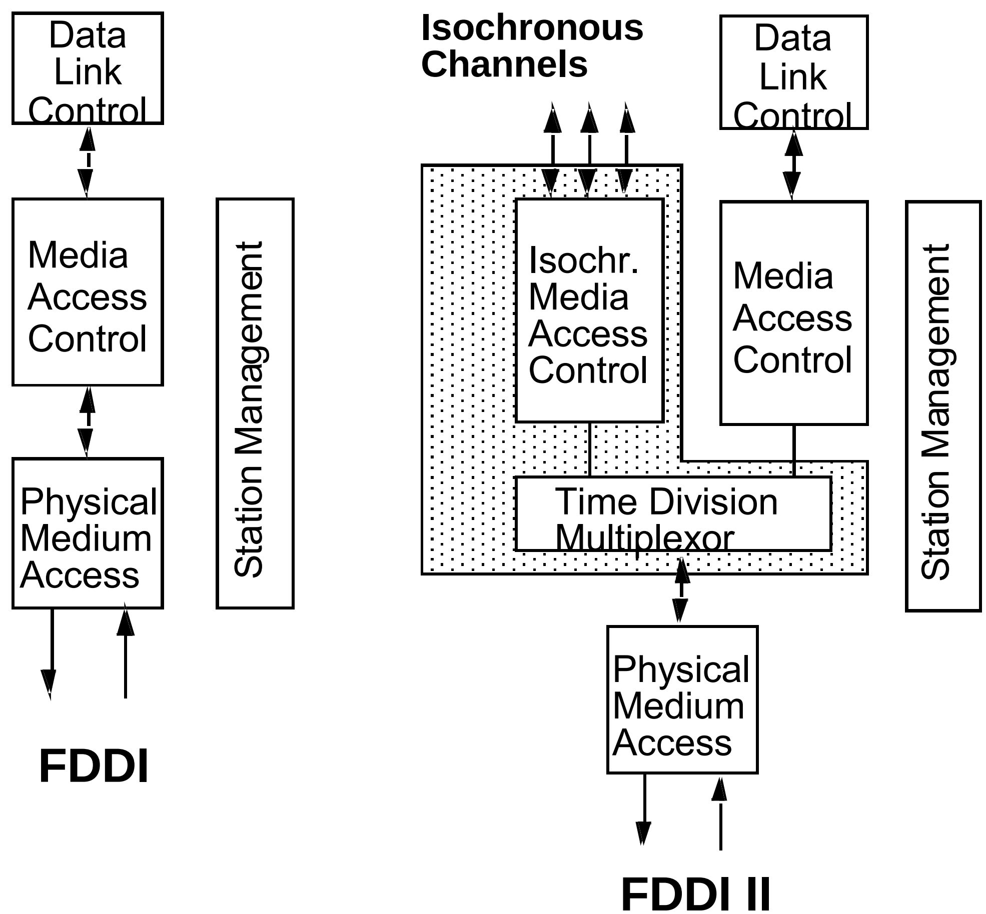
- fiber is expensive, especially for short distance connections
- complex protocol ⇨ “expensive” hardware

FDDI II: Traffic Types



- *Isochronous:* circuit switched, guaranteed bandwidth, fixed delay
- *Synchronous:* packet switched, guaranteed bandwidth, limited delay
- *Restricted mode*: residual bandwidth shared between two stations, “restricted token”
- *Non-restricted mode:* residual bandwidth, timed token protocol, 8 priority levels

FDDI II: Conceptual Structure



FDDI II: Concept

Time Division Multiplexor:

- Divides LAN into multiple bit streams

Structure:

- 16 Wide Band Channels (WBC) a 6.144 MBit/s
  (= 4* US, 3*European ISDN primary rate)
- One WBC can be isochronous or FDDI
- Isochronous WBC can be divided into multiples of 8 kbit/s

WBC:

- WBC can be combined together
- Allocation between 2 or more stations
- Full-duplex connections

Bandwidth allocation:

- Performed by Station Management (SMT)

4.5 DQDB (Distributed Queue Dual Bus)

Previously QPSX: Queued Packet Switch

Asynchronous part stable (IEEE 802.6),
Isochronous part not standardized

Design goals, compatibility with

- IEEE 802.x MAC frame formats
- B-ISDN cell structure and speed

Bus characteristic:

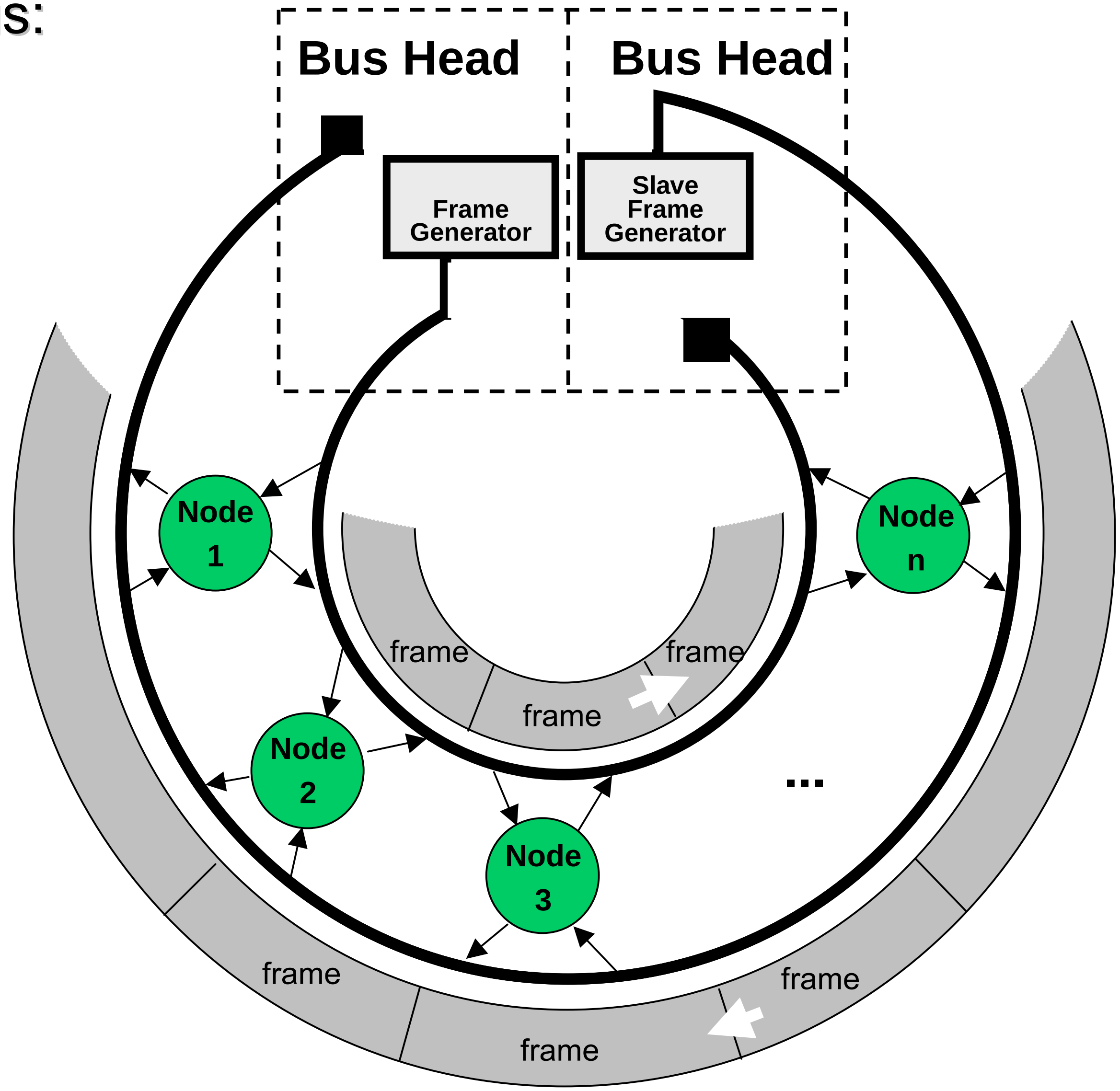
- Dual slotted bus, 125msec frame rate

Traffic modes:

- Asynchronous (packet switching) traffic
- Isochronous (circuit switching) traffic

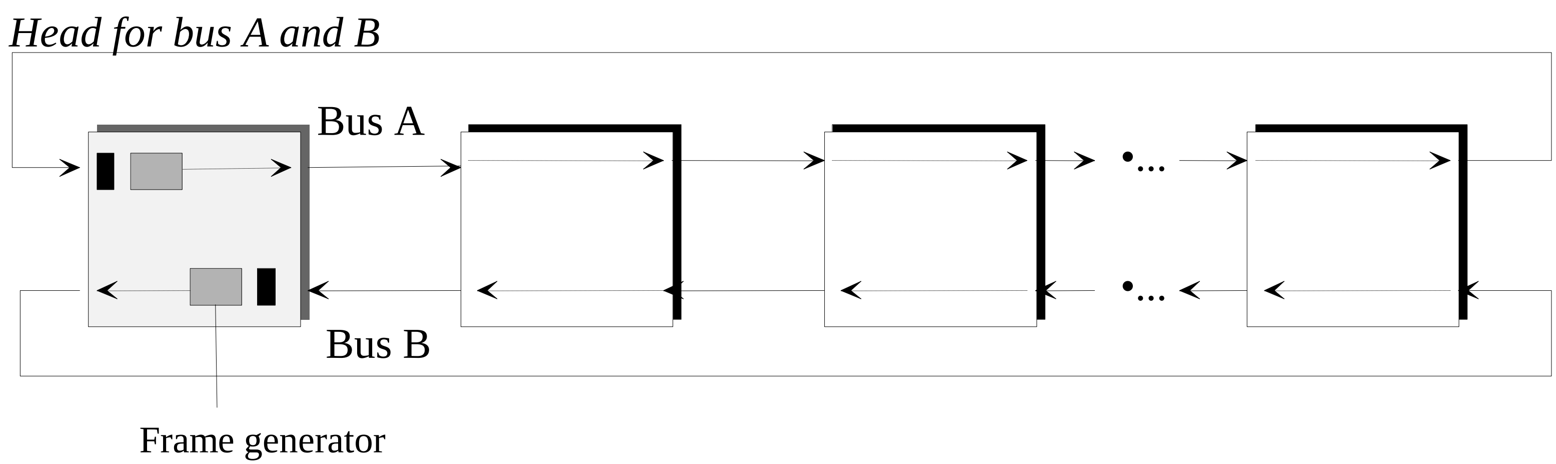
DQDB: Topology 1

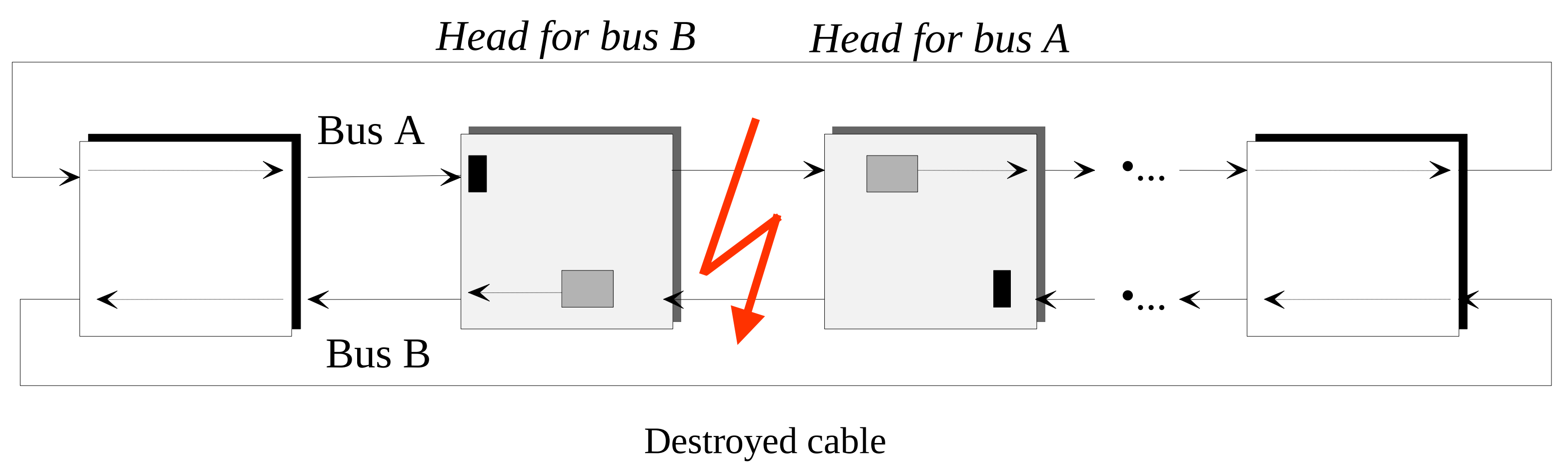
Dual Bus:



DQDB: Topology 2

Fault tolerance:





DQDB: Traffic Types

Integrated Communication Systems

ICSY

Queued Arbitrated (QA) Slots:

- Allocated through “distributed queue” MAC procedure
- Similar to asynchronous data traffic in FDDI

Pre-Arbitrated (PA) Slots:

- Assigned to a specific node by the Frame Generator
- Identified by VCI in slot header
- Ignored by the distributed queue medium access procedure
- Number and timing of PA slots is variable
- Slot contains:
  - 48 usable bytes (every 125 ms)
  - n * 64 kbit/s channel

DQDB: MAC protocol QA-mode 1

Integrated Communication Systems

I C S Y

Distributed algorithm to determine medium access

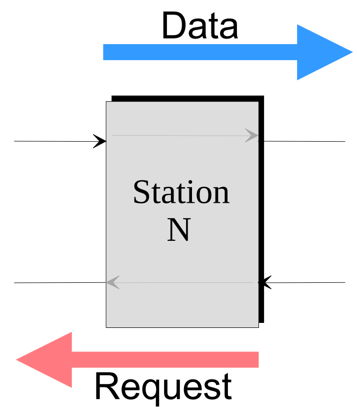
- Implementation of a distributed queue per bus, i.e. there is one queue for each direction
- Each bus is used to coordinate the data transfer of the other bus
- The queue specifies the sequence the stations have bus access
  - A station has bus access when it is the first in the queue and an empty frame passes
  - The queue implements FIFO (First-In-First-Out)
  - Each stations is in the queue only once
  - Each stations knows how many of the following stations have bus access before itself, i.e. how many empty frames must pass before an empty frame can be used

DQDB: MAC protocol QA-mode 2

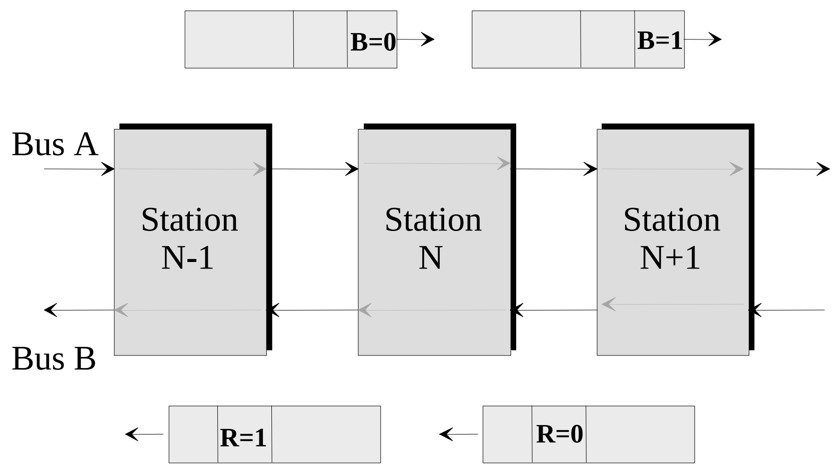
Integrated Communication Systems

ICSY

MAC protocol:



- A station must know if the receiver is on the left or the right
- Send request for an empty frame in the opposite direction than the receiver
  - Waiting for a frame where the request bit is 0
  - Setting the request bit and add station to queue
- Wait til station is the first in the queue
- Wait for an empty frame
- Send data

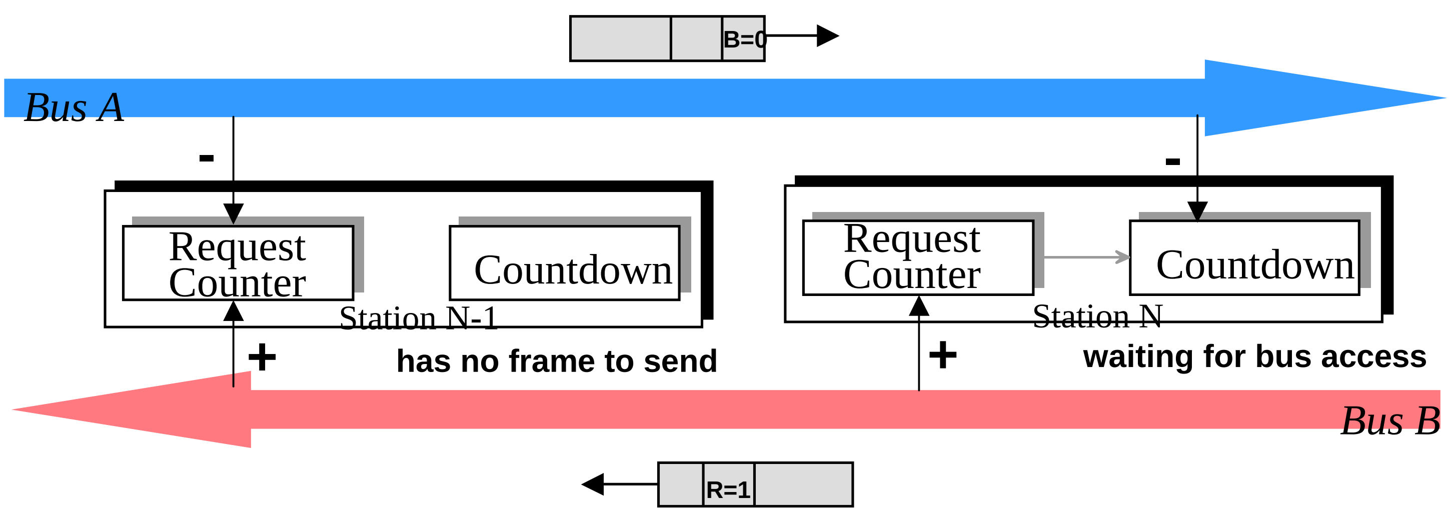


DQDB: MAC protocol QA-mode 3

Queue implementation (for Bus A)

- A station does not want to send a frame
  - Request bit set on bus B ⇨ increment request counter
  - Empty frame on bus A ⇨ decrement request counter
- A station gets a frame to send
  - Copy request counter to countdown and clear request counter
- A station is waiting for bus access
  - Request bit set on bus B ⇨ increment request counter
  - Empty frame on bus A and countdown > 0 ⇨ decrement countdown
  - Empty frame on bus A and countdown = 0 ⇨ send frame

Example: www.lkn.ei.tum.de/mmprog/mac/protocols/dqdb/dqdb4-slow.htm



DQDB: MAC protocol PA-mode

Medium access with support for isochonous data flows

Requires setup of a connection

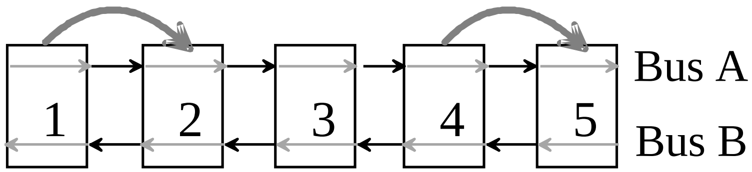
- Using speciall management functionality
- Establishes a virtual connection (VC) and defines a virtual connection identifier (VCI)

Bus-Head will generate special PA frames with the required frequenze

- Aggregated use of PS frames by all VCs
  - More efficient bandwidth usage
- Use of dedicated PA frames for each VC
  - Easier implementation for the DQDB stations

DQDB: Efficiency

- Frames are always reserved for the whole bus length
  - Not efficient if sender and receiver are close to each other
- Clear frames when they have passed the receiver
  - Enables re-use of frames



  - DQDB defines that stations are allowed to set bits only, this must be changed
  - Re-used frames are not considered by the distributed queue algorithm, i.e. more empty frames than neccessary will pass the stations near to the bus head
- Solution: Erasure-Nodes
  - Are allowed to clear bits
  - May remove reservation bits after clearing a frame

DQDB: Usability for Multimedia Data

Performance guarantees for asynchronous traffic:

- Four priorities:
  - High priority traffic is always sent before traffic of a lower priority
- Fairness problems:
  - stations near to a bus head, have a better chance to send data in this direction

Performance guarantees for isochronous traffic:

- Guaranteed bandwidth, reservation is possible
- Fixed delay
- Few Implementations

DQDB: Usability for Multimedia Data

Integrated Communication Systems

I C S Y

Flexibility:

- usable for LAN and WAN, e.g. DQDB connection between Perth and Melbourne (3.500 km).
- different physical media with different line speed available (30/45/140/155 Mbit/s, full-duplex)

Multicast capability:

- not available

Efficiency:

- High throughput at high utilization
- High load leads to unfairness
- Data always travels to the bus head, a receiver does not remove data. This could save Bandwidth.

Cost:

- no market

4.6 ISDN (Integrated Services Digital Network)

Standardization:

- ITU recommendations (former CCITT)
- ETSI and ANSI standards

Characteristics:

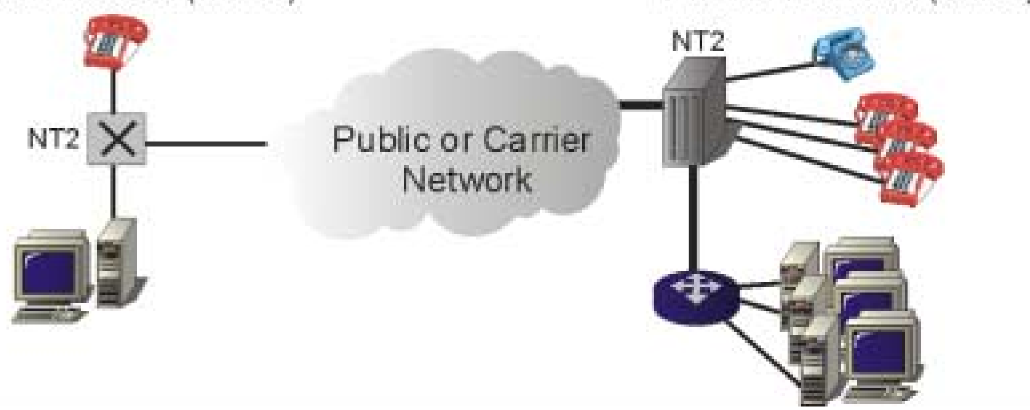
- Public, digital, end-to-end network
- Implements digital bit pipe
  - Based on 64 kbit/s data rate
  - Multiple full duplex data channels
- Support for multiple media and services within one network:
  - Voice, low quality video, image data, text data,
  - supplementary services
- Common signaling channel with common set of signaling protocols

Technology

- Circuit Switching
- Fixed bandwidth channel assignment

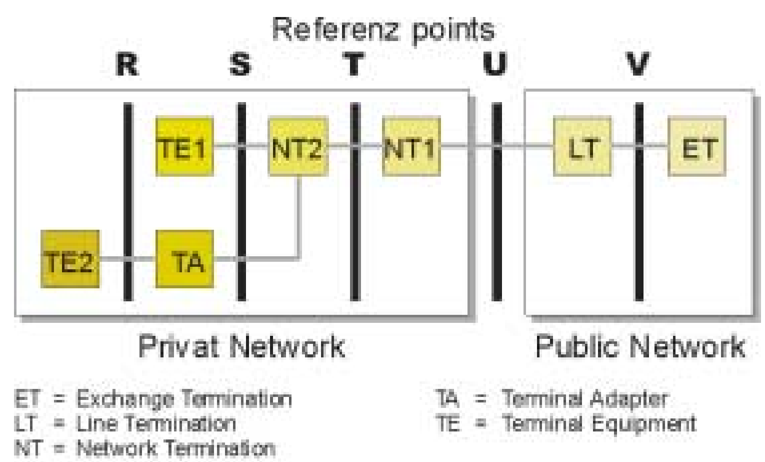
ISDN: Topology + Interfaces

Star topology, different technologys in LAN and WAN



Formats are defined for Interfaces only

- Interfaces are described as referenz points



ISDN: Interfaces

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 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

ISDN: Network Access

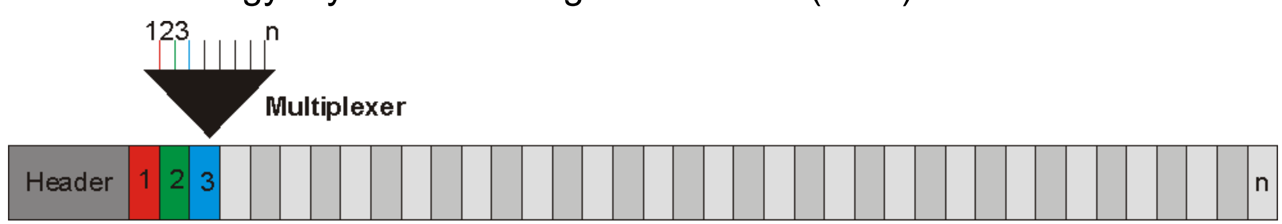
Referenz point T:

- Concurrent D-Channel access, collisions may occure
- Explizit assignment of a B-Channel to Terminal-Equipment by signalling

Time Division Multiplexing mapps several 64 kbps channels to one faster channel

- A frame consist of a header and a fixed number of slots

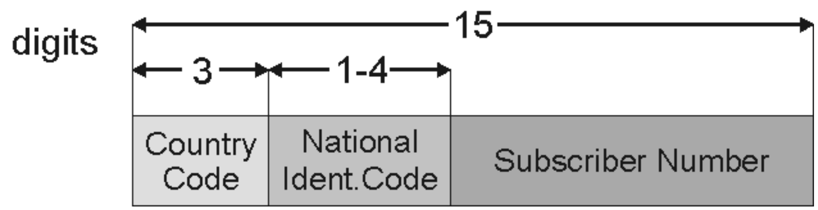
- A frame is generated each 125µS
- The slot size is 8 bit
- During signaling a fixed mapping between channels and slot numbers is defined, this is called Synchronous Time Divison Multiplexing (STDM)
  - The mapping is valid for two adjacent devices only
  - Technology: Synchronous Digital Hierachie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



ISDN: Addresses

Defined by the ITU in E.164

Format:



- Prefixes are not part oft 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 national identification code for Kaiserslautern
  - 205 is the subscriber number of the university
  - 2263 is a sub address, it is used within a private network only

ISDN: Usability for Multimedia Data

Integrated
Communication
Systems

ICSY

Performance:

- guaranteed bandwidth
- low delay and low delay variation
  (not guaranteed, e.g. Satellite links with significant higher delay)

Flexibility:

- fixed bandwidth
- typically used for end-to-end communication, therefore ISDN is used in LAN and WAN.
- independent of physical media

Multicast capability:

- no multicast capabilities

Efficiency:

- low bandwidth utilization

Costs:

4.7 B-ISDN (Broadband ISDN) / ATM

Standardization:

- ITU recommendations (former CCITT)
- ATM Forum (organization of vendors, specifications only)

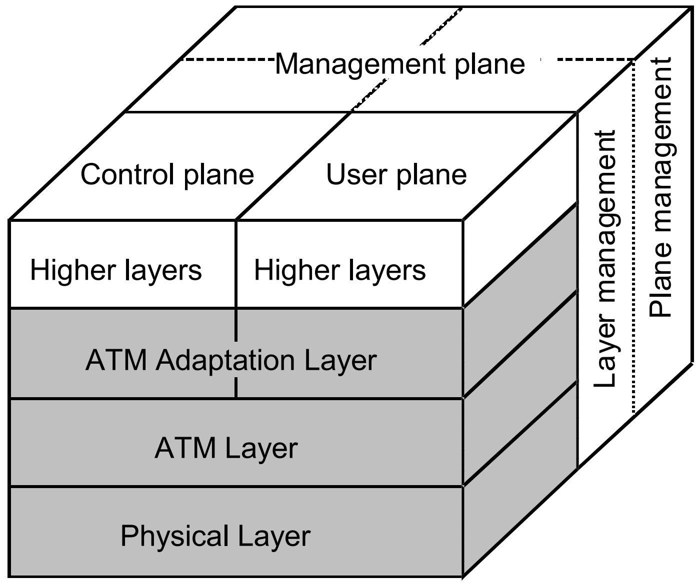
Characteristics:

- 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

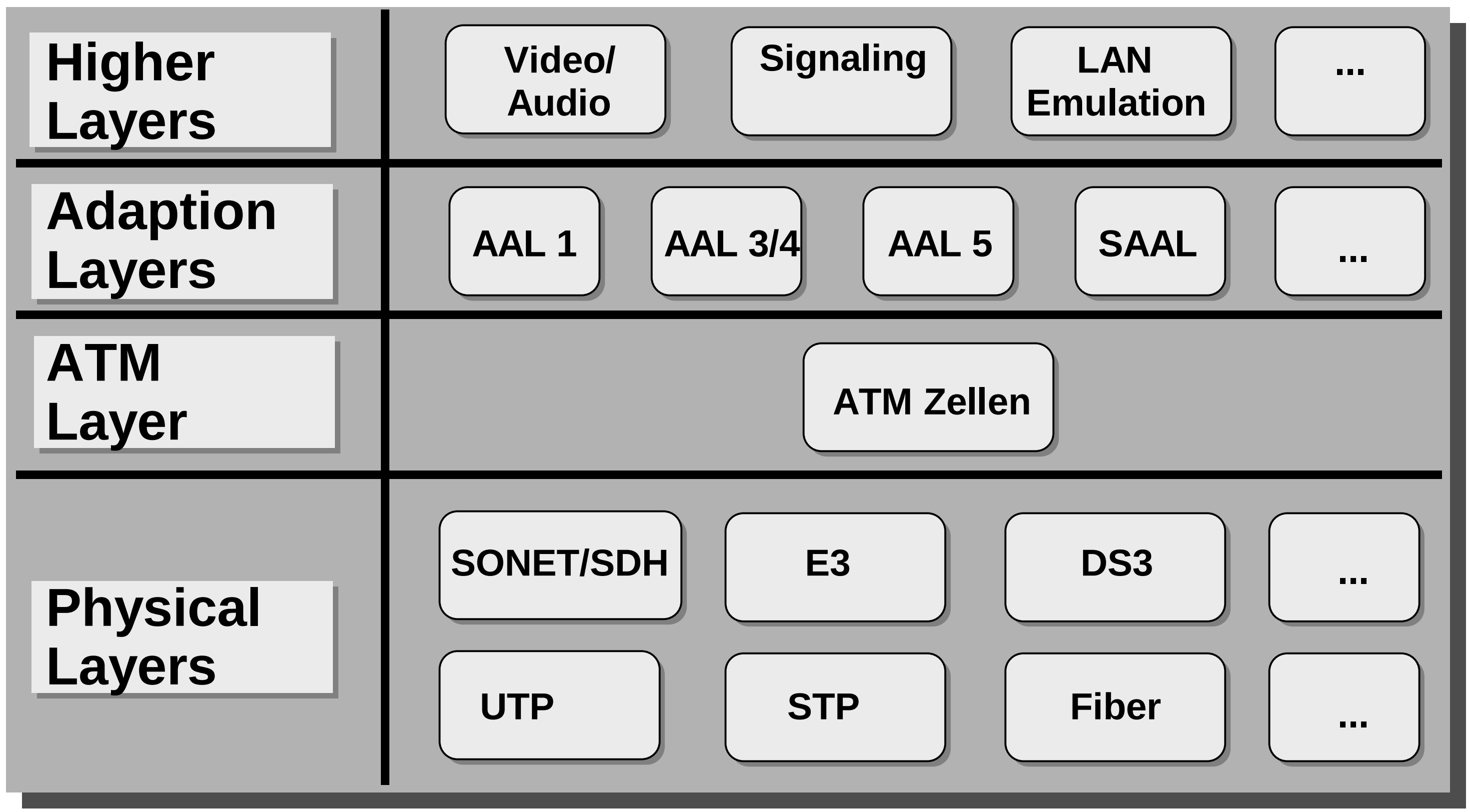
ATM: Reference Model



- Higher layer provide end-to-end services
- ATM Adaption Layer (AAL):
  - adaption of service data to cells (48 Bytes)
- 53 byte cells handled by ATM Layer:
  - 5 byte header (VPI, VCI, HEC)
  - switching/multiplexing of cells

ATM Layer Overview

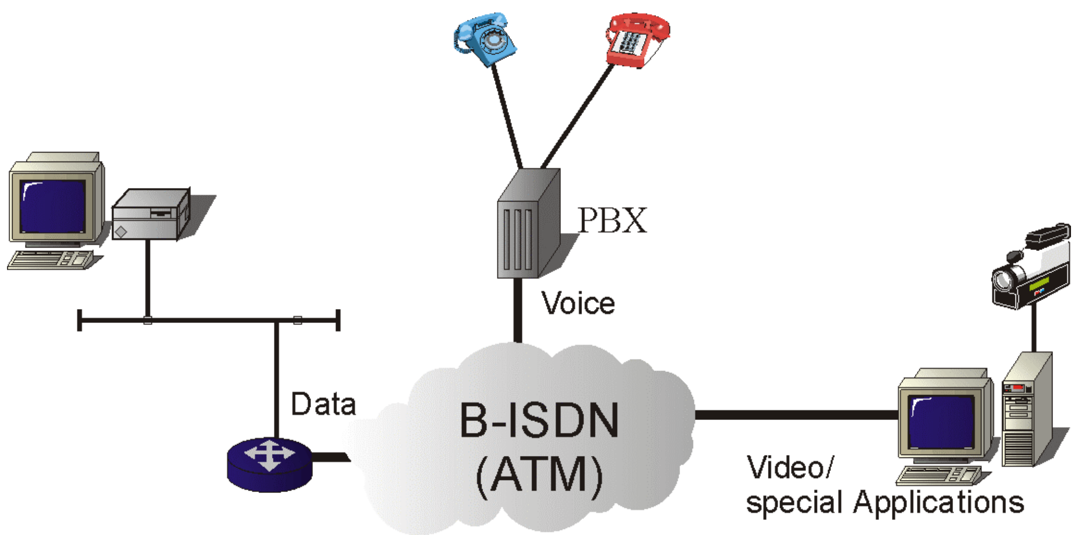
Examples:



ATM: Topology

Star topology

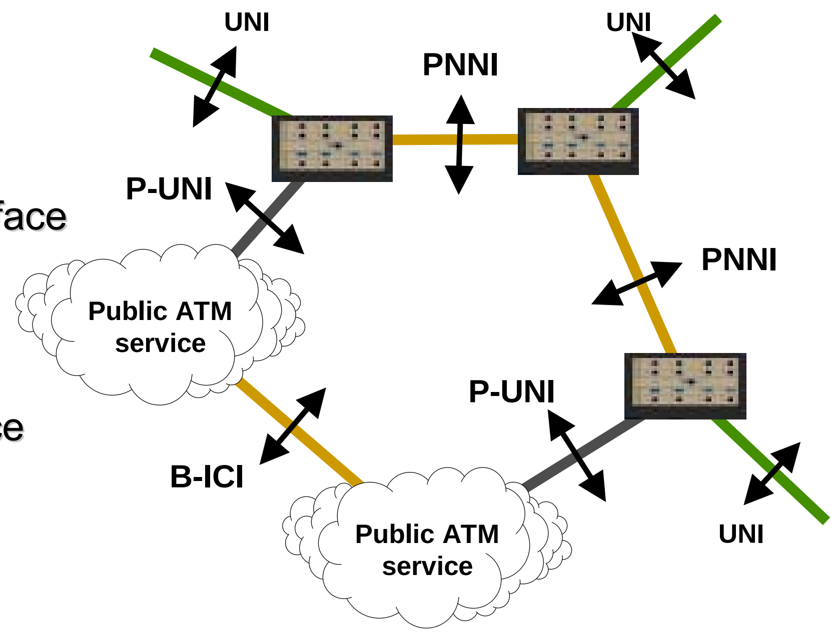
- Unlike ISDN only one technology: ATM
- Is independent of the physical layer
  - 2 Mbit/s – N Gbit/s
  - Wireless, Satellite
  - Usual: implementation on top of SDH or SONET



ATM: Interfaces

Like ISDN several Interfaces are defined

- UNI = User-Network-Interface (host to network)
- PNNI = Private Network-Network-Interface (network device to network device)
- P-UNI = Public-UNI (private network to public network)
- B-ICI = Broadband-Intercarrier-Interface (between Carriers)



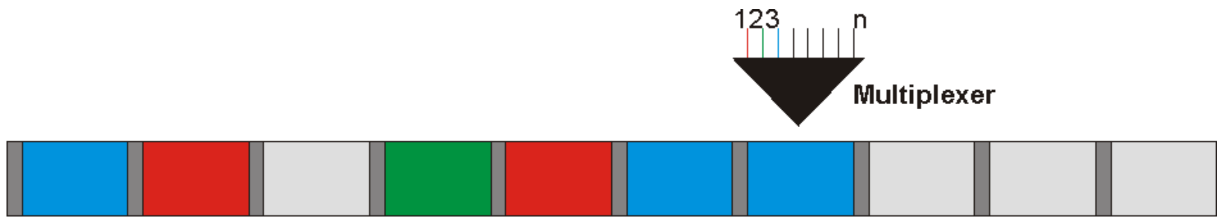
Basically the interfaces differ in level of signaling only

ATM distinguishes between network and user

- A user could be a host (UNI) or a network (P-UNI)

ATM: Network Access

ATM = Asynchronous Transfer Mode because the Asynchronous Time Division Multiplexing (ATDM) is used



- STDM uses slots, ATDM uses cells
- The sequence of the cells on a link is not fixed (asynchron)
  - A Sender defines a useful sequence
  - Enables arbitrary bandwidth for each connection
  - High efficiency because no empty cells must be sent if data is available
- Reservation of bandwidth can be handled by the cell multiplexer
- Each cell has a header identifying the connection a cell belongs to

ATM = Asynchronous Transfer Mode

According to ITU-T Recommendation I.113 asynchron means:

" ... it is asynchronous in the sense that the recurrence of cells containing information from an individual user is not necessarily periodic." (I113)

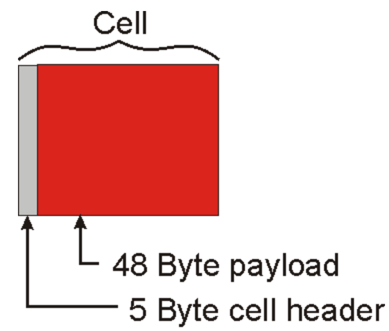
ATM: Cells

Integrated Communication Systems

I C S Y

Cells are packets of a constant size

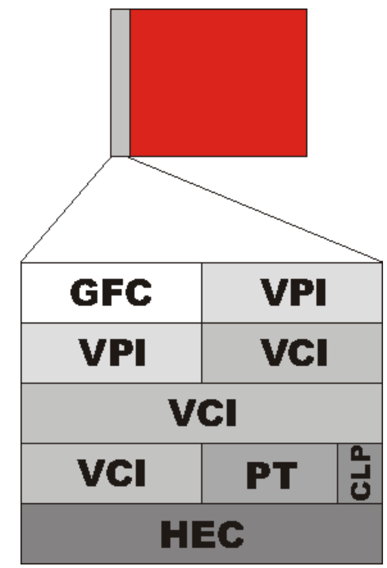
- Simplifies scheduling of the multiplexer



Small size enables low delay even on low bandwidth links

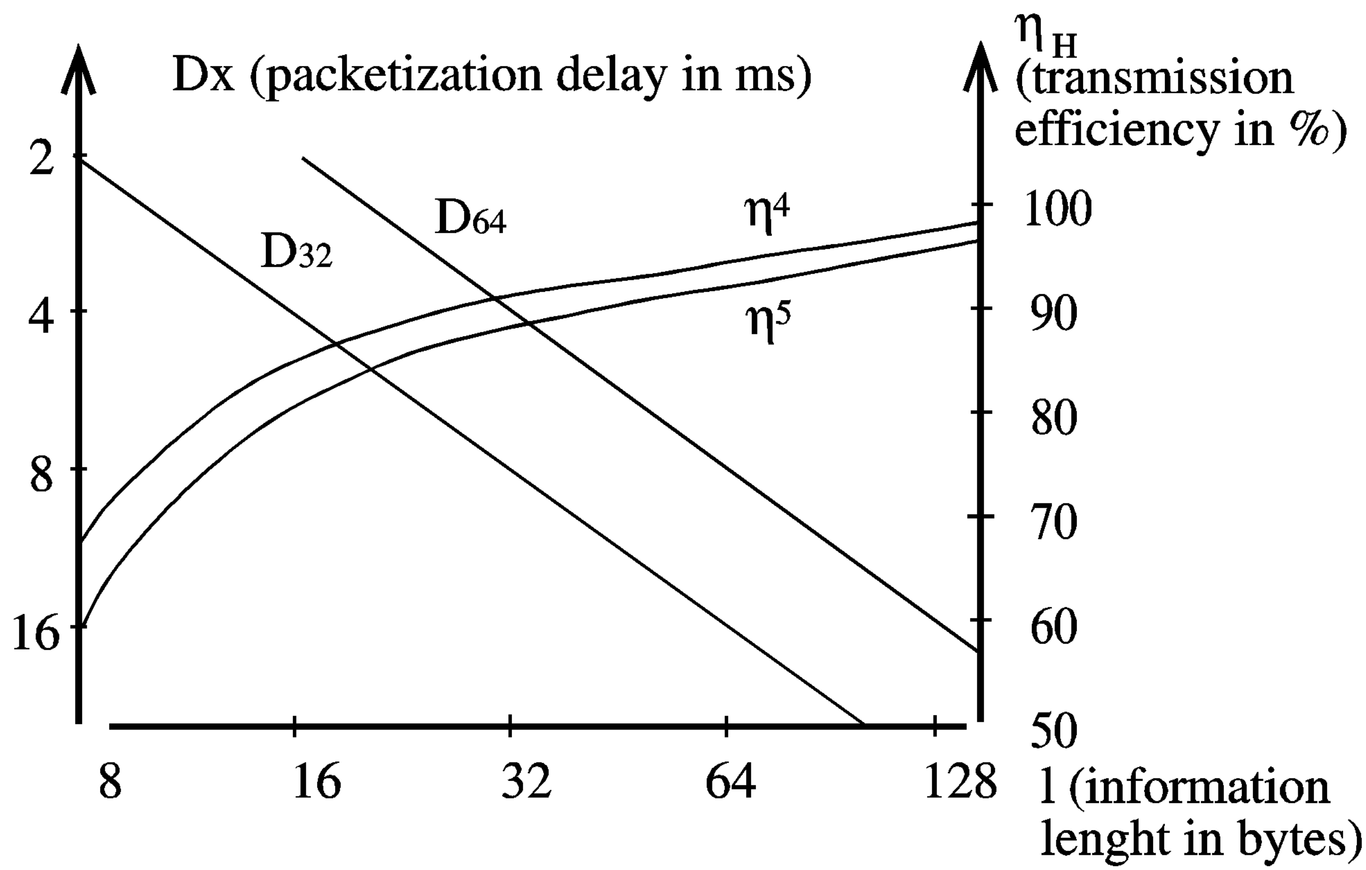
Overhead of cell header ~ 9,43 %

Cell header

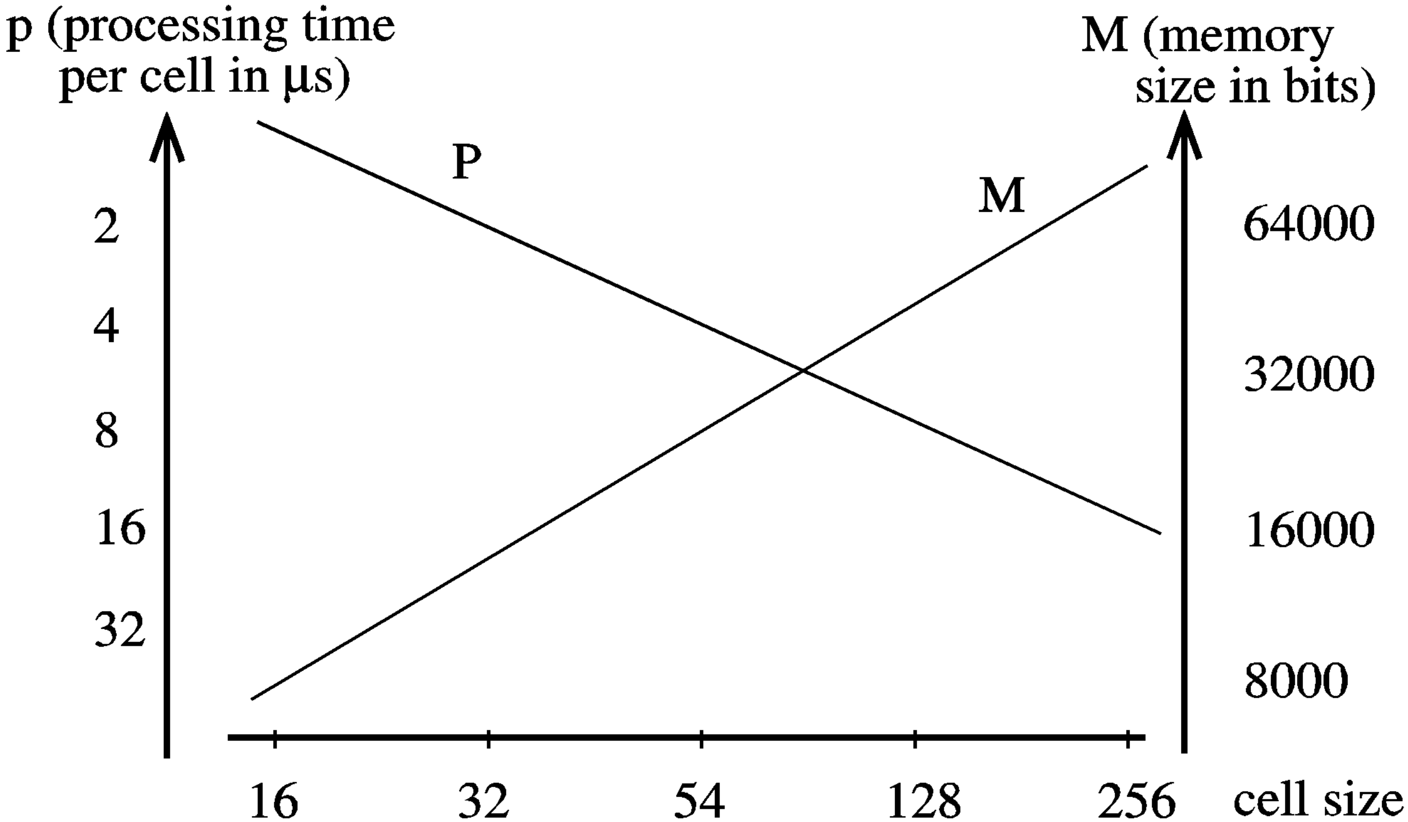


- Basically identifier of the connection
  - VPI = Virtual Path Identifier
  - VCI = Virtual Channel Identifier
- Payload type
  - Label data or management information
- Cell loss priority
  - In case of congestion drop cells with CLP=1 first
- Header Error Control – CRC for the first 4 header bytes

ATM: Cell Size 1



ATM: Cell Size 2



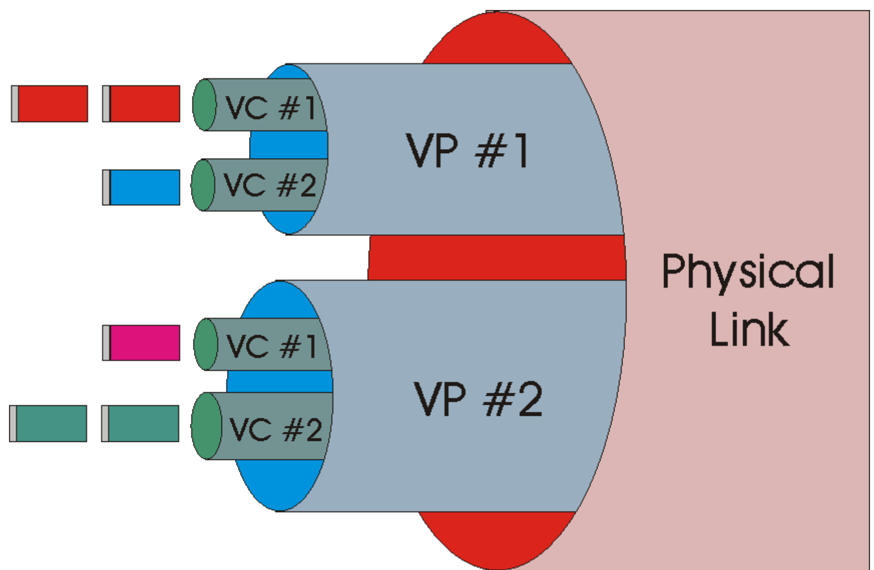
ATM: Virtual Path/Circuit

ATM is connection oriented

- Virtual paths (VP) build a logical topology on top of the physical topology
- Virtual Circuit (VC) are connection on virtual paths

Length:

- Physical link: connects two physical devices
- Virtual Circuit: connects two end-systems
- Virtual Path: link ≤ path ≤ circuit



Connections may be

- point-to-point (full-duplex)
- point-to-multipoint (half-duplex)

VPs are static
= permanent virtual path (PVP)

VCs may be static or dynamic
= permanent or switched virtual channel (PVC/SVC)

ATM: Characteristics of VC/VP

Integrated Communication Systems

ICSY

Logical association between the endpoints of a link (individual link)

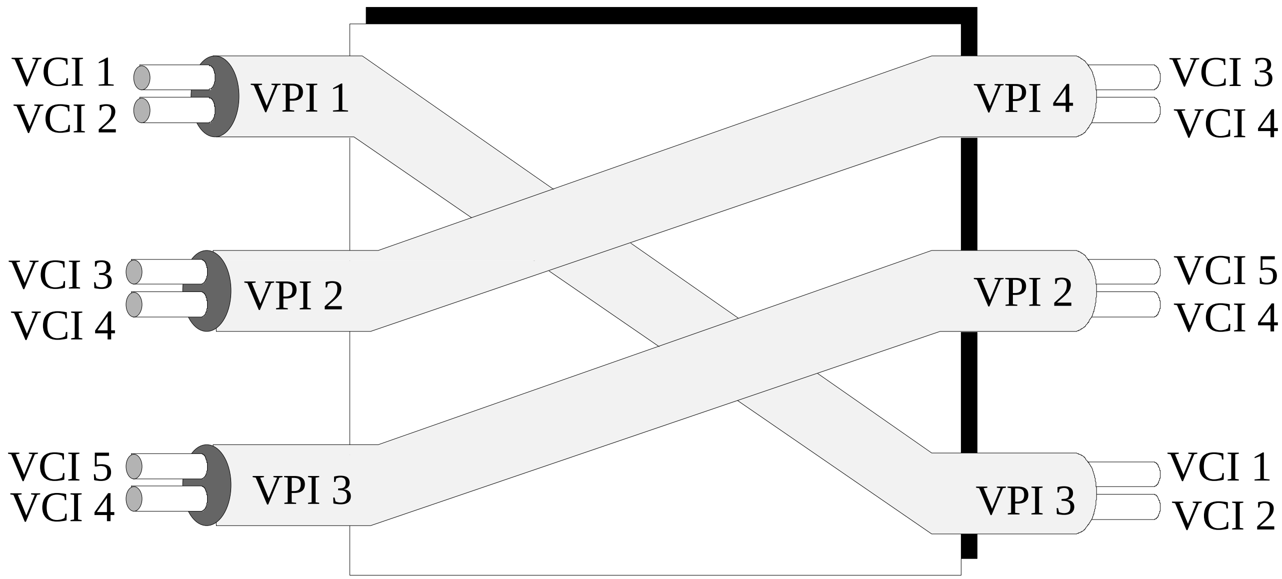
Virtual Channel Characteristics:

- Bi-directional data transfer
- Guaranteed sequential delivery
- Error detection by HEC and correction of single bit errors
- QoS characteristic associated with each virtual channel connection and with each direction of a channel

Virtual Path Characteristics :

- Route through a network
- Carries various VCs
- VP also has a QoS (the limit for all VCs)

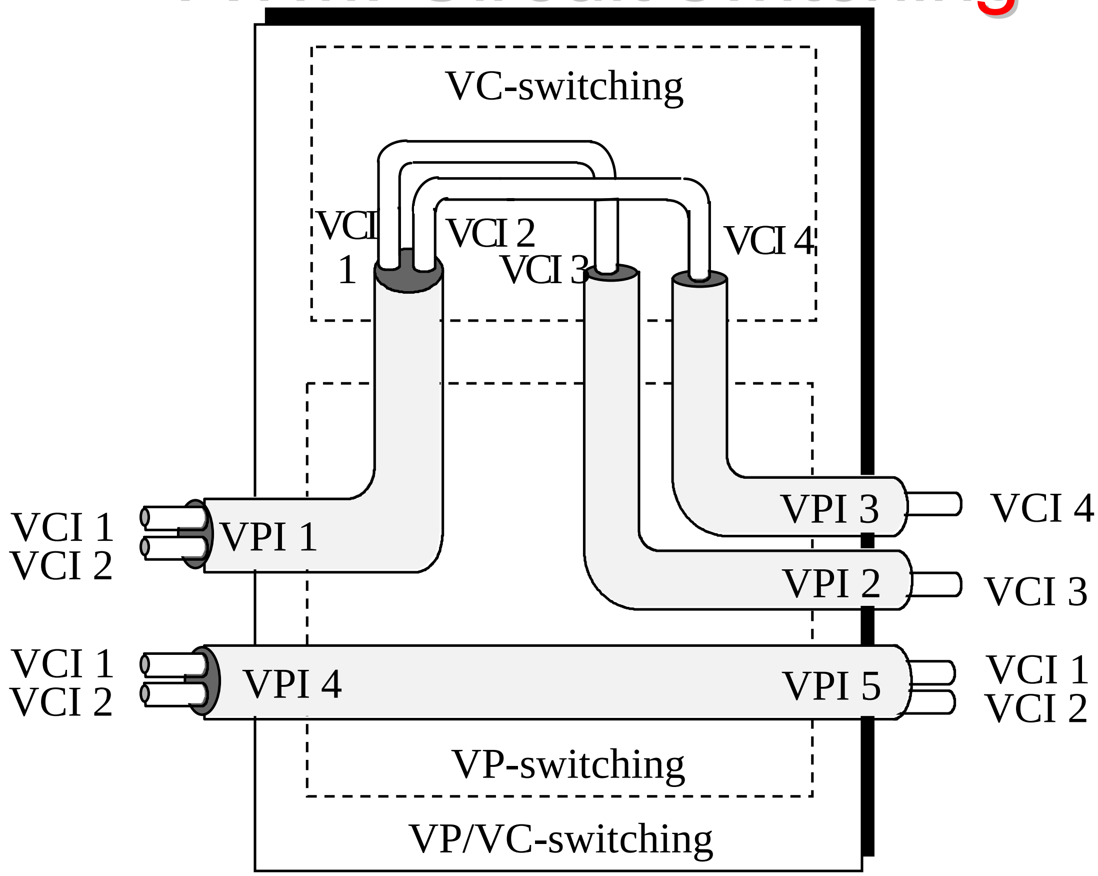
ATM: Path switching



Switching with regard to VPI only

VCI are left unchanged

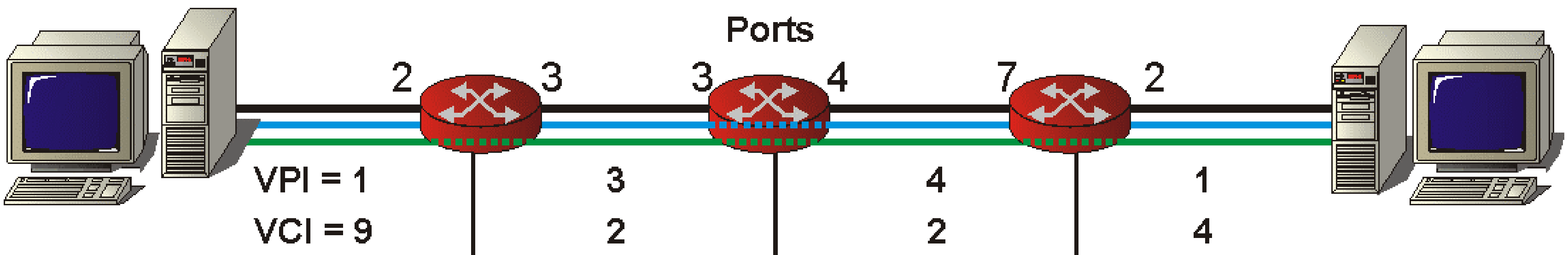
ATM: Circuit switching



Switching with regard to VPI and VCI

- If the VCI is used for switching, this means the VP ends at that switch
- VCs of one path could be spread over several new paths

ATM: Switching Table



Switching table

	IN	OUT
port #	2	3
VPI	1	3
VCI	9	2

Switching table

	IN	OUT
port #	3	4
VPI	3	4
VCI	-	-

Switching table

	IN	OUT
port #	7	2
VPI	4	1
VCI	2	4

Link — Path — Channel

ATM: Traffic Contract

No error detection and correction, but ...

... mechanisms to guarantee Quality of Service

The ATM contract

The Application

The ATM Network

at the connection set-up

The Application:
- **specifies its needs in Quality of Service : Type of Traffic, Bit-Rate, Transit Delay, etc**

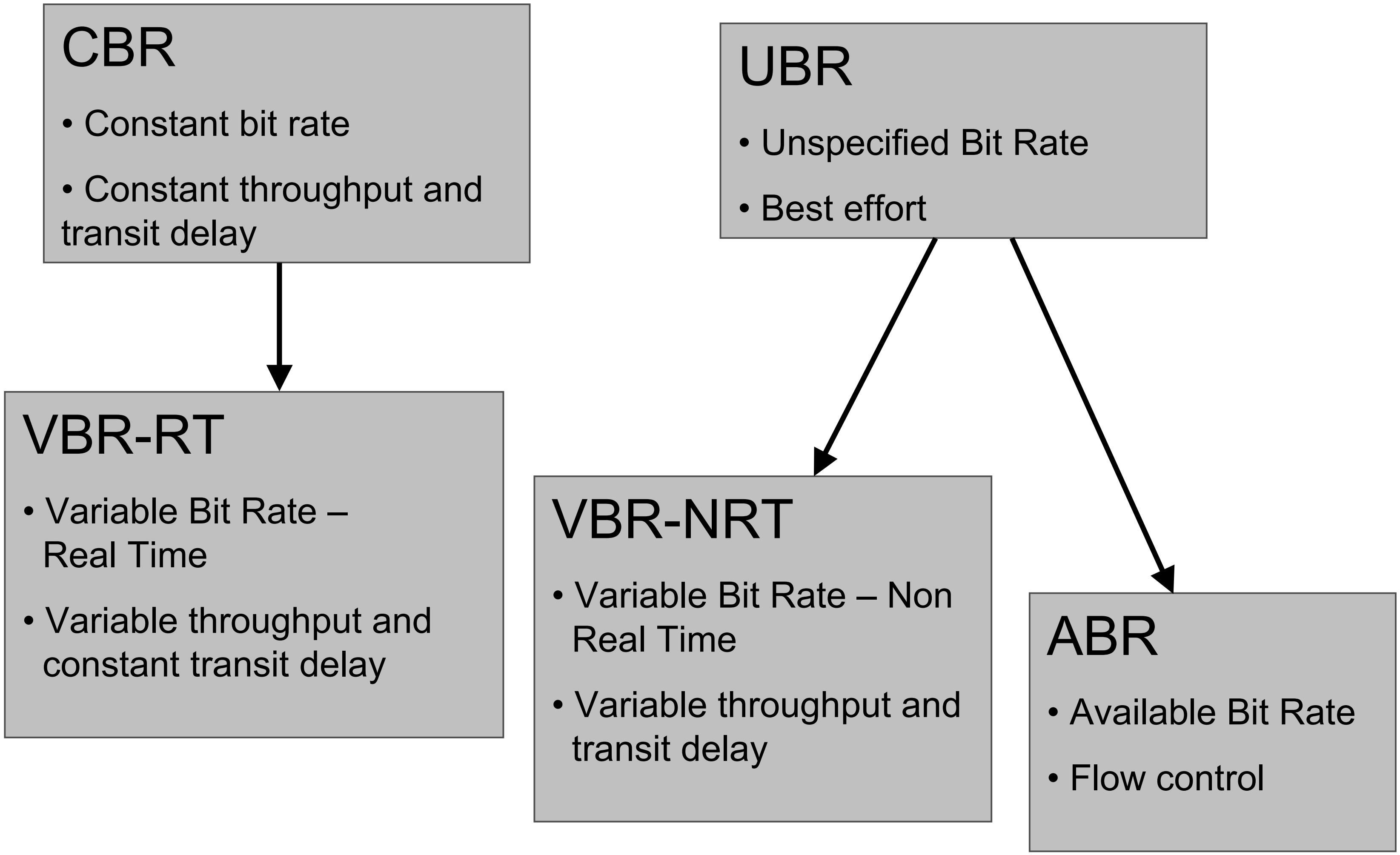
The ATM Network:
- **checks the resources**
- **reserves the bandwidth (CAC)**
- **commits to provide the service**

during the communication

The Application:
- **regulates its traffic according to the contract**

The ATM Network:
- **controls if the application abides the contract (UPC)**

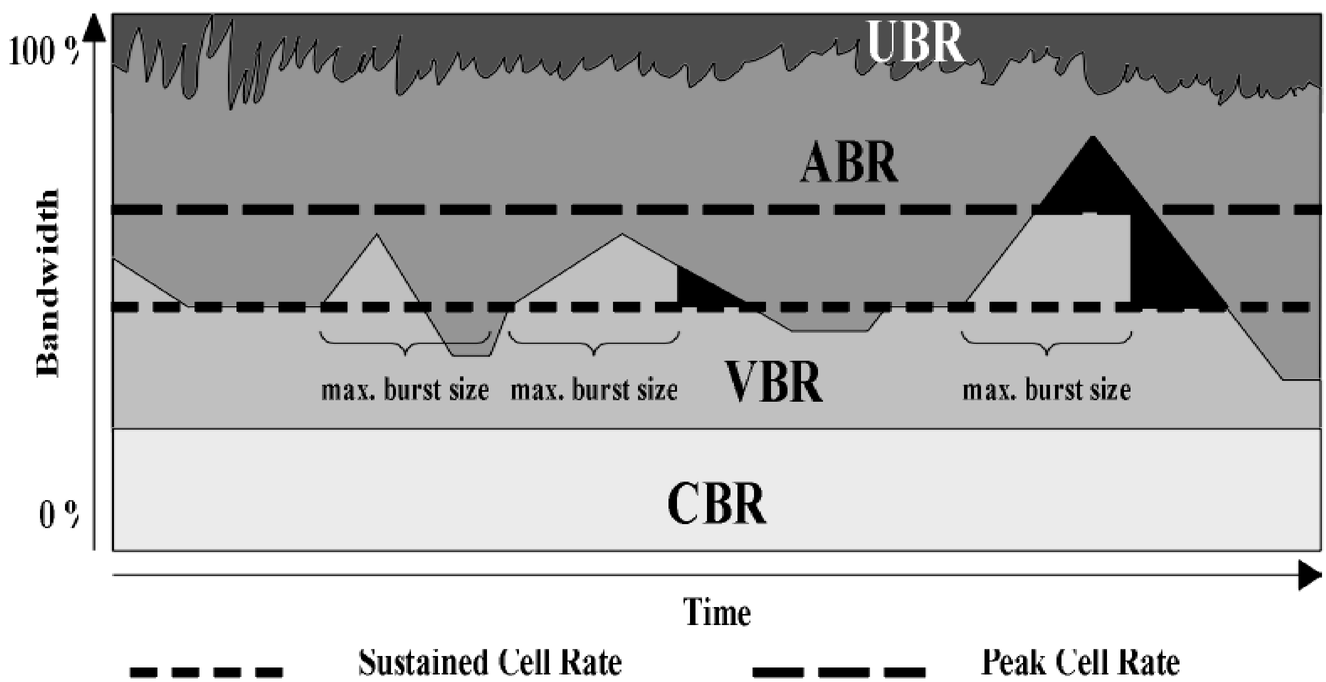
ATM: Service Categories 1



ATM: Service Categories 2

Distribution of bandwidth

- CBR: fixed constant bandwidth
- VBR: fixed constant bandwidth up to sustained cell rate
  for a short time (max. burst size) more bandwidth usage is possible
- ABR: variable bandwidth based on feedback of the network
- UBR: best-effort



duration of a burst:

$$\frac{MBS - 1}{PCR}$$

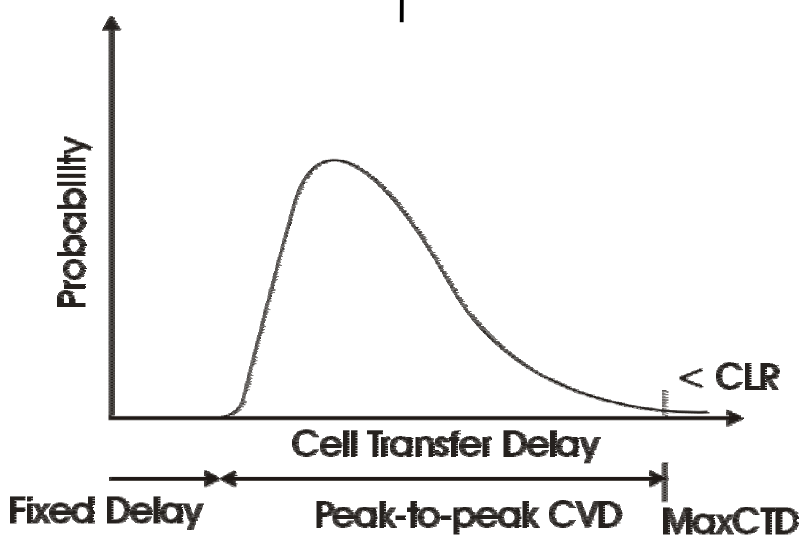
time between two bursts:

$$\frac{MBS}{SCR}$$

Quality of Service Parameter

Integrated Communication Systems

QoS Acronym	**Parameter Name**	**Negotiated?**
peak-to-peak CDV	Cell Delay Variation	YES
maxCTD	max. Cell Transfer Delay	YES
CLR	Cell Loss Ratio	YES
CER	Cell Error Ratio	NO
SECBR	Severely Errored Cell Block Ratio	NO
CMR	Cell Misinsertion Rate	NO



Probability for exceeding maxCTD must be less than CLR

ATM: Usability for Multimedia Data

Performance:

- guaranteed bandwidth (fixed, variable, feedback)
- low delay and low delay variation (not guaranteed)

Flexibility:

- bandwidth on demand, limited by physical links and actual system load
- several traffic types CBR, RT-VBR, NRT-VBR, ABR and UBR
- independent of physical media
- used for LAN and WAN

ATM: Usability for Multimedia Data

Integrated Communication Systems

ICSY

Multicast capability:

– uni-directional point-to-multipoint is available today

Efficiency:

– high bandwidth utilization
– statistical multiplexing increases utilization, VBR channels:
  - SUM of “sustained cell rates” must be <= 100%
  - SUM of “peak cell rates” may be > 100%

Costs:

– a complex and therefore an expensive technology