4 Local Area Networks (LANs)

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What is a LAN?

Definition

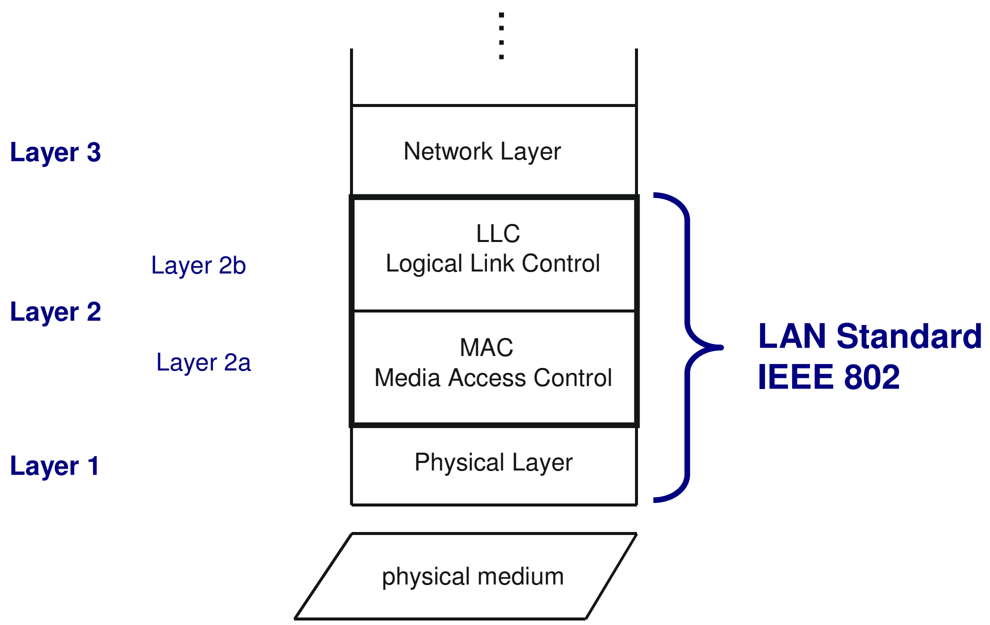
A **LAN** (Local Area Network) is a network for the bit-serial transmission of data between independent peer stations.

It is usually under the legal control of a single user (single enterprise) and is usually limited to the user pemises.

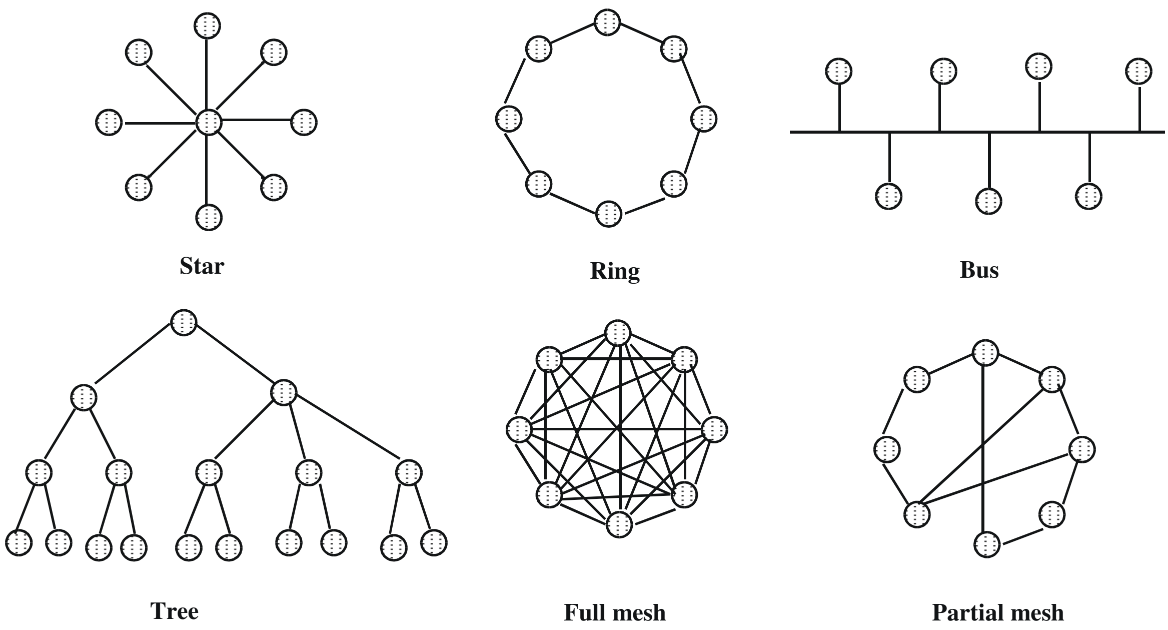
Characteristics of a Local Area Network

- High transmission speed (10 -1000 MBit/s)
- Easy, inexpensive connection of stations
- No need to take Telekom rules and regulations into account
- Different types of devices can be connected easily:
  - personal computers
  - high-end Unix workstations
  - department servers/file servers/mail servers
  - mainframes
  - printers and other peripheral devices
- Interconnection to wide-area networks (WANs) possible via routers (layer 3)

LANs in the ISO Reference Model



4.1 Topologies of Local Area Networks



Point-to-Point vs. Broadcast Networks

Point-to-point network

- Exactly two stations are physically connected by each link.
- Multicast and broadcast require the explicit duplication of packets in the network nodes.
- For long-distance, multi-hop traffic, in the partly meshed topology, **routing** has to be performed explicitly in order to find a path to the receiver.

Broadcast network

- Several stations (typically more than two) share the physical medium.
- All stations can hear all messages, i.e., multicast and broadcast are “for free”.
- If two stations are sending at the same time, both messages are destroyed.
- The sender can hear his own message. If he hears exactly what he is sending he can assume that the receivers are also receiving the message correctly.
- Within a LAN segment (the local link) routing is not necessary!

4.2 Medium Access Control

Problem:

- broadcast medium
- independent stations

  => send collisions will occur

Solution: Medium Access Control

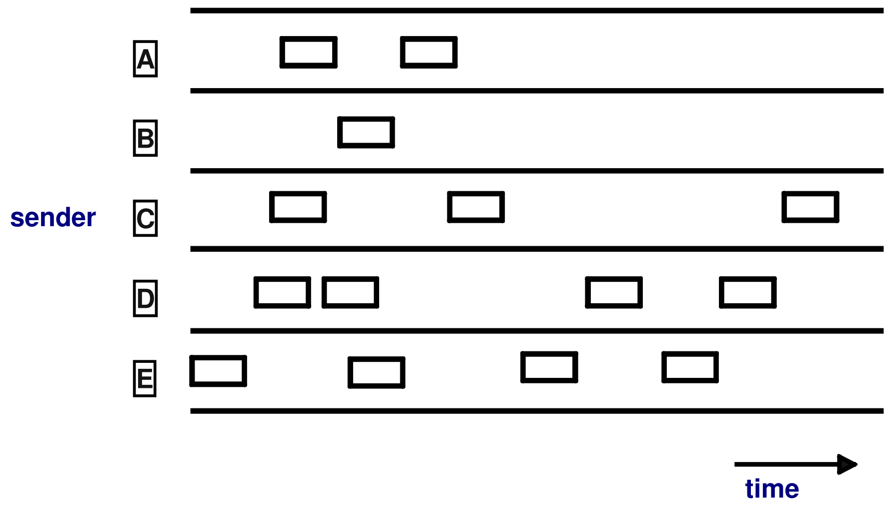
Two allocation principles:

- **Collision detection**
  Let collisions take place, detect them, repeat the transmission.
- **Collision avoidance**
  Use a circulating token to control the access to the medium.

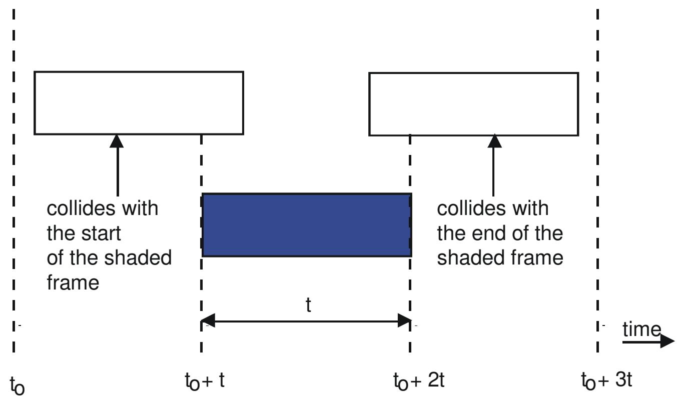
4.3 ALOHA

- Simple MAC protocol based on collision detection.
- Used for the first time in the "Packet Radio System" of the University of Hawaii in 1970.
- Senders can begin to transmit their frames at arbitrary times. A sender listens to the signal in the air while he is sending. If he detects a collision, i.e., hears a signal that is different from his own, he waits a random time interval and repeats his attempt to transmit.

ALOHA - Example



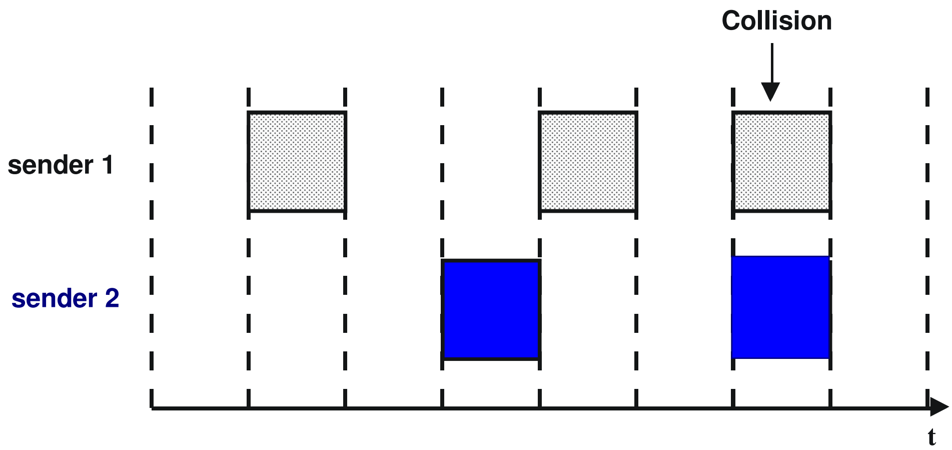
Colliding ALOHA Packets



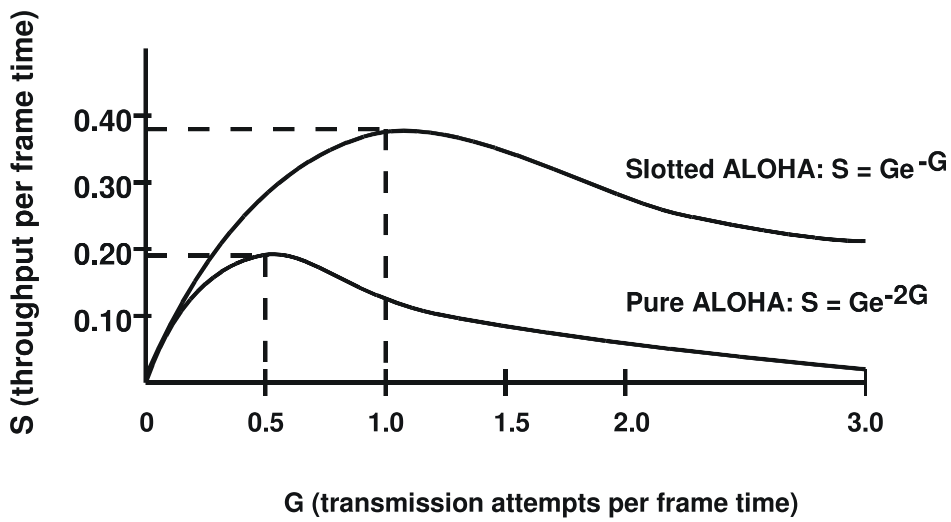
Dangerous time interval for the middle frame: Even if only the first bit of a new frame overlaps the last bit of a nearly terminated frame, both frames will be totally destroyed, both must be re-sent. Even a near-miss is a miss!

Slotted ALOHA

Time is divided into intervals, so called **time slots**. The interval size corresponds to the frame size. Transmission can only begin at the beginning of a time slot. Collisions are still possible but less frequent.



Information Flow-rate in ALOHA Systems



Maximum Data Rates of ALOHA and Slotted ALOHA

Maximum data rate of pure ALOHA:

$$\frac{1}{2e} \approx 0{,}18$$ packets per packet time

Maximum data rate of "slotted ALOHA":

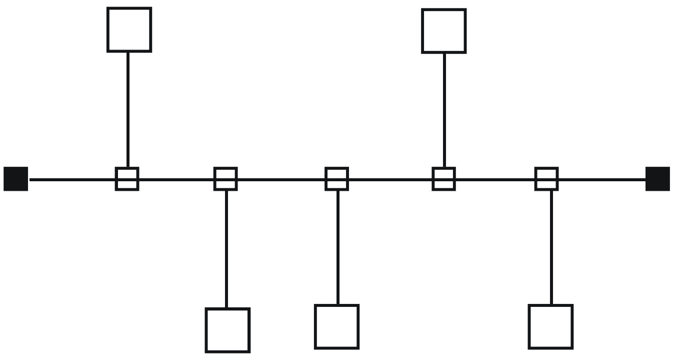
$$\frac{1}{e} \approx 0{,}36$$ packets per packet time

4.4 CSMA/CD (Ethernet)

CSMA/CD = **C**arrier **S**ensing with **M**ultiple **A**ccess and **C**ollision **D**etection

Standard: IEEE 802.3 und ISO IS 8802/3: MAC and physical layer for CSMA/CD

Topology: Bus



- Bi-directional data flow
- Bus interruption => network failure

CSMA/CD Basic Assumptions and Principles

Assumptions

- All stations can hear each other on the medium.
- The frame transmission time is much longer than the maximum propagation delay between the stations. In other words, the sender is still sending when the most distant station in the LAN segment begins to hear the transmission (and even twice as long, as we will see later).

Principles

Carrier **S**ensing, **M**ultiple **A**ccess (**CSMA**)

(also called "listen before talk")

A station that wants to send senses the medium:

- If the medium is occupied, sending is postponed.
- If the medium is free, sending begins immediately.

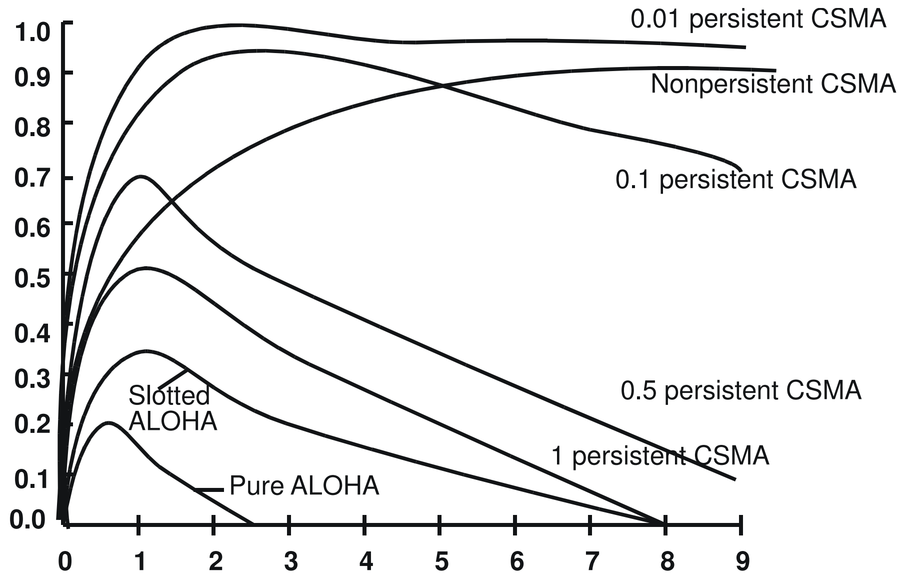
CSMA/CD Retry Strategies

What will a station do when it has been waiting for the end of another transmission, and the medium becomes free?

- **non-persistent**
  The station waits a random time interval ("backoff time") and then starts a new transmission attempt.
- **1-persistent**
  The station starts its own transmission immediately after the end of the other transmission (transmission probability = 1)
- **p-persistent** ($0 < p < 1$)
  At the end of the current transmission it sends its data immediately with a probability p or waits a random time interval with probability 1-p.

IEEE/ISO CSMA/CD is 1-persistent.

Channel Utilization with Different Retry Strategies

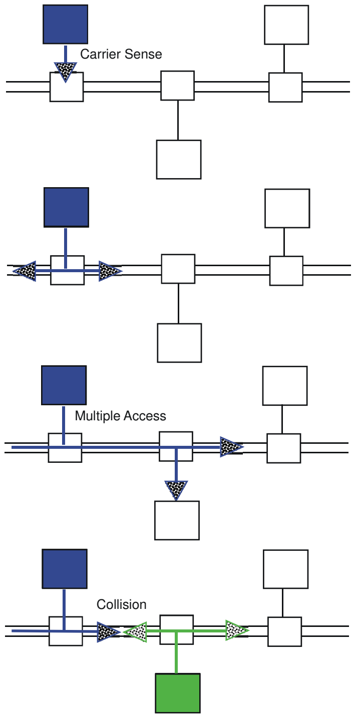


Collisions

If two or more stations begin to send **at the same time**, a **collision** occurs.

Note: There is an increased danger of collisions when another transmission is ending: All stations who's wish to send arose during the other trans-misssion are "synchronized" to the end of this other transmission.

CSMA/CD: Protocol



CSMA/CD – Frame Format

Preamble	SD	DA	SA	Info	FCS

Preamble = 7 Bytes

SD = Starting Delimiter (1 Byte)

DA = Destination Address (2 oder 6 Bytes)

SA = Source Address (2 oder 6 Bytes)

Info = n bytes of data

FCS = Frame Check Sequence (32-bit CRC)

CSMA/CD – Address Field Format

Address field format according to IEEE 802

48 -bit format

I/G	U/L	46 bit address

16 - bit - Format

I/G	15 bit address

I/G = 0 individual address
I/G = 1 group address
U/L = 0 globally administered address
U/L = 1 locally administered address

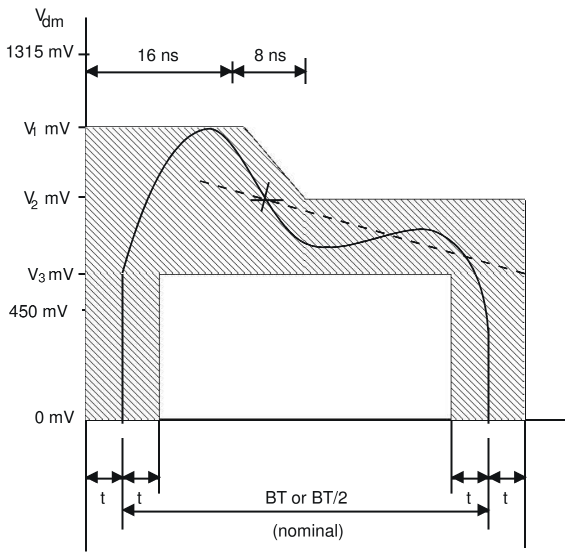
CSMA/CD – Bit Encoding

Manchester coding is used for the bit-serial data transmission on the physical medium.

Manchester coding is a binary line code that combines bit value and clock pulse in "bit symbols". Each bit symbol is divided into two halves. A rising signal in the middle of the interval stands for a "0", a dropping signal in the middle of the interval stands for a "1".

CSMA/CD – Physical Layer

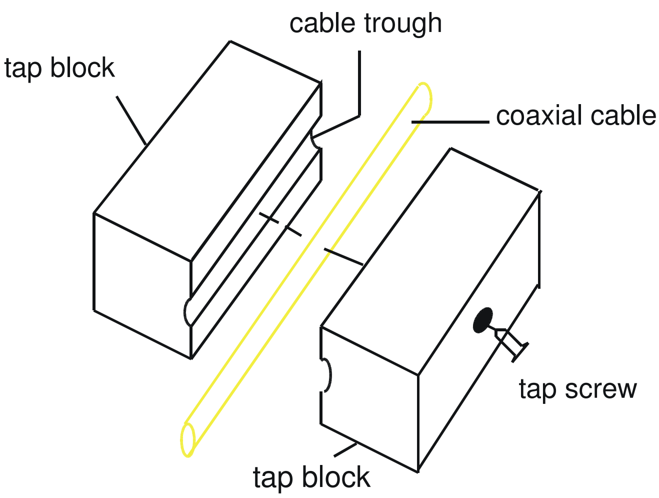
voltage limits for a bit signal at the physical layer of the Ethernet (tolerance area shaded)



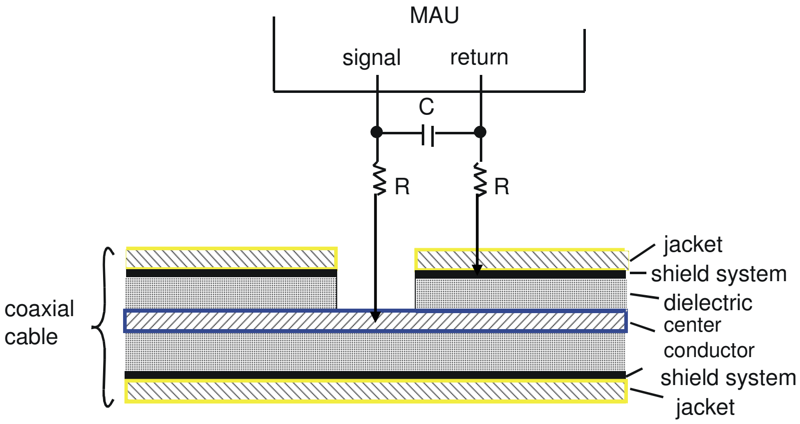
t = 2.5 ns AT 1-10 MHz data rates
V_2 = 0.89 V_1
V_3 = 0.82 V_2

CSMA/CD – The Yellow Cable (1)

Early (now historical) technology: a coaxial cable in bus topology in the cable conduct. Typically yellow. Additional connections to the "yellow cable" are possible at marked distances.



CSMA/CD – The Yellow Cable (2)

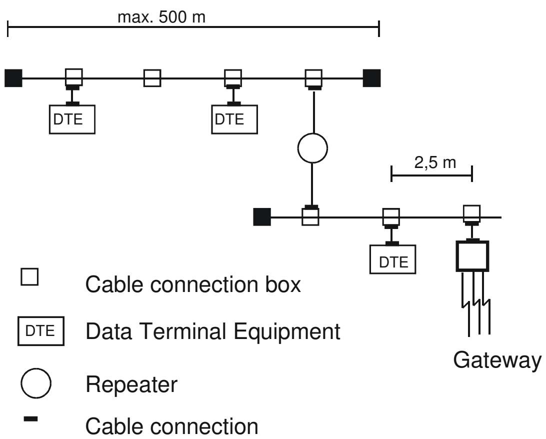


C = capacitive loading
R = contact resistance

Typical Coaxial Tap Connection Circuit

CSMA/CD – Parameters of the Early Standard

Baseband bus system with 10 Mbit/s



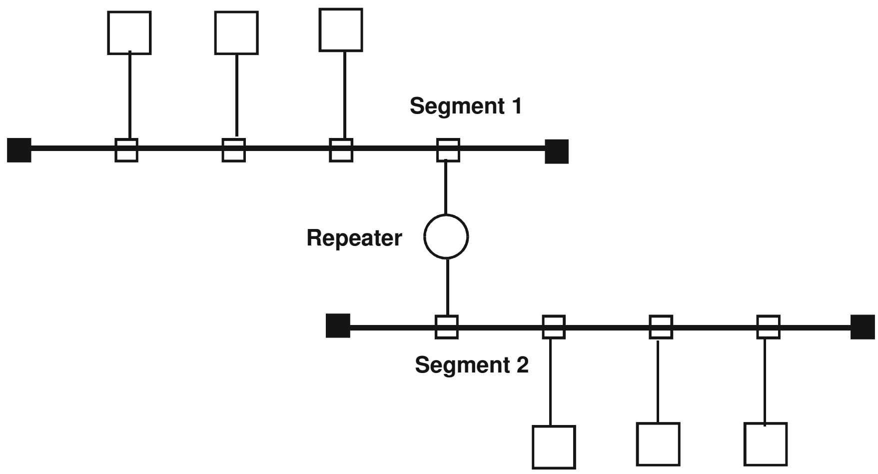
Specifications

Koaxial cabel 50 Ω

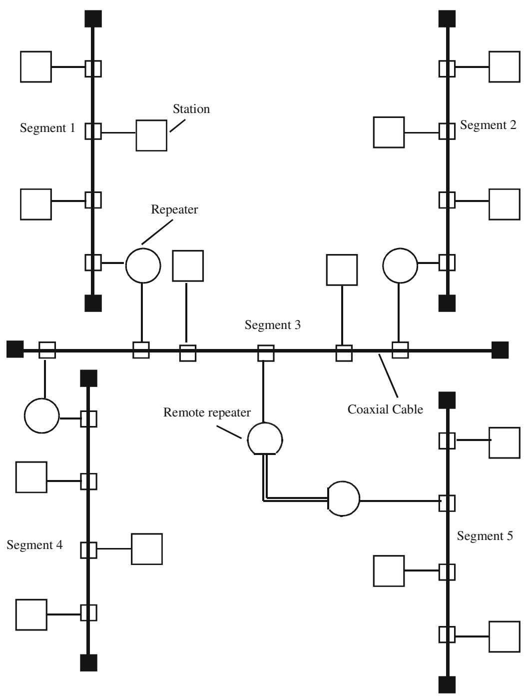
max. 100 stations per segment

max. 5 segments in a row (over repeaters)

Example 1: Medium-Size Configuration



Example 2: Large Configuration



4.5 Hubs and LAN Switching

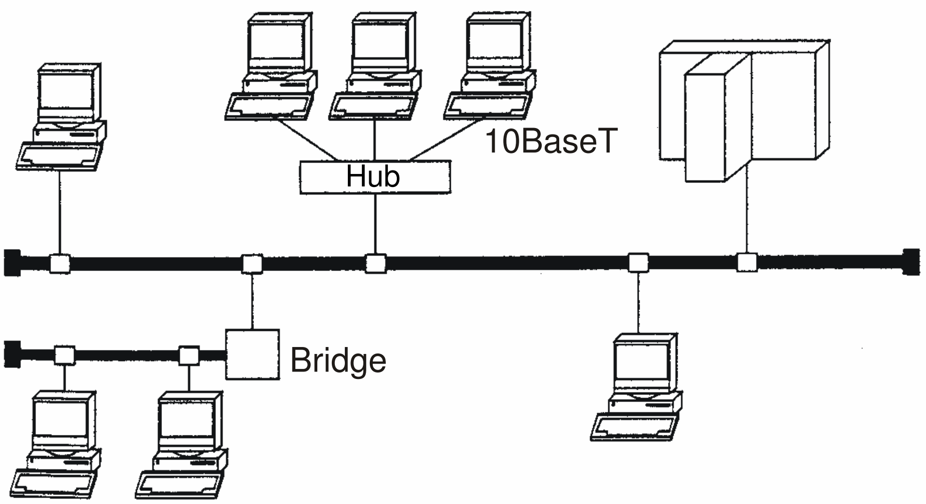
Hubs

In the early Ethernet years the Ethernet cables were actually installed in a physical bus topology (yellow cable or Thin-Wire Ethernet with commercial, prefabricated coaxial cables and T-connectors). The bus topology turned out to be impractical of locating faults, connecting new stations, etc.

Today Ethernet **hubs** with a star-shaped wiring are common, in particular in cable conducts in offices ("category 5 cable").

Note that the medium access control protocol in a hub is still CSMA/CD! However, carrier sensing and collision detection now take place in the hub only.

Ethernet LAN with a Hub and Two Coax Cables

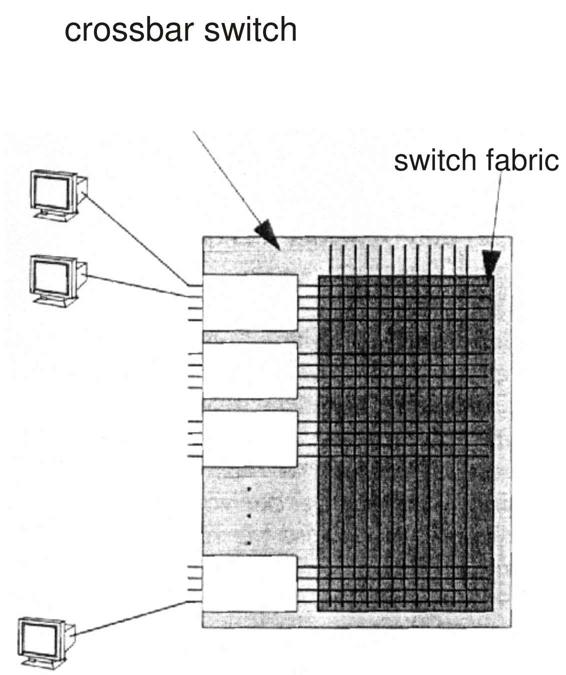


LAN Switching

Throughput in an Ethernet LAN can be further increased by **LAN switching**. The hub is replaced by a frame-switching node (switch), which forwards the individual frames between the star-topology cables. **The format of the Ethernet frames remains the same**, thus the end systems (stations) don‘t notice the difference!

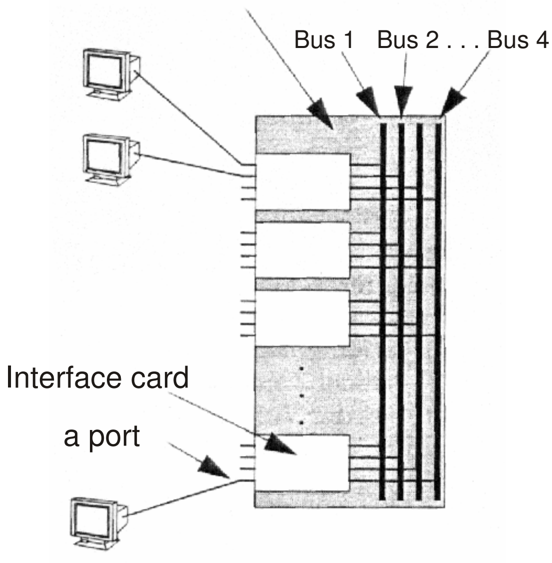
When doing LAN switching, the hub is replaced by a **frame switch**. It evaluates the MAC destination address and forwards the frame on the appropriate link. Unlike the hub, the LAN switch must internally operate much faster than the link rate, and it must contain buffers so that many frames arriving at the same time can be forwarded without collisions.

LAN Switch: Implementation with a Crossbar Switch



LAN Switch: Implementation with Busses

Several busses as an internal switching network



Cabel Types for the Ethernet

name	cable type	max. length	comment
10Base5 (yellow coaxial cable)	coaxial cable	500 m	The classical Ethernet wiring. The connection is made by transceivers and vampire clamps at the coaxial cable.
10Base2 (thin Ethernet or Cheapernet)	coaxial cable	185 m	A thin coaxial cable is used. The connection is made by BNC connectors.
10BaseT	twisted copper cable (shielded – STP, unshielded – UTP)	100 m	The stations are connected to a hub in a star configuration.
10BaseFB	fiber-optic cable	2 km	This type is usually used for ethernet backbone networks between hubs.
10BaseFL	fiber-optic cable	2 km	This type is used mainly between regenerators