Communication Networks I

L2 High speed LAN & MAN

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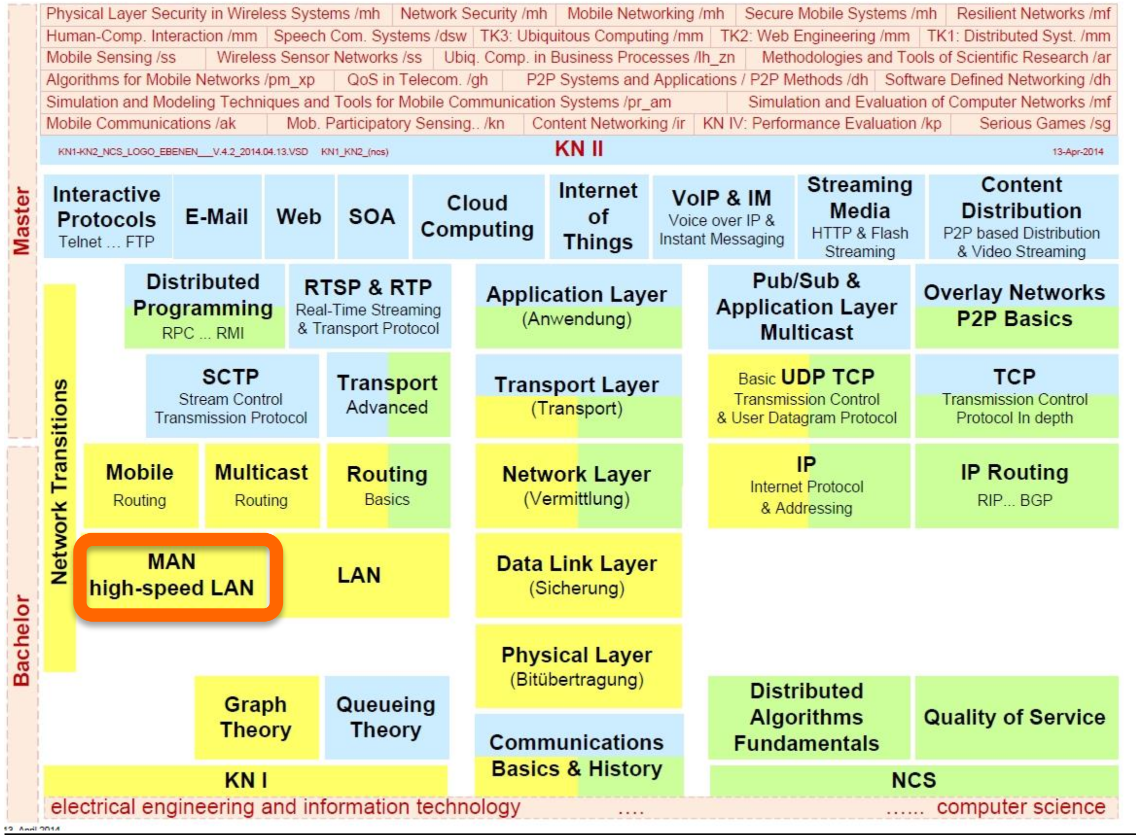

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Overview

1 High-Speed LANs, WANs and MANs

2 Ethernet Family
- 2.1 IEEE 802.3u: Fast Ethernet
- 2.2 IEEE 802.3z: Gigabit Ethernet
- 2.3 IEEE 802.3ae: 10Gbit Ethernet
- 2.4 IEEE 802.3ba: 40Gb/s and 100Gb/s Ethernet

3 Other High-Speed LANs
- 3.1 IEEE 802.9: Integrated Voice Data LAN - IVD LAN
- 3.2 IEEE 802.12: Demand Priority

4 Storage Area Network

5 MAN – Basic Characteristics

6 IEEE 802.6: Distributed Queue Dual Bus (DQDB)

7 Fiber Distributed Data Interface (FDDI)
- 7.1 FDDI: L1 Topology
- 7.2 FDDI MAC: Token Protocol
- 7.3 FDDI MAC: Timer Protocol
- 7.4 FDDI: Traffic Modes

LAN development

- towards
  - more speed
  - shared bandwidth
- of conventional data towards
  - integrated data (conventional & audio/video)

and

- sometimes also increasing extension (100 km)
- i.e. High-Speed LAN also as MAN

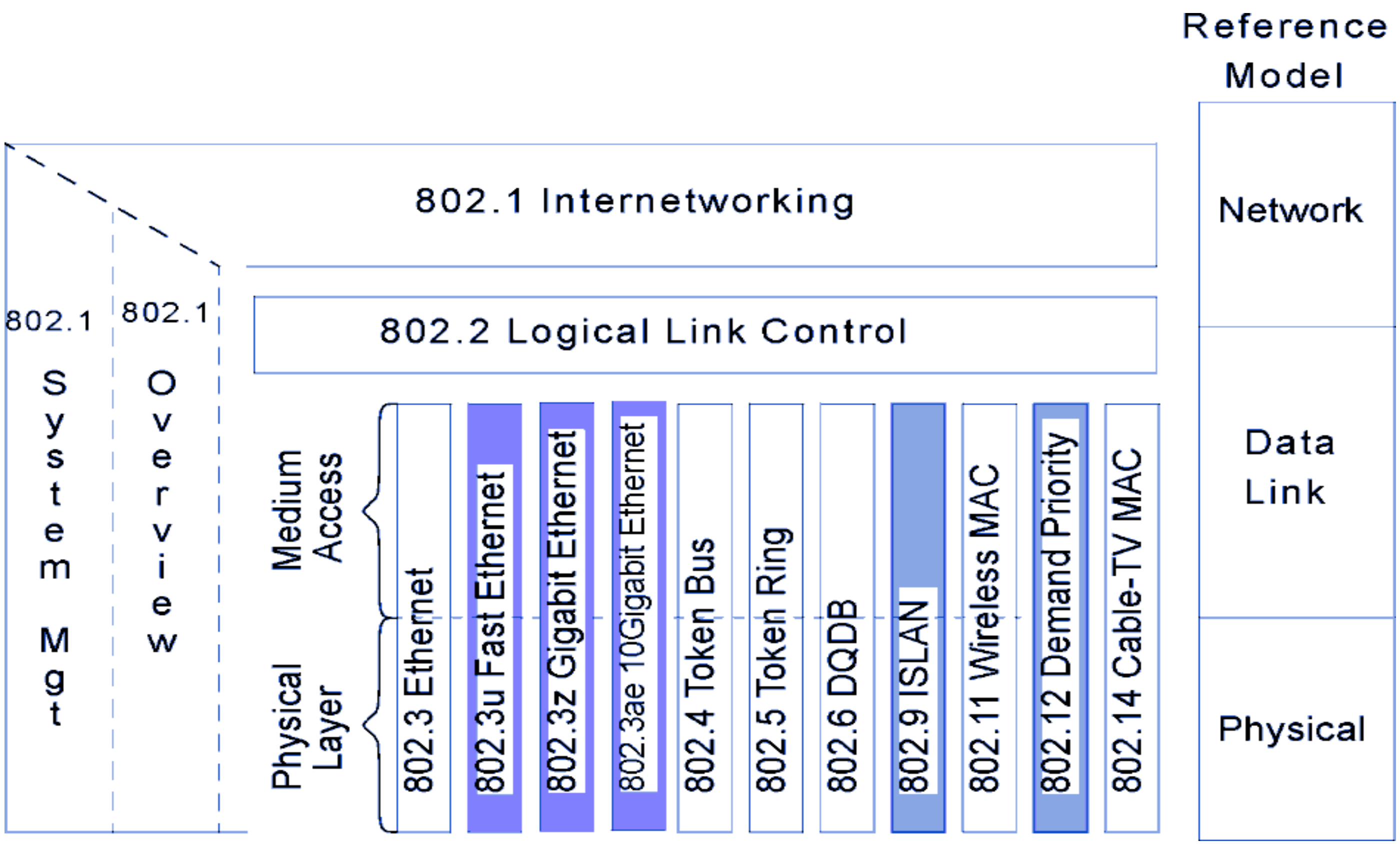
WAN development

- towards
  - more speed
  - bandwidth per connection
- from audio (video) towards
  - integrated services (conventional & audio/video)

and

- also decreasing extension (down to Desk Area range)
- i. e. WAN also as MAN (and LAN)

High-Speed LAN and IEEE



IEEE 802.3u, 802.9, 802.12

- High-Speed LANs

LAN, (MANs) and IEEE

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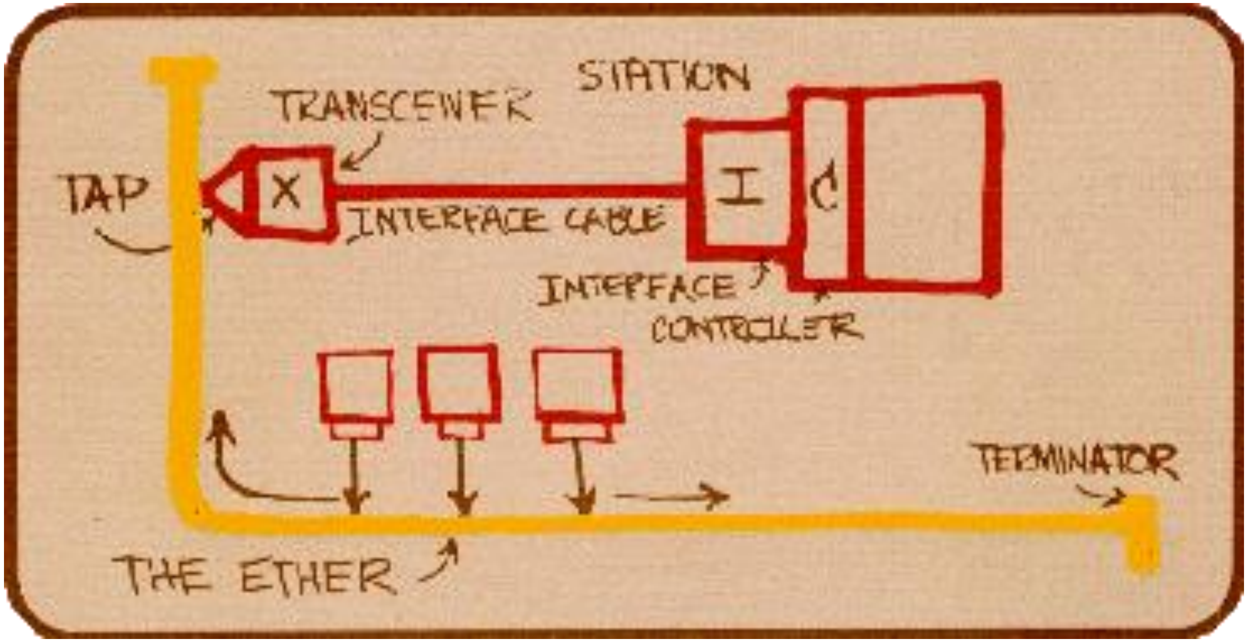
- 802.1 Overview Document Containing the Reference Model, Tutorial, and Glossary
  - 802.1 b Specification for LAN Traffic Prioritization
  - 802.1 q Virtual Bridged LANs
- 802.2 Logical Link Control
- 802.3 Contention Bus Standard 10 base 5 (Thick Net)
  - 802.3a Contention Bus Standard 10base 2 (Thin Net)
  - 802.3b Broadband Contention Bus Standard 10 broad 36
  - 802.3d Fiber-Optic InterRepeater Link (FOIRL)
  - 802.3e Contention Bus Standard 1 base 5 (Starlan)
  - 802.3i Twisted-Pair Standard 10base T
  - 802.3j Contention Bus Standard for Fiber Optics 10base F
  - 802.3u 100-Mb/s Contention Bus Standard 100base T
  - 802.3x Full-Duplex Ethernet
  - 802.3z Gigabit Ethernet
  - 802.3ab Gigabit Ethernet over Category 5 UTP

LAN, (MANs) and IEEE

- 802.4 Token Bus Standard
- 802.5 Token Ring Standard
  - 802.5b Token Ring Standard 4 Mb/s over Unshielded Twisted-Pair
  - 802.5f Token Ring Standard 16-Mb/s Operation
- 802.6 Metropolitan Area Network DQDB
- 802.7 Broadband LAN Recommended Practices
- 802.8 Fiber-Optic Contention Network Practices
- 802.9a Integrated Voice and Data LAN
- 802.10 Interoperable LAN Security
- 802.11 Wireless LAN Standard
- 802.12 Contention Bus Standard 1 OOVG AnyLAN
- 802.16 Wireless MAN Standard

From



The diagram

... was drawn by Dr. Robert M. Metcalfe in 1976 to present Ethernet ... to the National Computer Conference in June of that year. On the drawing are the original terms for describing Ethernet. Since then other terms have come into usage among Ethernet enthusiasts."

The Ethernet Sourcebook, ed. Robyn E. Shotwell (New York: North-Holland, 1985), title page.

To ...

2.1 IEEE 802.3u: Fast Ethernet

History

- High-Speed LAN COMPATIBLE to existing Ethernet
- 1992:
  - IEEE sets objective to improve existing systems
- 1995:
  - 802.3u passed as an addendum to 802.3
  - (alternative solution containing new technology in 802.12)

Principle

- Retain all procedures, format, protocols
- Bit duration reduced from 100ns to 10ns

Properties: CSMA/CD at 100 Mbps

- Cost efficient extension of 802.3
- Very limited network extension
  - sender has to be able to recognize collision during simultaneous sending
    →network extension must not exceed the size of the min. frame
    →frame at least 64 byte, i.e., 5 ms per frame at 100 Mbps
    → "collision domain diameter" = 412m, i.e., ca. 300m instead of ca. 3000m
- Many collisions (lower utilization)

IEEE 802.3u: Fast Ethernet

Basics

- Actually 10Base-T (Unshielded Twisted Pair)
- HUB as switch on L2

Medium

Name	Cable	Max. segment	Advantages
100Base-T4	**Twisted pair**	**100m**	**Uses category 3UTP**
100Base-TX	**Twisted pair**	**100m**	**Full duplex at 100Mbps (5UTP)**
100Base-F	**Fiber optics**	**2000m**	**Full duplex at 100Mbps**

100Base-F (fiber optics)

- Maximum segment length of 2000m too long for collision recognition
  → may be used only in context with buffered hub ports
  - collisions not possible

Usually improved procedure required

- For 100 Mbps and more
- To transmit data in real time

2.2 IEEE 802.3z: Gigabit Ethernet

History

- IF POSSIBLE,
  - High-Speed LAN compatible with existing Ethernet
- 1998: 802.3z passed as an Addendum to 802.3

Desirable principle

- If 100% compatible
  - retain all procedures, formats, protocols
  - bit duration reduced from 100ns over 10ns to 1ns
- But, then
  - maximum extension would also be 1/100 of the 10 Mbit/s Ethernet,
  - i. e., (depending on the type of cable) approx. 30m

IEEE 802.3z: Gigabit Ethernet

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Principle for

Point-to-point links

- Full duplex mode
- Interconnected by switch function
- With 1 Gbps in both directions
- No change of packet size

→ i.e., no need for further details

Shared broadcast mode

- Half duplex mode
- Interconnected by hub function
- CSMA/CD
- Tradeoff between distance and efficiency

→ i.e., see the following details

IEEE 802.3z: Gigabit Ethernet: Shared Broadcast Mode

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Principle

- Maintain (as far as possible) CSMA-CD with 64 byte minimum length
- Introducing two features
  - carrier extension
  - frame bursting

Carrier extension

- From 512 bit (64 byte) length, previously
- To 512 **byte** length
- By attaching a new extension field
  - following the FCS field (Frame Check Sum)
  - to achieve the length of 512 byte
- Procedure
  - added by sending hardware and
  - removed by receiving hardware
  - software does not notice this
- But low efficiency: transmit 46 byte user data using 512 byte: 9%

Frame bursting

- Allow sender to transmit CONCATENATED SEQUENCE OF MULTIPLE FRAMES in single transmission
  - needs frames waiting for transmission
  - better efficiency

Bits 7 6 5 4 3 2 1 0	
Preamble	7 Octets
Start frame delimiter	1 Octet
Destination address	2 or 6 Octets
Source address	2 or 6 Octets
Length	2 Octets
LLC Data	Variable (0-1500 Octets)
Pad	Variable (0-46 Octets)
FCS	4 Octets

7 byte	1 byte	2/6 byte	2/6 byte	2 byte	46-1500 byte	0-46 byte	4 byte
PA	SFD	DA	SA	L	Data	PAD	FCS

IEEE 802.3z: Gigabit Ethernet: Shared Broadcast Mode

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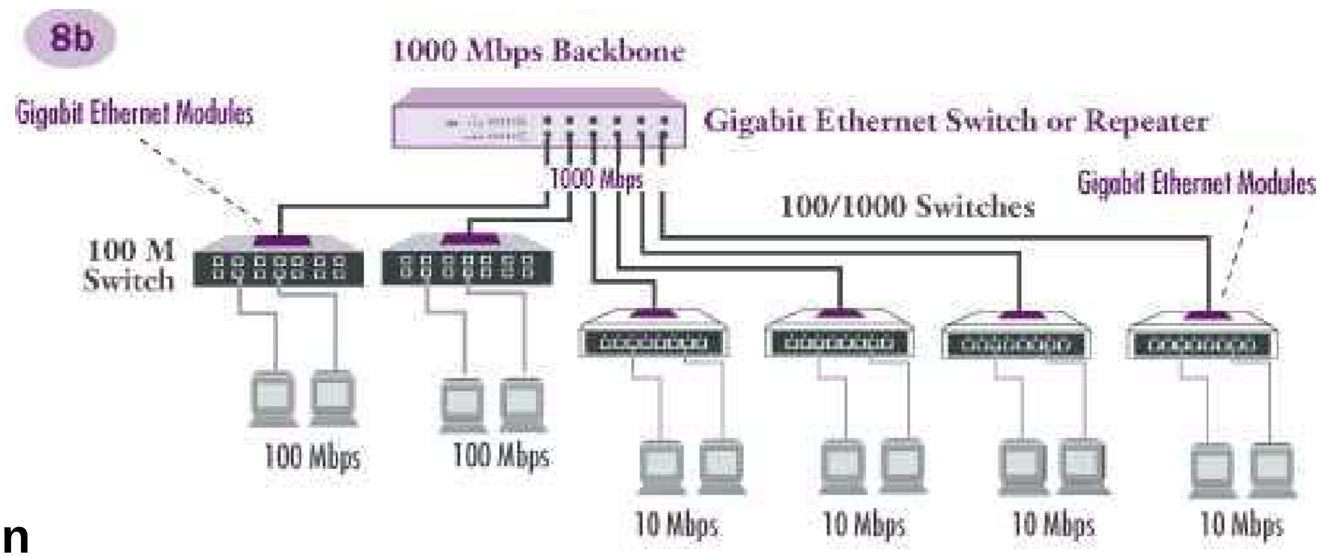
Maximum extension of a segment (i.e., of a Collision Domain)

5 UTP	100m
Coax	25m
Multimode fiber	550m
Single mode fiber	5000m



Possible uses

- Preferably in the "Backbone-Network"

Sources of information

- IEEE
  - http://grouper.ieee.org/groups/802/3/z/index.html
- Gigabit Ethernet Alliance
  - http://www.gigabit-ethernet.org

2.3 IEEE 802.3ae: 10Gbit Ethernet

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History

- 1999: IEEE 802.3ae task force founded
- 2002: approval as a standard

Objectives

- To preserve 802.3 frame format
  - incl. minimal and maximal frame sizes
- To support full duplex operation only
  → no CSMA/CD required

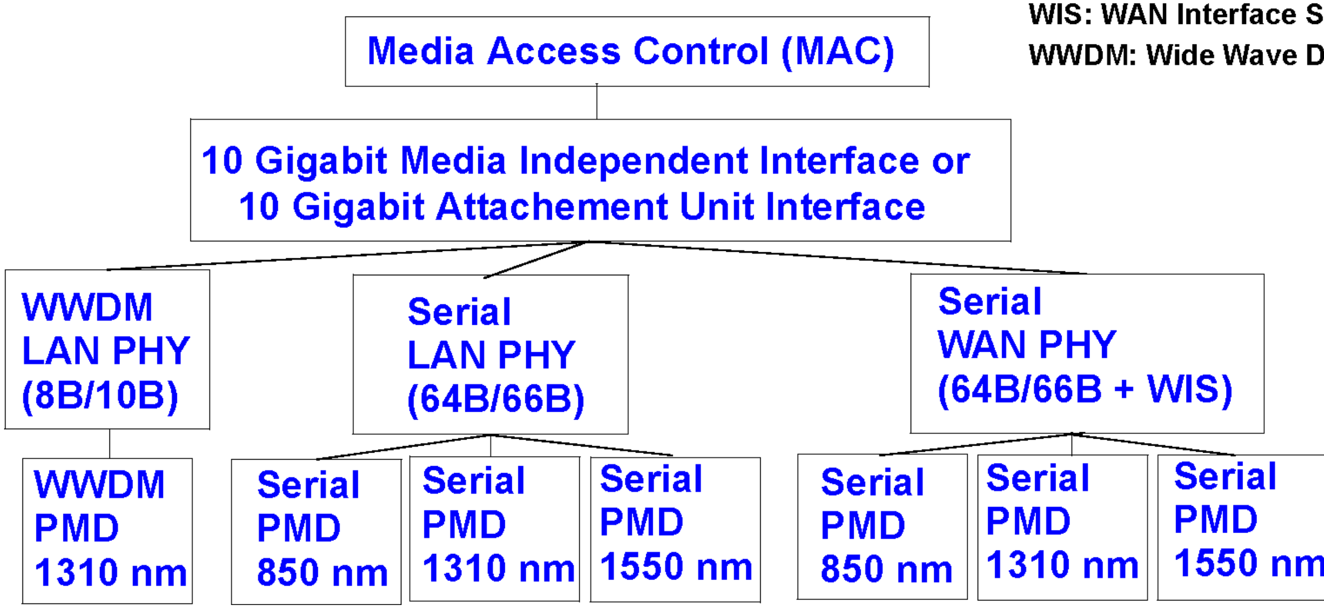
Sources of information

- IEEE
  - http://grouper.ieee.org/groups/802/3/ae/index.html
- further
  - 10 Gigabit Ethernet Alliance (10GEA) and others
  - http://www.10gea.org
  - http://www.10gigabit-ethernet.com/

IEEE 802.3ae: 10Gbit Ethernet

Architectural Components

PMD: Physical Media Dependent
WIS: WAN Interface Sublayer
WWDM: Wide Wave Division Multiplexing



Supported distances

- 850nm: 300 m
- 1310nm: 10 km
- 1550nm: 40 km

2.4 IEEE 802.3ba: 40Gb/s and 100Gb/s Ethernet

Further specifications on their way to be defined

Requirements

- To support full-duplex operation only
- To preserve the 802.3 frame format utilizing the 802.3 MAC
- To preserve minimum and maximum FrameSize of current 802.3 standard
- To support a bit error ratio (BER) better than or equal to $1 \cdot 10^{-12}$ at the MAC service interface

3 Other High-Speed LANs

See WAN, see MAN

but here some other…

Isochronous Ethernet (Iso-Ethernet)

Objective

- Within one LAN
  - Ethernet and
  - ISDN type channel structure
- Wiring: 1 pair of Unshielded Twisted Pair (UTP) cable

Data rates

- 10 Mbps
  - CSMA/CD like before
- 6,144 Mbps
  - Additionally 64 ISDN B channels (data) with 64 kbps each as time slots
  - Signaling Q.931 like (ISDN)

Comment

- Very low significance

"100-Mbps Demand Priority LAN"

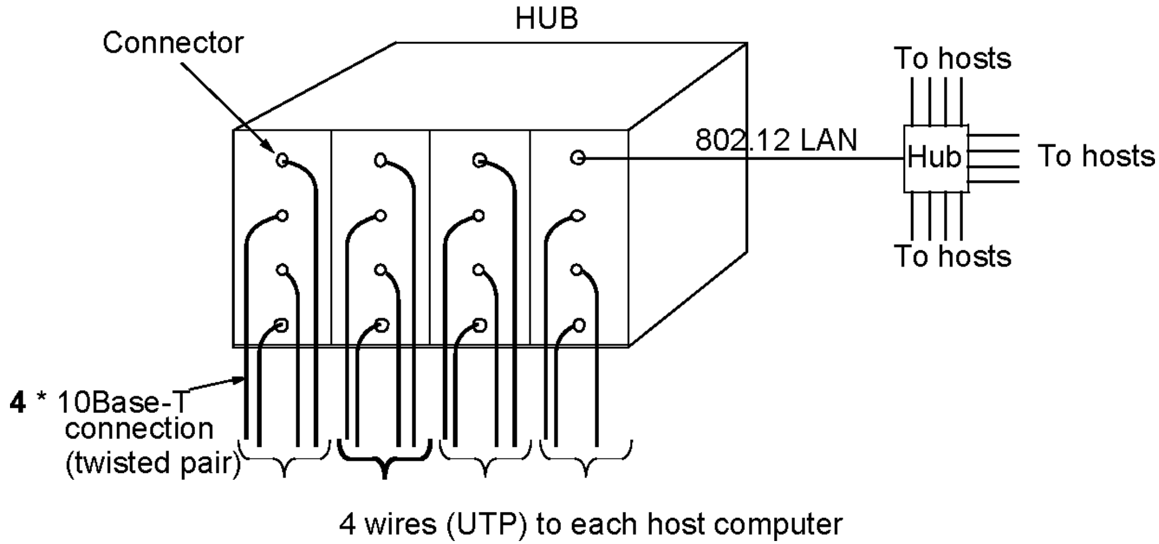
History

- Initiated in 1992 as the high-speed successor to 802.3 CSMA/CD
- Originally 100Base-VG
- Then 100Base-VG AnyLAN
- Then IEEE 802.12

Objective

- Increased speed
- Additional transmission of audio and video
- Retain existing LAN wirings
  - UTP 3, 4, 5 and STP
  - but UTP with 4 pairs each per station
- Compatibility with Ethernet and Token Ring
  - (the frames here should be sent over these)

Demand Priority: Physical Layer



Topology: connectors to hubs (or switches, as relaying centers)

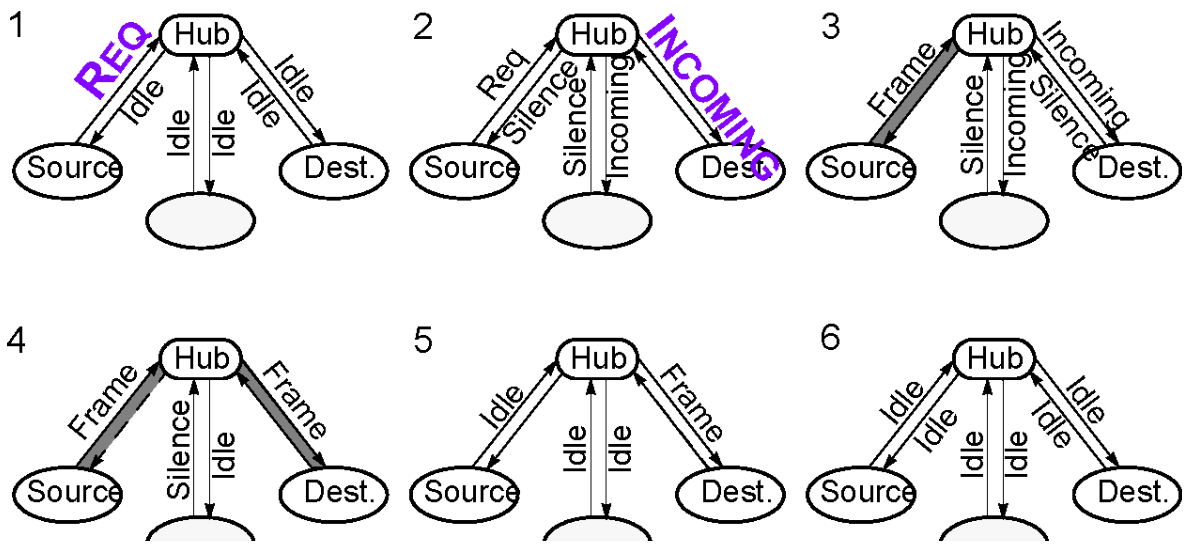
Encoding

- 5B6B (5 data bits as 6 bit on medium)
- With 4 line pairs
  - 30 MBaud per line pair
    - 30 * 5 / 6 = 25
    - 25 * 4 = 100

Line use

- Data transfer phase: 4 pairs unidirectional
- Transmission request: 2 pairs

Demand Priority: MAC



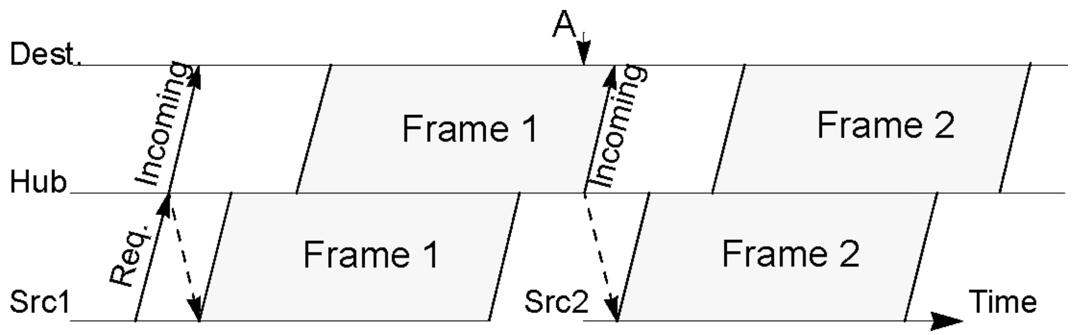
Access: logical sequence

Idle state (6)
- Idle: no current send requests

Accept/store desire to send (1 and 2)
- REQ request (1): station that wants to send notifies HUB about request to send
- (2) HUB decides about allocation, and
  - incoming: HUB notifies all other stations accordingly, and
  - silence: HUB notifies station that wants to send

Execute data transmission (3, 4 and 5)
- HUB reads destination address and tries immediately to route data
- HUB does not buffer the frame

Demand Priority: MAC



Access: temporal sequence

Station Management

- Initialization if new station is connected
  - Identify the station
    - bridge: receives all frames
    - normal station: receives frames addressed to this station only
    - frame type: 802.3, 802.5 or both types
  - MAC addresses of connected stations
    - have to be known at the HUB

Demand Priority: MAC

Priorities

- 2 levels of requests
  - high: REQ_H
  - normal: REQ_N
- Each frame has a priority assigned
- Scheduling in the HUB
  - within a priority: Round-Robin procedure
  - non-preemptive (normal priority can not be suspended)
- Problem of starving low priority data
  - if frame with normal priority has to wait longer than 250 ms (because of high priority traffic),
  - it is treated as high priority and is sent next

Connecting several HUBs

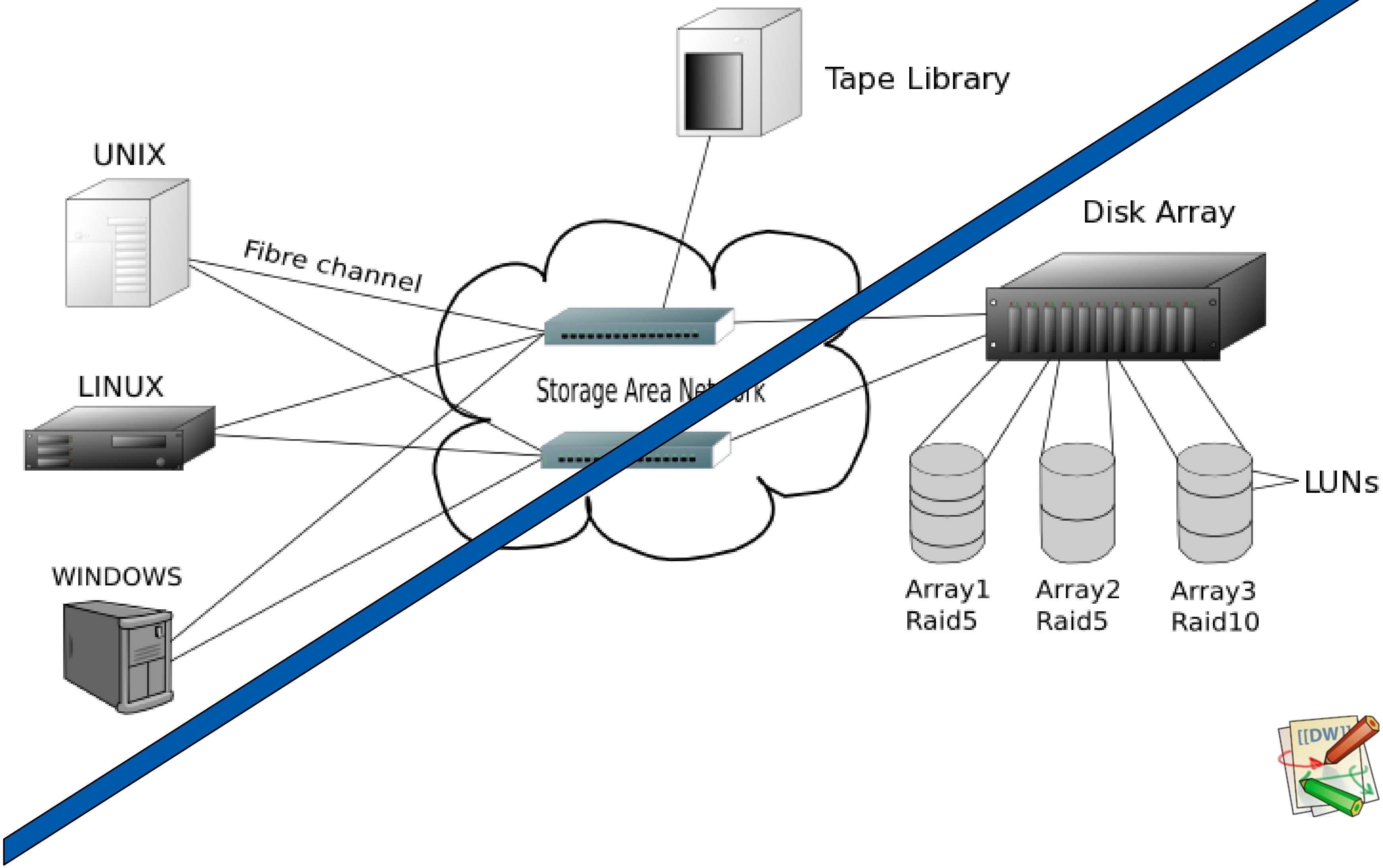
- Tree structure, with stations representing leaves
- All stations follow an explicit sequence
- HUB: has a marked port to connect with other HUBs
- Communication between HUBs is done through requests
  - to coordinate global access

Demand Priority

Properties

- Data is sent only to the actual destination, not to all the stations
  →more efficient when compared with Token Ring, Ethernet
  →access to foreign data limited
- Utilization
  - up to 90% with large frames
  - 40% - 90% in general
- Optimization
  - HUB: connects a sender with a receiver
  - Switch: enables parallel transmission

Storage Area Network



5 MAN – Basic Characteristics

Extension: city-wide

High transmission rates (>100 Mbps)

Transmission of

- Data
- Voice
- Video

Data transmission

- Asynchronous (data)
- Isochronous (voice, video)

Typical MAN traffic

- LAN interconnection
- Digital images, voice, video
- Conventional traffic

LAN development

- Towards
  - increased speed
  - shared bandwidths
- Of conventional data towards
  - integrated data (conventional & audio/video)
- Also larger expansions (100 km)

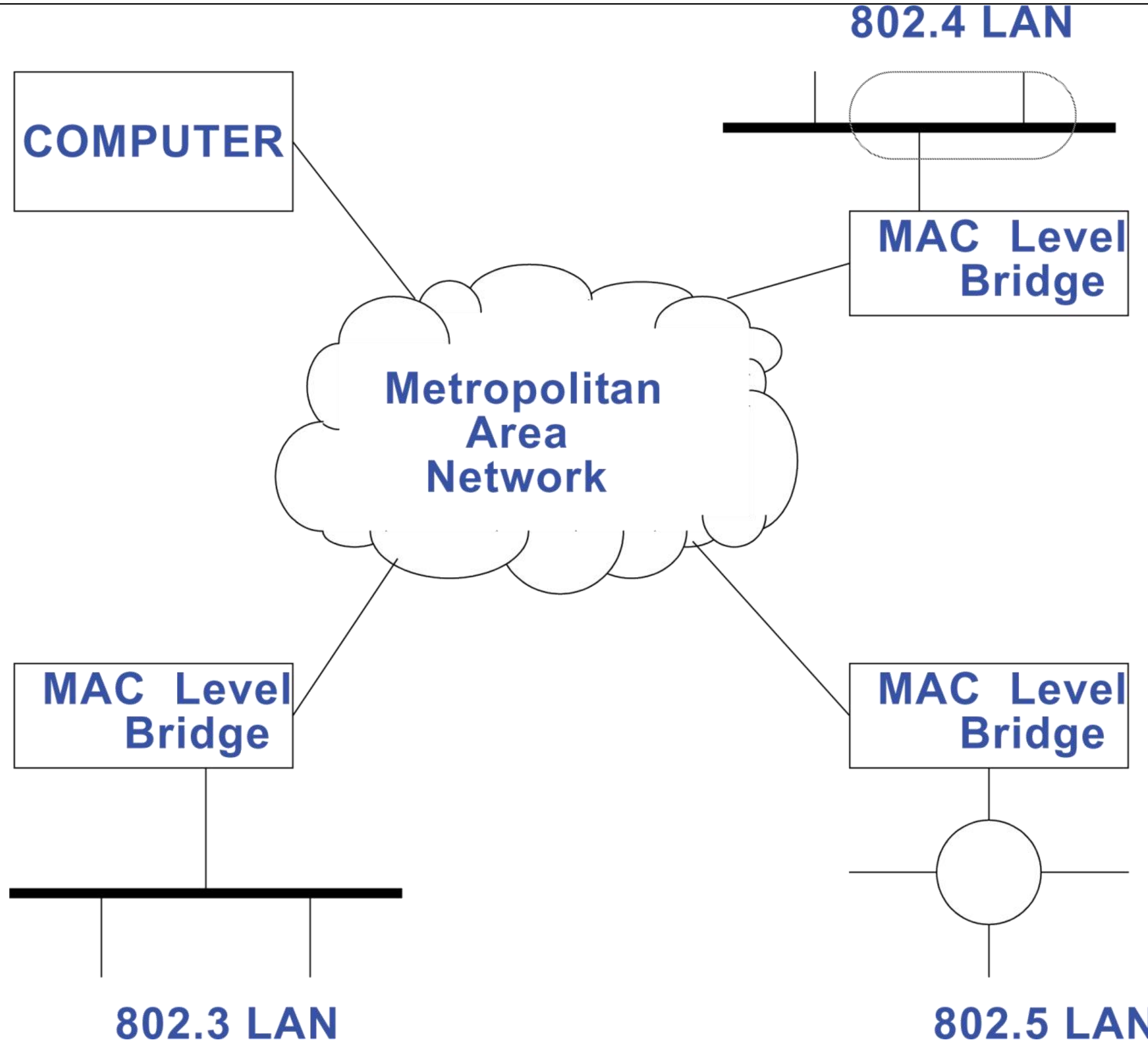
→ i. e. High-Speed LAN also as MAN

WAN development

- Towards
  - increased speed
  - bandwidth per connection
- From audio (video) towards
  - integrated services (conventional & audio/video)
- Also smaller expansions (down to the Desk Area range)

→ i. e. WAN also as MAN (and LAN)

MAN Applications



Distributed Queue Dual Bus DQDB

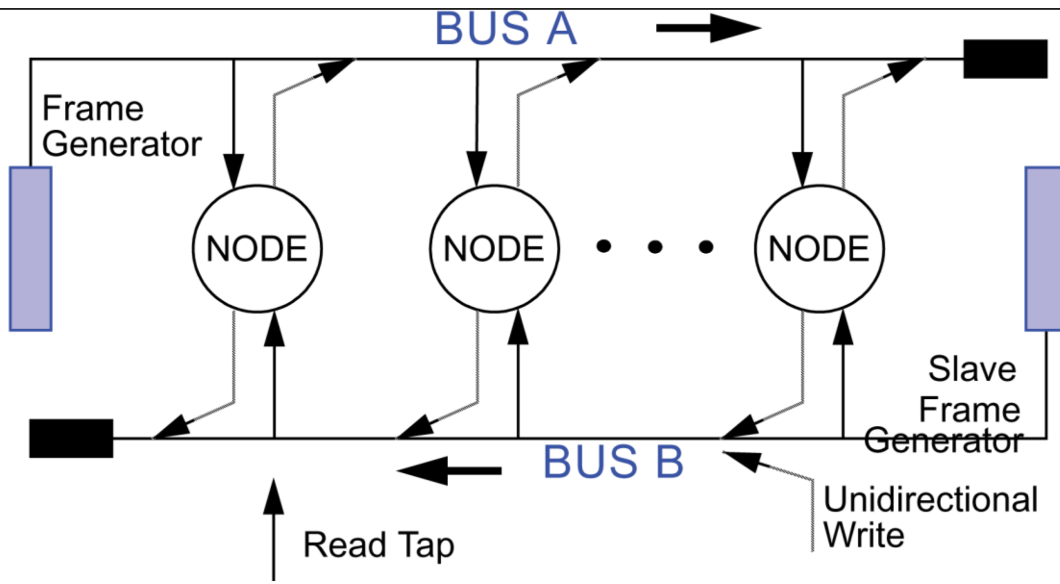
History

- 1987: IEEE decision for DQDB as IEEE 803.6

Objective: MAN

- To be compatible with the IEEE 802.x MAC frame format
  - for ASYNCHRONOUS data traffic (packet switching)
- To be compatible with ATM - B-ISDN cell structure and data rates
  - for ISOCHRONOUS traffic (circuit switching)

DQDB Network Architecture



Dual bus

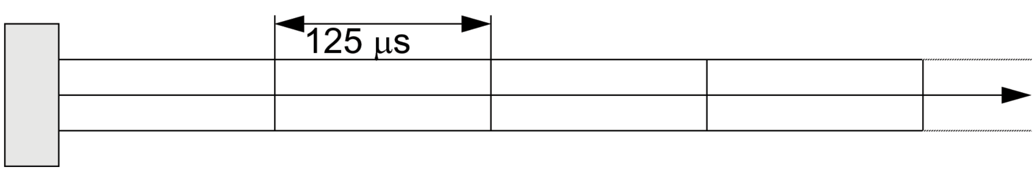
- 2 unidirectional buses for data transfer
- Transmission in opposing directions
- Medium: fiber optic, coax, radio frequencies, . . .

Station (node)

- Connected to both buses
- Per bus: read access and unidirectional write access

Frame generator

- Generates every 125 msec



7 Fiber Distributed Data Interface (FDDI)

History

- Based on the IEEE 802.5 Token Ring principle
- Standardized (ANSI X3T9.5, ISO 9314) in 1988
- Used since 1990

Physical Features

- Ring: optical LAN with 100 Mbps
- Up to 200 km long,
- Up to 2 km distance between single stations
- Up to 500 random stations
- Error rate $< 2.5 \cdot 10^{-10}$

Protocol

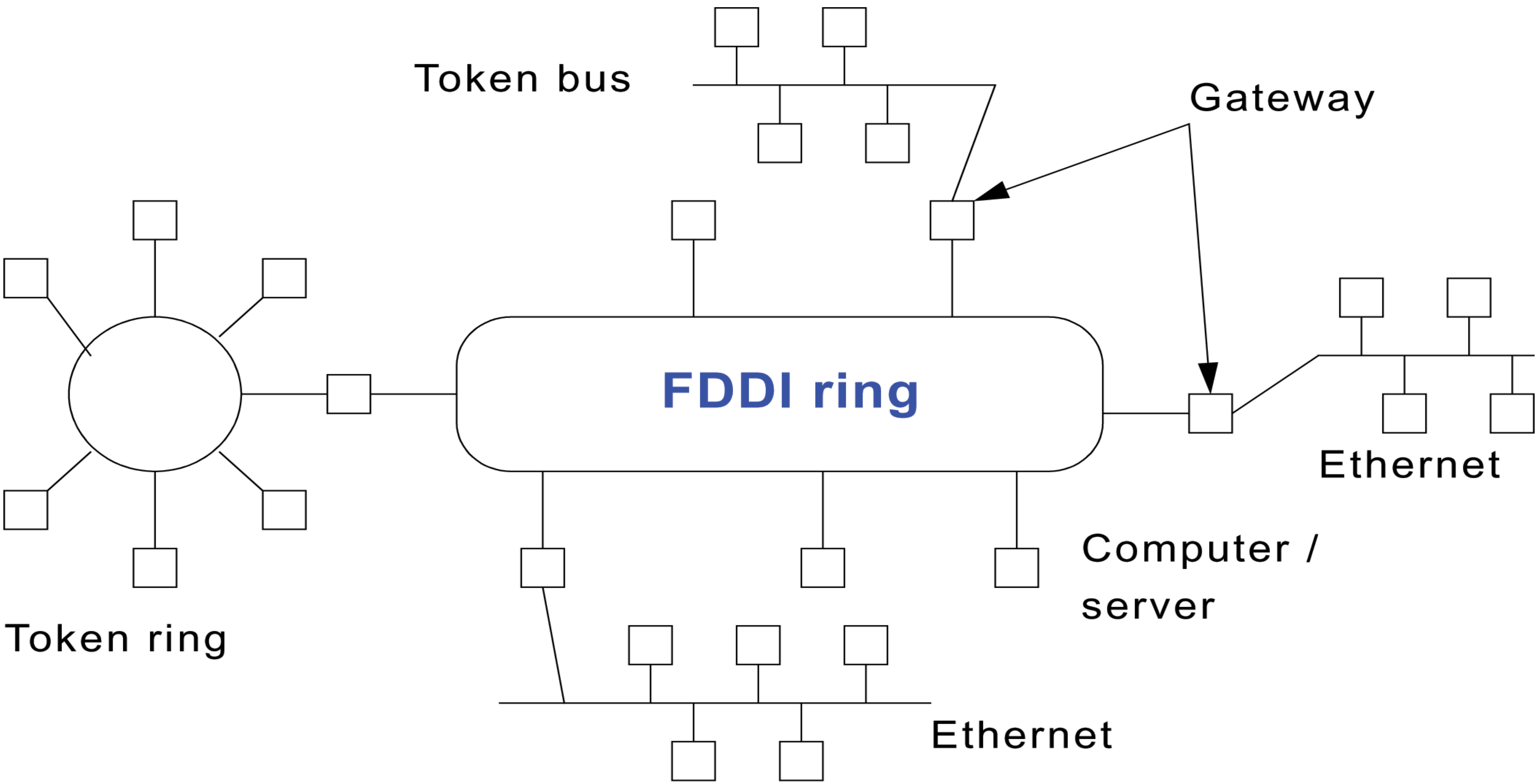
- Enhancement of the Early Token Release
- Time-controlled procedure with token
- Frame with approx. 4096 bytes

Traffic types

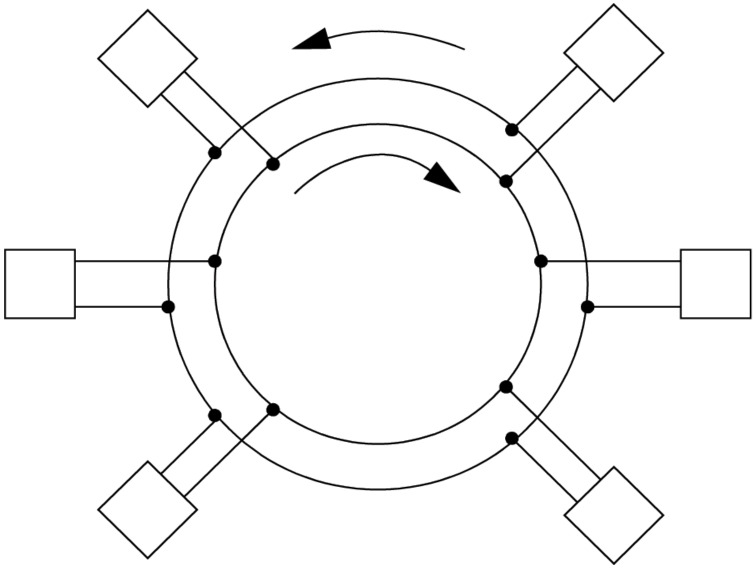
- Asynchronous: bandwidth allocation based on payload
- Synchronous: fixed bandwidth

... Applications

FDDI: Applications



7.1 FDDI: L1 Topology



2 fiber glass rings

- Opposite transmission direction
- Primary ring: actual communication
- Secondary ring: backup

Medium

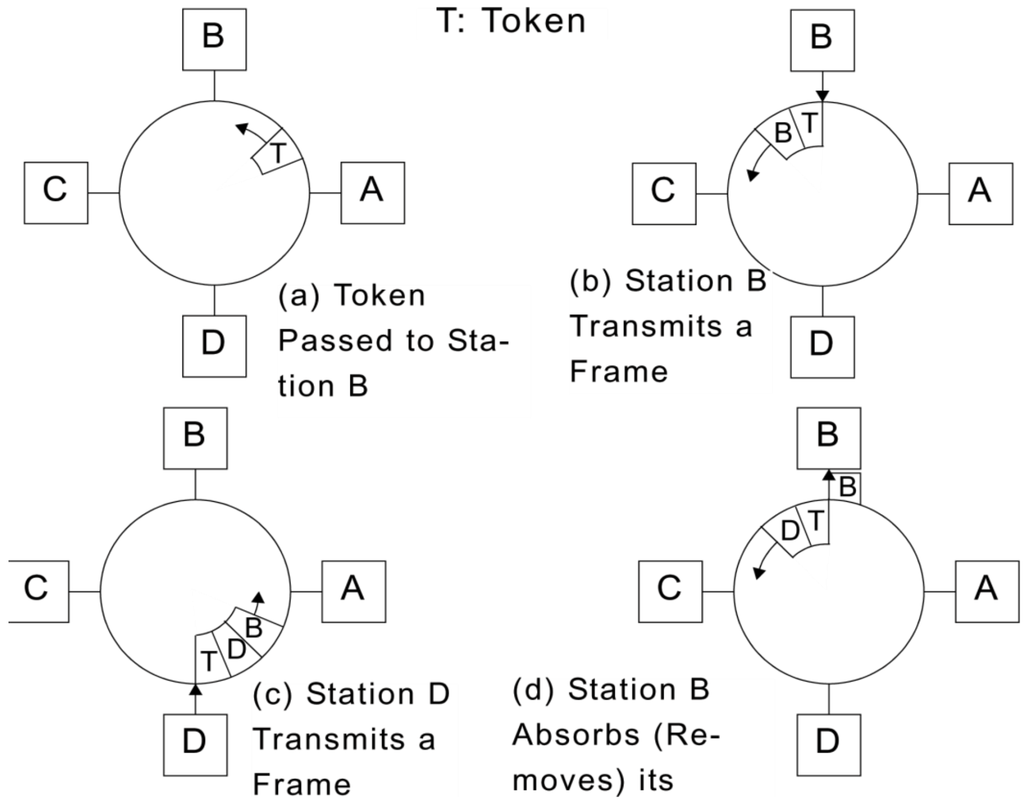
- Multi-mode optical fiber:
  - 62.5 nm in diameter
  - wave length 1300 nm
- Sender: usually LED
- Detector: usually PIN diode
- Also CDDI: Copper Distributed Data Interface

7.2 FDDI MAC: Token Protocol

Difference to 802.5

- 802.5:
  Station can regenerate token only after message has circulated through the ring
  → large delays in long rings

- FDDI:
  Station can generate token immediately after transmission has ended (like early token release)
  → possibly several frames on the ring



7.3 FDDI MAC: Timer Protocol

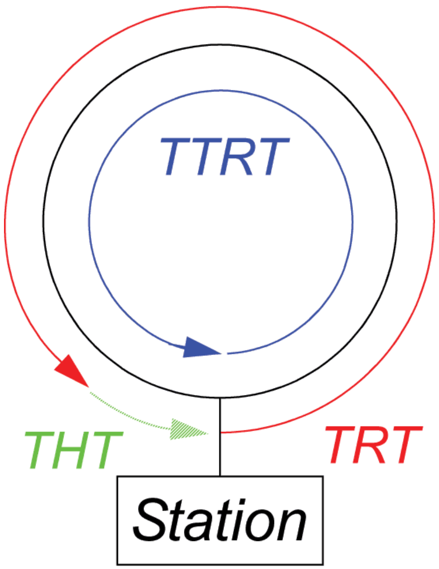
Essential parameters:

Token Rotation Time (TRT)

- Elapsed time since the station last received a token
- Continuously monitored by each station
- Maximum TRT = 2 · TTRT

Target Token Rotation Time (TTRT)

- Target for maximum time between possibilities to send (for asynchronous traffic only)
- i. e.
  - pre-defined during configuration
  - valid for all stations on the ring
  - possible values: 4 ms < TTRT < 165 ms (recommended value: 8 ms)



Token Holding Time (THT):

- Maximal duration at which a station may send data
- Depends on current TRT value
  - long THT: poor response time, but greater data throughput
  - short THT: lower throughput but short delay for station to gain access

7.4 FDDI: Traffic Modes

Asynchronous traffic

- May only utilize free capacity
- Station determines TRT when it receives the token
- i. e.
  - TRT < TTRT: station may send asynchronous data within the time frame TTRT-TRT
  - TRT >= TTRT: station is not allowed to send any asynchronous data during this cycle
- But: most implementations only support asynchronous mode

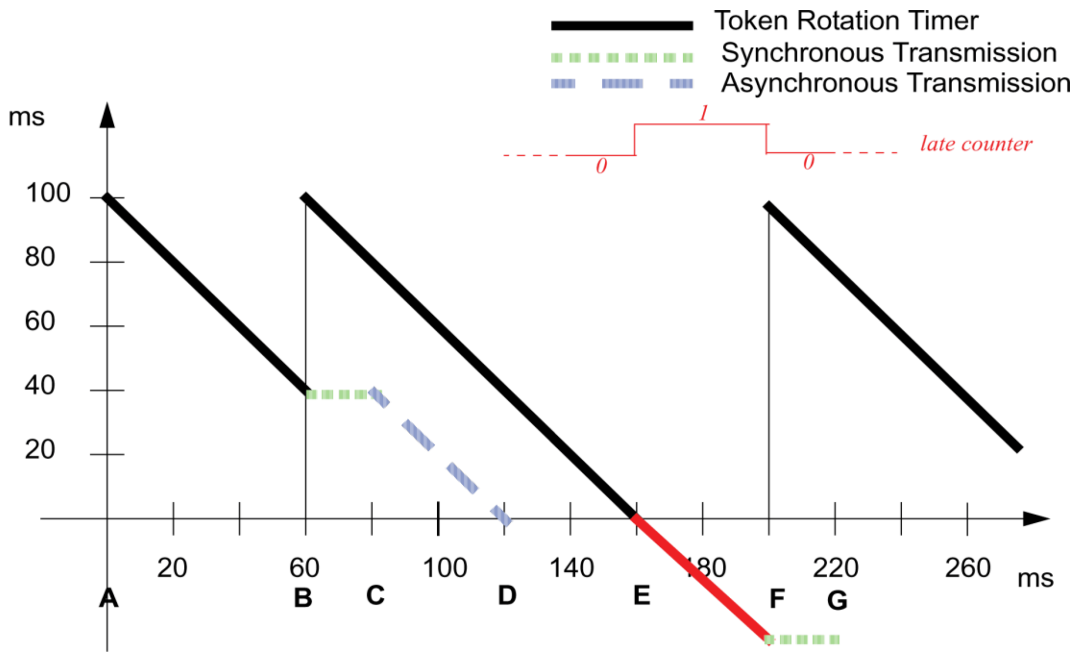
Synchronous traffic

- Conceived for real-time data
- Network management assigns bandwidth SA_i to each station S_i ,
  - i. e. after the token has been received, it is guaranteed that Si may send synchronous data for the duration of SA_i
- i. e.

$$\sum_{i} SA_i < TTRT$$

- Max. bandwidth for synchronous traffic defined by: TTRT
- Max. delay for synchronous traffic: 2·TTRT
- (because TRT never gets larger than 2·TTRT)

FDDI Timer Protocol: Example (Inside a Station)



Legend:

A: Token received, no data to be sent this cycle, token passed to next station

B: Token captured, synchronous transmission begins

C: Synchronous transmission complete, asynchronous transmission begins

D: Time expired, asynchronous transmission ends, token passed to next station

E: Token rotation timer expires, TRT now exceeds TTRT, late counter incremented

F: Token arrives late, token rotation timer accumulates lateness, synchronous transmission starts, no asynchronous transmission permitted this cycle

G: Synchronous transmission ends, token passed to next station

FDDI Timer Protocol: Example of Various Stations

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Assumptions

- Ring with 3 stations
  - each station always wants to send ASYNCHRONOUS traffic
  - each station always wants to send 1 (time unit) SYNCHRONOUS traffic
- TTRT = 8 (time units),
  if TRT = TTRT happens only synchronous traffic is sent

Station 1			Station 2			Station 3		
TRT	asyn	syn	TRT	asyn	syn	TRT	asyn	syn
0	**8**	**1**	**9**	**-**	**1**	**10**	**-**	**1**
11	**-**	**1**	**3**	**5**	**1**	**8**	**-**	**1**
Comment: cycle starts here								
8	**-**	**1**	**8**	**-**	**1**	**3**	**5**	**1**
8	**-**	**1**	**8**	**-**	**1**	**8**	**-**	**1**
3	**5**	**1**	**8**	**-**	**1**	**8**	**-**	**1**
8	**-**	**1**	**3**	**5**	**1**	**8**	**-**	**1**
Comment: cycle restarts here ...								
8	**-**	**1**	**8**	**-**	**1**	**3**	**5**	**1**
8	**-**	**1**	**8**	**-**	**1**	**8**	**-**	**1**
...	**...**	**....**	**.**	**.**	**.**	**.**		**.**