Communication Systems
High-Speed LANs and MANs

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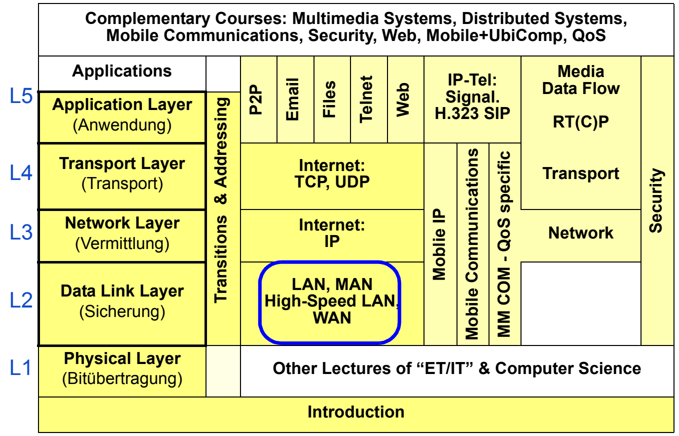
Kommunikationssysteme: High-Speed LANs and MANs

Scope



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Overview

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1. High-Speed LANs, WANs and MANs

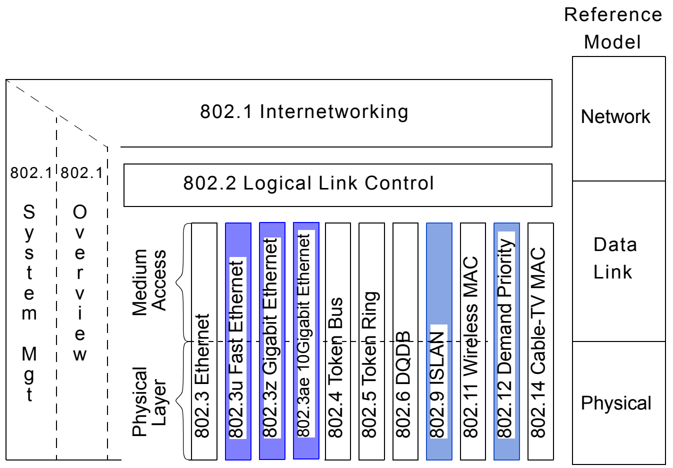
LAN development

- **towards**
  - more speed
  - shared bandwidth
- **from conventional data towards**
  - integrated data (conventional & audio/video)
- **also increasing expansion (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)
- **also decreasing expansion (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**

2. 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 100 ns to 10 ns

Properties: CSMA/CD at 100 Mbps
- **cost efficient extension of 802.3**
- **very limited network expansion**
  - sender has to be able to detect collision during simultaneous sending
    - network expansion must not exceed the minimum frame size
    - frame at least 64 byte, i.e. 5 ms at 100 Mbps per bit
  - i.e., extension only a few 100 m
    "collision domain diameter" = 412 m (instead of 3000m)
- **many collisions (lower utilization)**

IEEE 802.3u: Fast Ethernet (2)

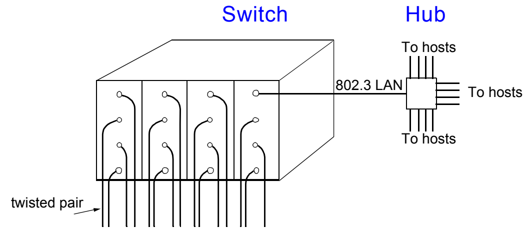
Use of 10Base-T (Unshielded Twisted Pair) wiring style
- **no 10Base-2 or 10Base-5**

Medium

Name	Cable	Max. segment	Characteristics
100Base-T4	Twisted pair	100m	Uses category 3 UTP • cables can't handle 100 Mbps Manchester signalling speed: 25 MHz • needs 4 twisted pairs (1+1+2: to/from hub, switchable) • no Manchester but ternary encoding (8B/6T)
100Base-TX	Twisted pair	100m	Full duplex at 100Mbps (Cat 5 UTP) • better cable quality • uses 2 twisted pairs (one each to/from hub) • 4B/5B encoding (16 out of 32 bit combinations)
100Base-F	Fiber optics	2000m	Full duplex at 100Mbps • two multimode fiber (one per direction)

IEEE 802.3u: Fast Ethernet (3)

Interconnection devices:
- **Hubs**
- **or switches**



100Base-F:
- maximum segment length of 2000 m too long for collision detection

⇒ **may be used only in context with buffered switch ports**
- collisions impossible

usually improved procedure required
- **for 100 Mbps and more**
- **to transmit data in realtime**

3. 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 100 ns over 10 ns to 1 ns
- **then**
  - maximum expansion would also be 1/100 of the Ethernet,
  - i.e., (depending on the type of cable) approx. 30 m

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IEEE 802.3z: Gigabit Ethernet (2)

Two modes of operation

- **full-duplex**
- **half-duplex**

full-duplex

- **with switches, all lines are buffered and only one sender**
- **no channel sensing necessary, CSMA/CD not used**
- **maximum length of cable determined by signal strength**
  - not by collision considerations

half-duplex

- **with hubs: no buffering but internal coupling of signals**
- **collisions possible: CSMA/CD necessary**
- **maximum distance 1/100 of classical Ethernet, i.e. 25m**
  - unacceptable short

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IEEE 802.3z: Gigabit Ethernet (3)

Principle:

- **maintain (as far as possible)**
  - CSMA-CD with 64 byte minimum length
- **introducing two features**
  - carrier extension
  - frame bursting

Carrier extension

- **from previously 512 bit (64 byte) length to 512 byte length**
- **i.e., by attaching a new extension field, following the FCS field (Frame Check Sum) to achieve the length of 512 byte**
- **added by sending hardware and removed by receiving hardware software doesn't notice this**
- **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**

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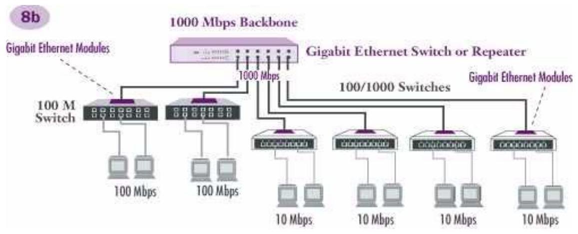
IEEE 802.3z: Gigabit Ethernet (4)

Name	Cable	Max. segment	Characteristics
1000Base-SX	Fiber optics	550m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000m	Single (10µ) or multimode (50, 62.5µ)
1000Base-CX	2 pairs of STP	25m	Shielded twisted pair
1000Base-T	4 pairs of UTP	100m	Standard category 5 UTP

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

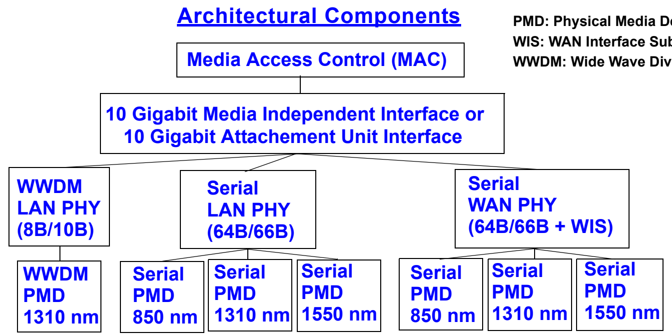
4. IEEE 802.3ae: 10 Gigabit Ethernet

History:
- Q3 of 1999: IEEE 802.3ae task force founded
- June 2002: approval as a standard

Objectives:
- higher capacity for storage area networks, integrated services networks...
- distance for single-mode fiber up to 40 km (5 km in Gigabit Ethernet)
  - ⇒ to connect, for example, two campuses of a company
- interoperability to SONET, existing network management systems,...

Principle:
- works over optical fiber only, no UTP or coax
- full-duplex mode
  - ⇒ no collisions
  - ⇒ no collision detection (CSMA/CD) necessary!
- same "Ethernet" packet format (minimum frame size, maximum frame size...)
- two PHYs: for LAN and for WAN, respectively

IEEE 802.3ae: 10 Gigabit Ethernet (2)



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

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

Sources of information:
- IEEE
  - http://grouper.ieee.org/groups/802/3/ae/index.html
- 10 Gigabit Ethernet Alliance (10GEA)
  - http://www.10gea.org

5. IEEE 802.9: Integrated Voice Data LAN - IVD LAN

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
- 6,144 Mbps
  - additionally 64 ISDN B-channels with 64 kbps each
  - as time slots
  - signaling Q.931 like (ISDN)

Comment
- historical only
- has not gained significance

6. IEEE 802.12: Demand Priority

"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 (priorities)
- 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)

Comment:
- has not gained sufficient support / deployment
- mainly obsolete

7. MAN Features

Expansion city-wide

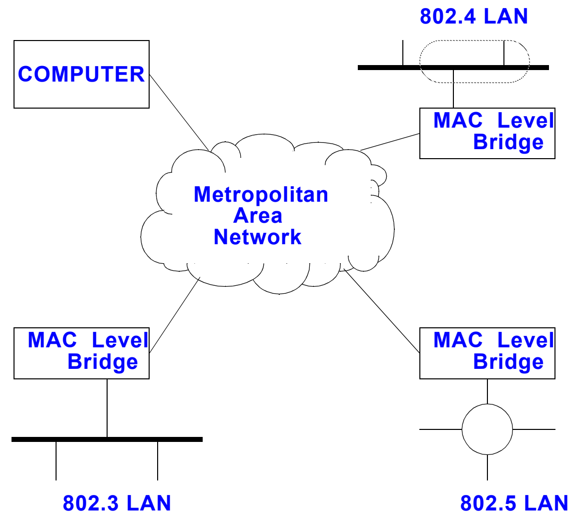
High transmission rates (>100 Mbps)

Transmission of
- data
- voice
- video

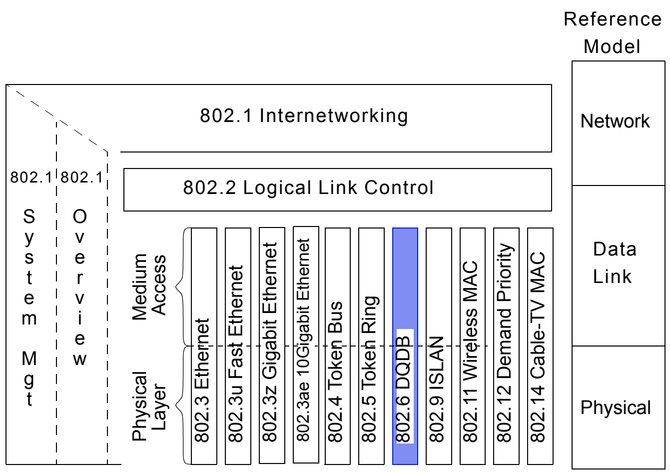
Data transmission
- Asynchronous (data)
- isochronous (voice, video)

Typical MAN traffic
- LAN connections
- digital images, voice, video
- conventional traffic

MAN Applications



MAN and IEEE



e. g. IEEE 802.6
- MAN standard

8. IEEE 802.6: Distributed Queue Dual Bus (DQDB)

Distributed Queue Dual Bus DQDB

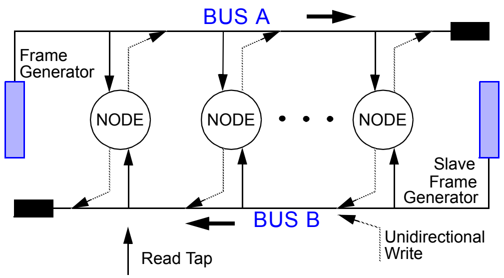
History
- originally 2 candidates
  - MST: Multiplexed Slot and Token Ring
  - DQDB: Distributed Queue Dual Bus
- 1987: IEEE decision for DQDB
- previously QPSX
  - Queued Packet Switch
  - QPSX as named used by an Australian company

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

DQDB Network Architecture

Dual bus

- 2 unidirectional buses
  both used for data transfers
- transmission in opposing directions



Station (node)

- connected to both buses
- per bus: read access and unidirectional write access

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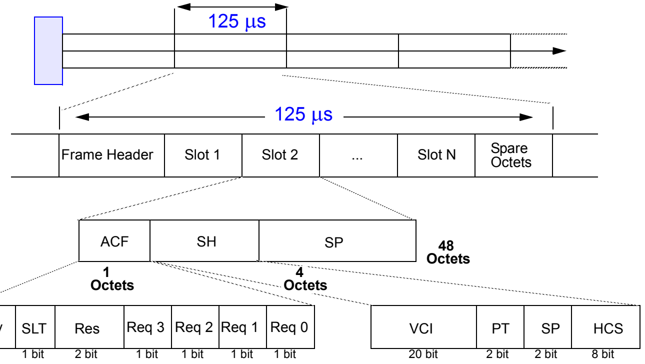
DQDB Network Architecture (3)

Frame generator

- generates frames every 125 µsec (i.e., 8 kHz)
- Individual stations may reserve slots
  - station downstream may reserve empty slots coming from the generator
  - station further upstream must let these slots pass



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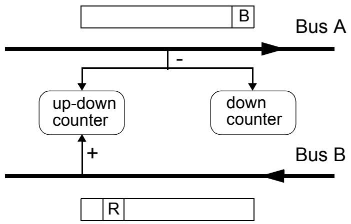
DQDB: Protocol

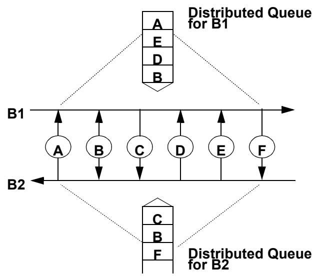
Up-down-counter:

- Node without send request monitors bus
- Up-down-counter is incremented
  when a slot passes by on bus B
  with request bit set
- Up-down-counter is decremented as
  empty slot passes by on bus A
- Node knows at any time number of
  pending downstream requests for slots



Down-counter:

- If station wants to send
  it copies up-down-counter into down-counter
  and sends a request on bus B
- When down-counter reaches zero,
  node may send at next empty slot



Fairness Problems:

- Distance to generator
- Distance between stations

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9. 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 $< 2{,}5 \cdot 10^{-10}$

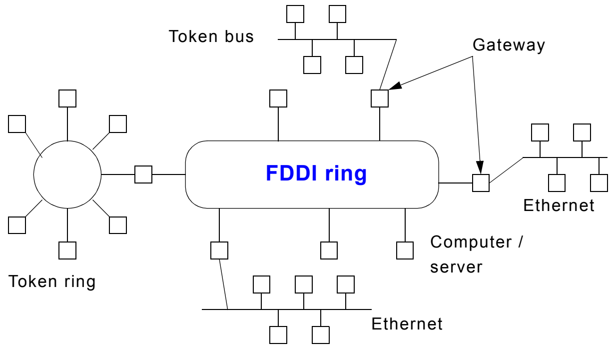
Protocol

- 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

FDDI: Applications



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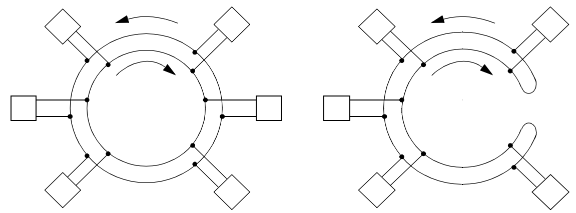
9.1 FDDI: L1 Topology



2 fiber glass rings
- **opposing transmission routes**
- **primary ring: actual communication**
- **secondary ring: backup**

Medium
- **multimode optical fiber: 62.5 nm in diameter**
- **wave length 1300 nm**
- **sender: usually LED**
  detector: usually PIN diode
- **also CDDI: Copper Distributed Data Interface**

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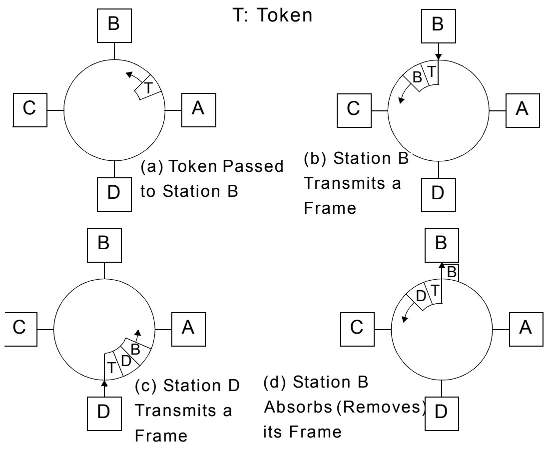
9.2 FDDI MAC: Token Protocol

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
  - (early token release)

⇒ **possibly several frames on the ring**



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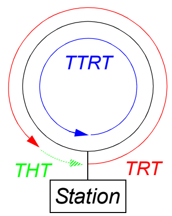
FDDI: Timers

Token Rotation Time (TRT)
- **Elapsed time since the station last received a token**
- **Measured by each station**
- **Maximum TRT = 2*TTRT**

Target Token Rotation Time (TTRT)
- **target for maximum time between possibilities to send (for asynchronous traffic only)**
- **pre-defined during (re-) configuration**
- **valid for all stations on the ring**
- **4 ms < TTRT < 165 ms (8 ms recommended)**



Token Holding Time (THT):
- **Maximum amount of data that a station may send**
- **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**

FDDI: Traffic Modes

Asynchronous Traffic:

- **May only utilize free capacity**
- **station determines TRT when it receives the token**
  - TRT < TTRT:
    station can send asynchronous data within the time frame TTRT-TRT
  - TRT >= TTRT:
    station must not send any asynchronous data during this cycle
- **Most implementations only support asynchronous mode**

Synchronous Traffic:

- **Guaranteed bandwidth traffic**
- **Bandwidth for each station A: SA_i (guaranteed)**
  - bandwith SA_i assigned assigned by network management to each station S_i
  - after the token has been received, it is guaranteed that S_i may send synchronous data for the duration of SA_i
- **$\sum S_A$ < TTRT**
- **Maximum time for synchronous traffic: TTRT**
- **Maximum delay for synchronous traffic: 2*TTRT (because TRT never gets larger than 2*TTRT)**