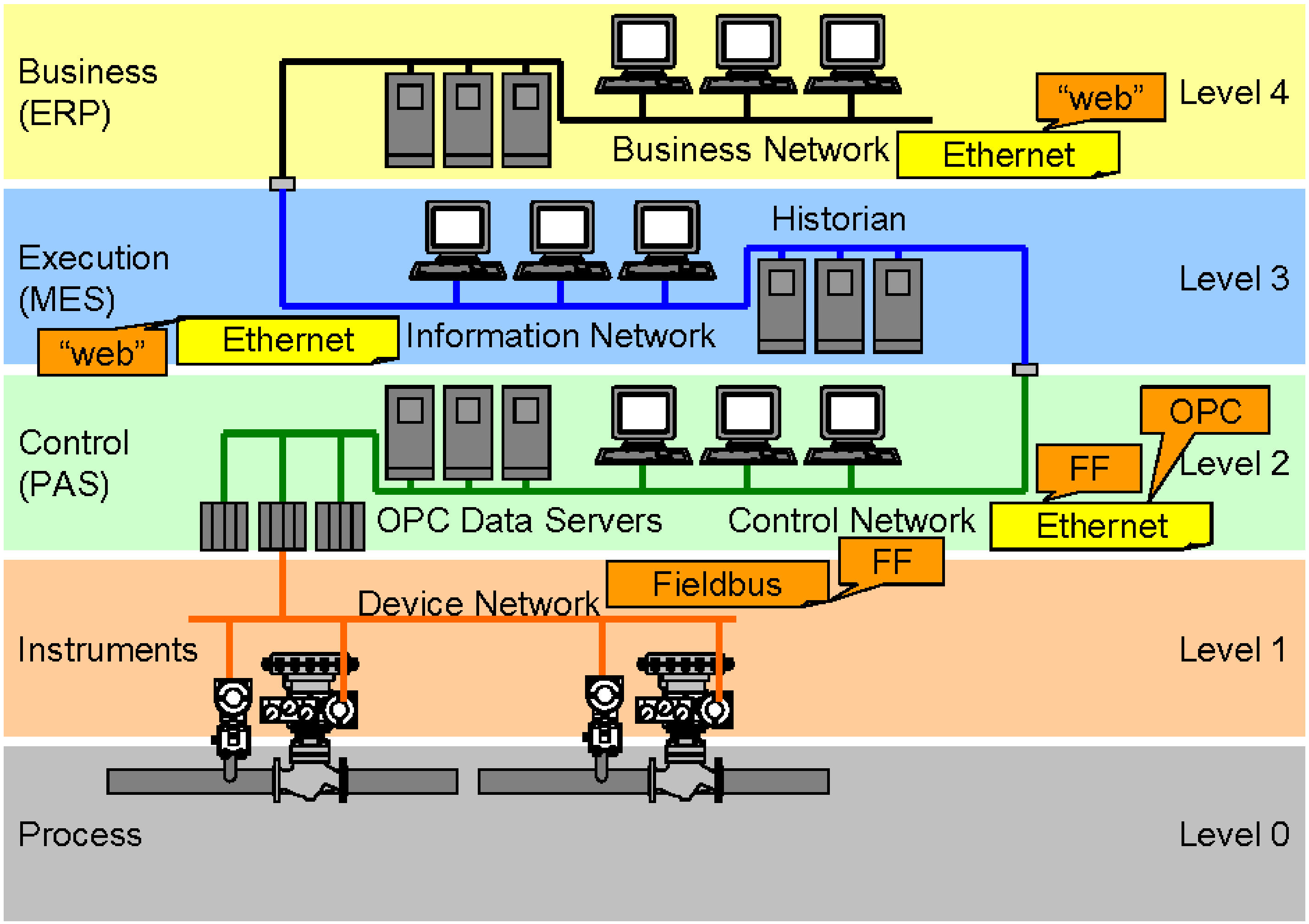
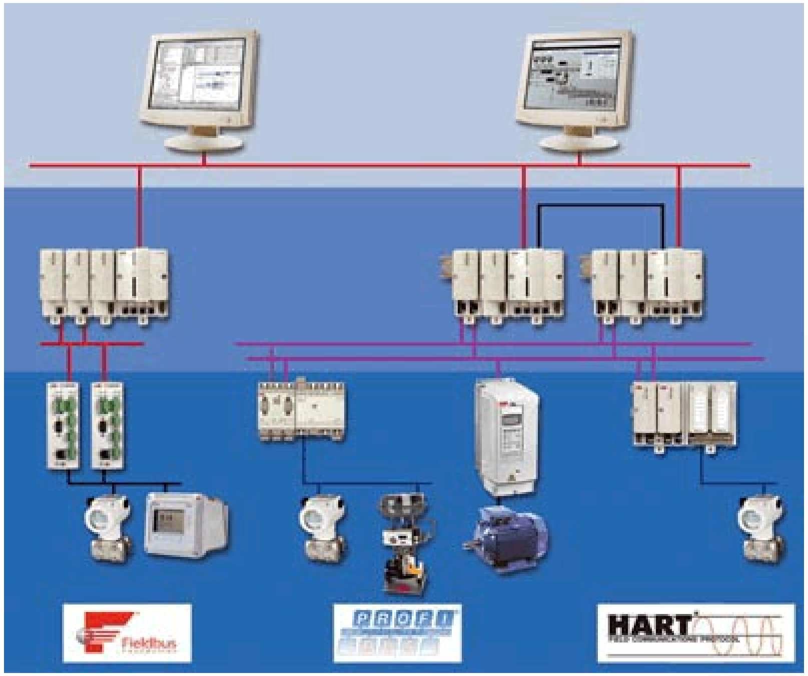
Fieldbus I

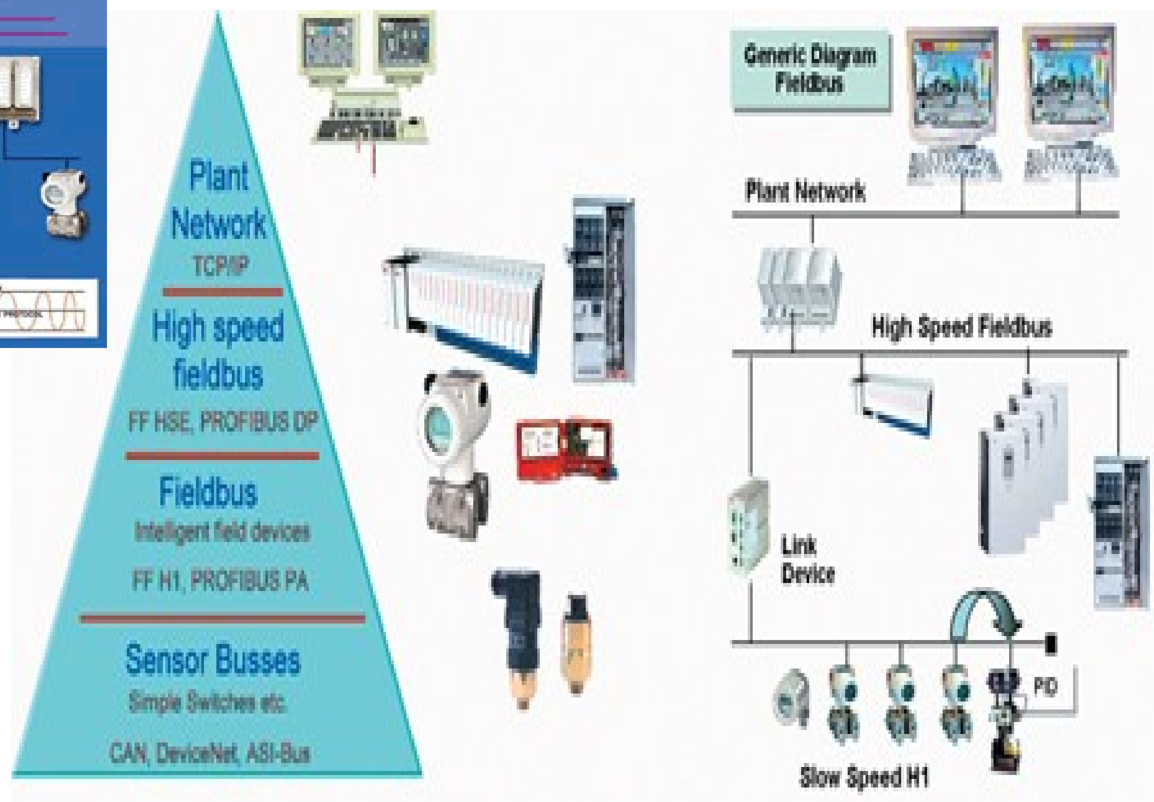
- Slides collected from numerous sources

Fieldbus I
see
en.wikipedia.org/wiki/Fieldbus



Hierachy / concepts





Areas of application and examples

- Industrial communication
  - Production engineering
    - » Transmission of programs to computerised numerical control machines
    - » Control of plants / automation of car manufacturing
  - Process engineering
    - » Control loops in a refinery
    - » Control and regulation at aluminium smelting
  - Power generation
    - » Conventional thermal power station / nuclear power plant
    - » Hydroelectric power plant / pumped-storage power station
- Automotive engineering
    - » Distributed real time regulation in cars
    - » Commercial vehicles
    - » Control of special functions in work machines
- Building services engineering
    - » Light control in residential houses
    - » Air-conditioning technology in functional buildings

Requirements and features

- Cost savings during assembly of cabling
- Reduction of weight
- Increased reliability
- Decreased amount of maintenance
- Easier and more efficient fault diagnosis
- Increased flexibility of the plant
- Network provides easy access
  - Configurable sensors/actuators
  - Readings and status from sensors/actuators available from everywhere
- Redundancy

Basic functionality

- Very simplified
  - Read remote
  - Write remote
  - Subscribe from remote
- The real world is more complex
- Communication patterns may influcence a lot
  - Master – slave
  - Multi master
  - Equal nodes

- Fieldbus is the name of a family of industrial computer network protocols used for real-time distributed control,
  ...
- standardized as IEC 61158
- private company versions exists
  - They may have nothing to do wihh 61158...
- but interoperability is a “must”
- as well as safety, security, fault tolerance,…
- The five nines: 99.999% uptime ~= 5 minutes downtime a year !

IEC 61158

- IEC 61158 consists of the following parts, under the general title Digital data communications for measurement and control – Fieldbus for use in industrial control systems:

- Part 1: Overview and guidance for the IEC 61158 series
- Part 2: Physical Layer specification and service definition
- Part 3: Data Link Service definition
- Part 4: Data Link Protocol specification
- Part 5: Application Layer Service definition
- Part 6: Application Layer Protocol specification

61158 FB's

- COMMUNICATION PROFILE "FAMILIES"
  - CPF 1: FOUNDATION Fieldbus
  - CPF 2: CIP
  - CPF 3: PROFIBUS
  - CPF 4: P-NET
  - CPF 5: WorldFIP
  - CPF 6: INTERBUS
  - CPF 7: SwiftNet (withdrawn)
  - CPF 8: CC-Link
  - CPF 9: HART
  - CPF 10: Vnet/IP
  - CPF 11: TCnet
  - CPF 12: EtherCAT
  - CPF 13: Ethernet Powerlink
  - CPF 14: EPA
  - CPF 15: MODBUS-RTPS
  - CPF 16: SERCOS[5][6]

Standards

- AS-Interface
- CAN
- EtherCAT
- FOUNDATION fieldbus
- Interbus
- LonWorks
- Modbus
- Profibus
- BITBUS
- CompoNet
- SafetyBUS p
- RAPIEnet

... - that might be a reason for new standards will be a success

- AS-i – Actuator-sensor interface, a low level 2-wire bus establishing power and communications to basic digital and analog devices
- BSAP – Bristol Standard Asynchronous Protocol, developed by Bristol Babcock Inc.
- CC-Link Industrial Networks – Supported by the CLPA
- CIP (Common Industrial Protocol) – can be treated as application layer common to DeviceNet, CompoNet, ControlNet and EtherNet/IP
- ControlNet – an implementation of CIP, originally by Allen-Bradley
- DC-BUS – communication over DC power lines, originally by Yamar Electronics Ltd
- DeviceNet – an implementation of CIP, originally by Allen-Bradley
- DF-1 - used by Allen-Bradley ControlLogix, CompactLogix, PLC-5, SLC-500, and MicroLogix class devices
- DNP3 - a protocol used to communicate by industrial control and utility SCADA systems
- DirectNet – Koyo / Automation Direct proprietary, yet documented PLC interface
- EtherCAT
- Ethernet Global Data (EGD) – GE Fanuc PLCs (see also SRTP)
- EtherNet/IP – IP stands for "Industrial Protocol". An implementation of CIP, originally created by Rockwell Automation
- Ethernet Powerlink – an open protocol managed by the Ethernet POWERLINK Standardization Group (EPSG).
- FINS, Omron's protocol for communication over several networks, including ethernet.
- FOUNDATION fieldbus – H1 & HSE
- HART Protocol
- HostLink Protocol, Omron's protocol for communication over serial links.
- Interbus, Phoenix Contact's protocol for communication over serial links, now part of PROFINET IO
- MECHATROLINK – open protocol originally developed by Yaskawa, supported by the MMA
- MelsecNet, and MelsecNet II, /B, and /H, supported by Mitsubishi Electric.
- Modbus PEMEX
- Modbus Plus
- Modbus RTU or ASCII or TCP
- OSGP – The Open Smart Grid Protocol, a widely use protocol for smart grid devices built on ISO/IEC 14908.1
- OpenADR – Open Automated Demand Response; protocol to manage electricity consuming/controlling devices
- Optomux – Serial (RS-422/485) network protocol originally developed by Opto 22 in 1982. The protocol was openly documented[1] and over time used for industrial automation applications.
- PieP – An Open Fieldbus Protocol
- Profibus – by PROFIBUS International.
- PROFINET IO
- RAPIEnet – Real-time Automation Protocols for Industrial Ethernet
- Honeywell SDS – Smart Distributed System – Originally developed by Honeywell. Currently supported by Holjeron.
- SERCOS III, Ethernet-based version of SERCOS real-time interface standard
- SERCOS interface, Open Protocol for hard real-time control of motion and I/O
- GE SRTP – GE Fanuc PLCs
- Sinec H1 – Siemens
- SynqNet – Danaher
- TTEthernet – TTTech
- MPI – Multi Point Interface

FB's

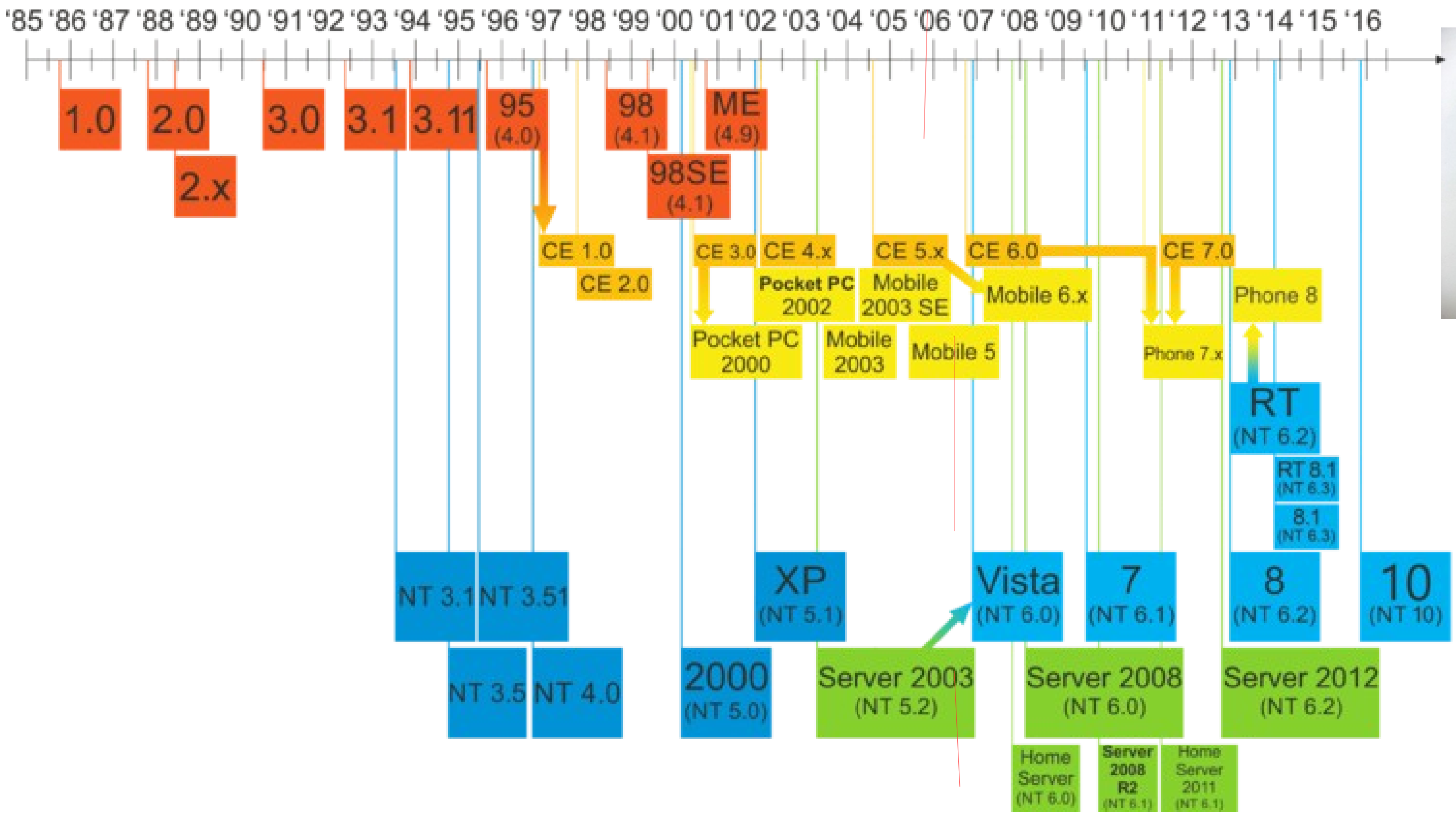
Fieldbus	Bus power	Cabling redundancy	Max devices	Synchronisation	Sub millisecond cycle
AFDX	No	Yes	Almost unlimited	No	Yes
AS-Interface	Yes	No	62	No	No
CANopen	No	No	127	Yes	No
CompoNet	Yes	No	384	No	Yes
ControlNet	No	Yes	99	No	No
CC-Link	No	No	64	No	No
DeviceNet	Yes	No	64	No	No
EtherCAT	No	Yes	65,536	Yes	Yes
Ethernet Powerlink	No	Optional	240	Yes	Yes
EtherNet/IP	No	Optional	Almost unlimited	Yes	Yes
Interbus	No	No	511	No	No
LonWorks	No	No	32,000	No	No
Modbus	No	No	246	No	No
PROFIBUS DP	No	Optional	126	Yes	No
PROFIBUS PA	Yes	No	126	No	No
PROFINET IO	No	Optional	Almost unlimited	No	No
PROFINET IRT	No	Optional	Almost unlimited	Yes	Yes
SERCOS III	No	Yes	511	Yes	Yes
SERCOS interface	No	No	254	Yes	Yes
Foundation Fieldbus H1	Yes	No	240	Yes	No
Foundation Fieldbus HSE	No	Yes	Almost unlimited	Yes	No
RAPIEnet	No	Yes	256	Under Development	Conditional
Fieldbus	Bus power	Cabling redundancy	Max devices	Synchronisation	Sub millisecond cycle

Take a look :-)

- http://kom.aau.dk/~jdn/edu/litt/fb/www.easydeltav.com/
- Happy interesting reading

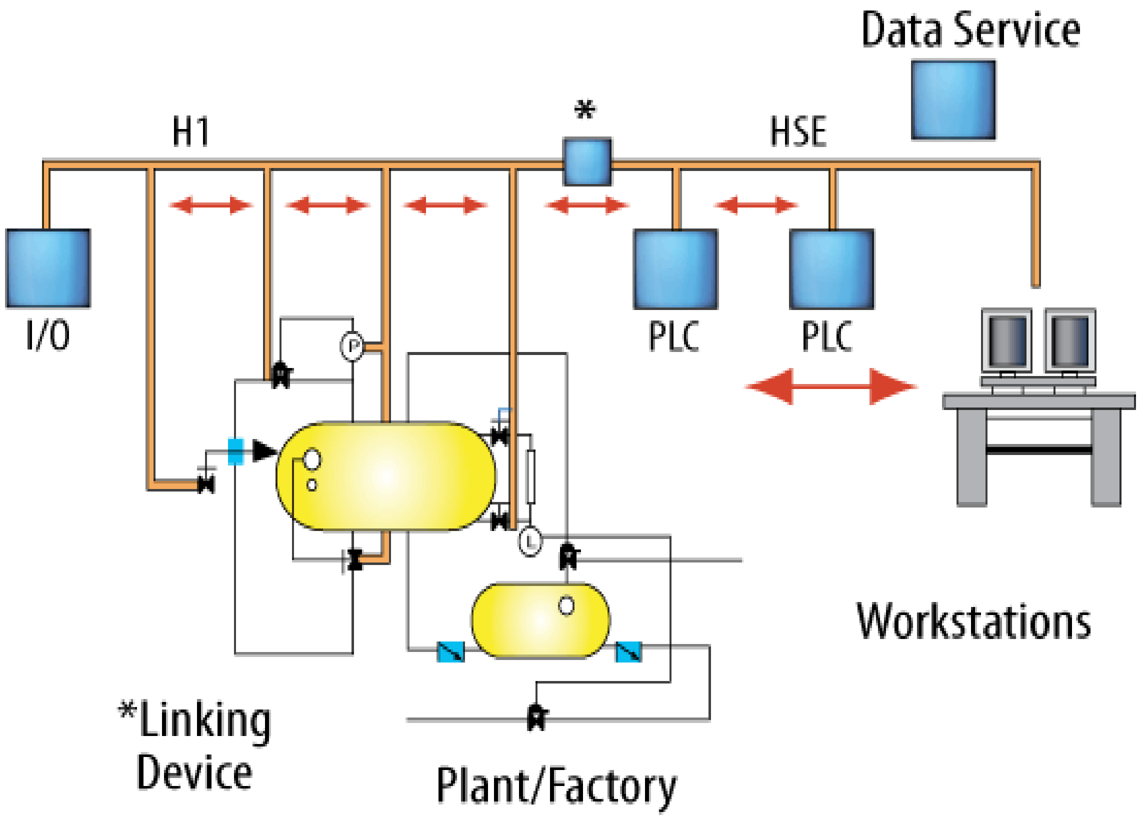
looking back

- this year 2019
- In 2006 …
- and maintenance is still ongoing of your 2006 product
- Ventilation system in Fr Bajersvej 7 was installed in 1989...



- Reliable networking
- Real time behaviour
- Safety Criticial ?

- Reliable (sub)systems
- Cheap ?
- **+ 10 year lifetime**
- **+ 10 year lifetime**
- **+ 10 year lifetime**
- testet, documented
- vendor independent ?!



A little bit about safety

SIL	Low demand mode: average probability of failure on demand	High demand or continuous mode: probability of dangerous failure per hour
1	$\geq 10^{-2}$ to $< 10^{-1}$	$\geq 10^{-6}$ to $< 10^{-5}$
2	$\geq 10^{-3}$ to $< 10^{-2}$	$\geq 10^{-7}$ to $< 10^{-6}$
3	$\geq 10^{-4}$ to $< 10^{-3}$	$\geq 10^{-8}$ to $< 10^{-7}$ (1 dangerous failure in 1140 years)
4	$\geq 10^{-5}$ to $< 10^{-4}$	$\geq 10^{-9}$ to $< 10^{-8}$

- Some math

- Nuclear plants is SIL-3 or SIL-4
- 1000 reactors worldwide == 1000*365*24 hours/year ~= 10^6 hours/years

- SIL-3 gives a worst case dangeours failure every 10 year
  - Please count reactor accidents after the lecture..

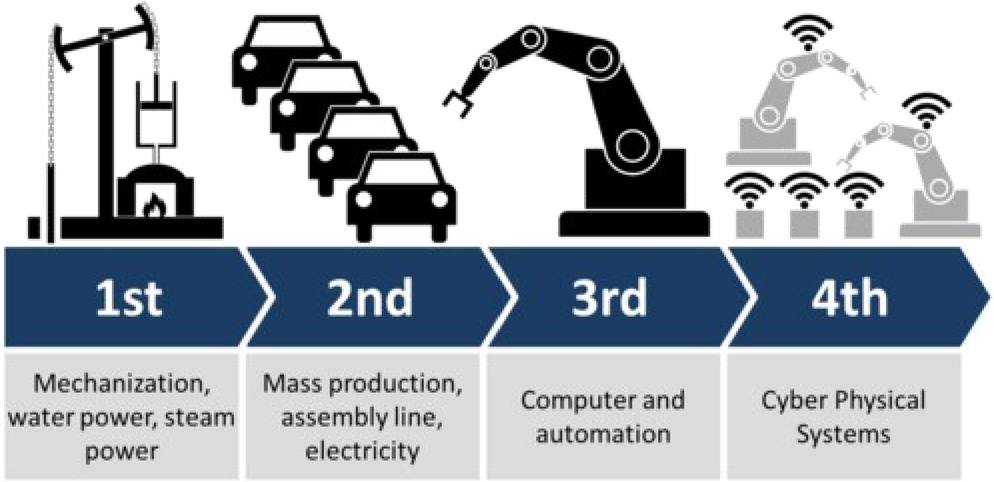
- See www.vtt.fi/julkaisut/muut/2012/10-Th2-4.pdf
  - They state it’s nearly impossible to claim a SIL-4 system…
  - Finland have nuclear plants (Olkiluoto)

IOT systems

- Maintenance
- Update
- Security and safety

- The area is very interesting
- The direction in the future is not clear now
- Except it will be wireless

- Low power and very scarse communication may be a problem for safety

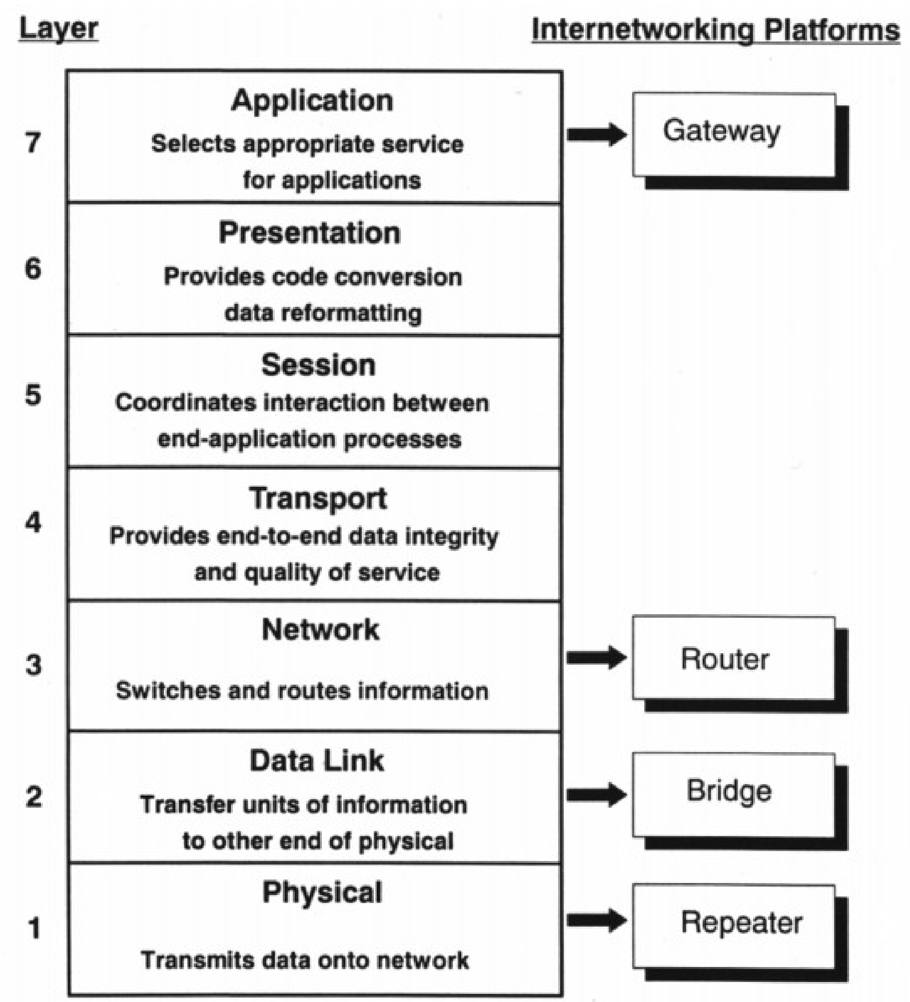


Example: Sigfox

- Wireless @ ISM band (free frequencies)
- Today available in 50-60 countries
- +90&% coverage in DK :-)
- Data: Max 140 pkgs/24hour each 12 byte data
- Many commercial devices available
- For plant control ? Hmmm ... nope

ISO ref model

Fieldbuses and the ISO OSI reference model



- Fieldbus systems often define several OSI layers in one standard
- Mostly layers 3 to 6 are nonexistent
  - Efficient, fast data processing
  - No routing
  - No fragmentation
- In the majority only layers 1-2 or layers 1-2-7 are defined

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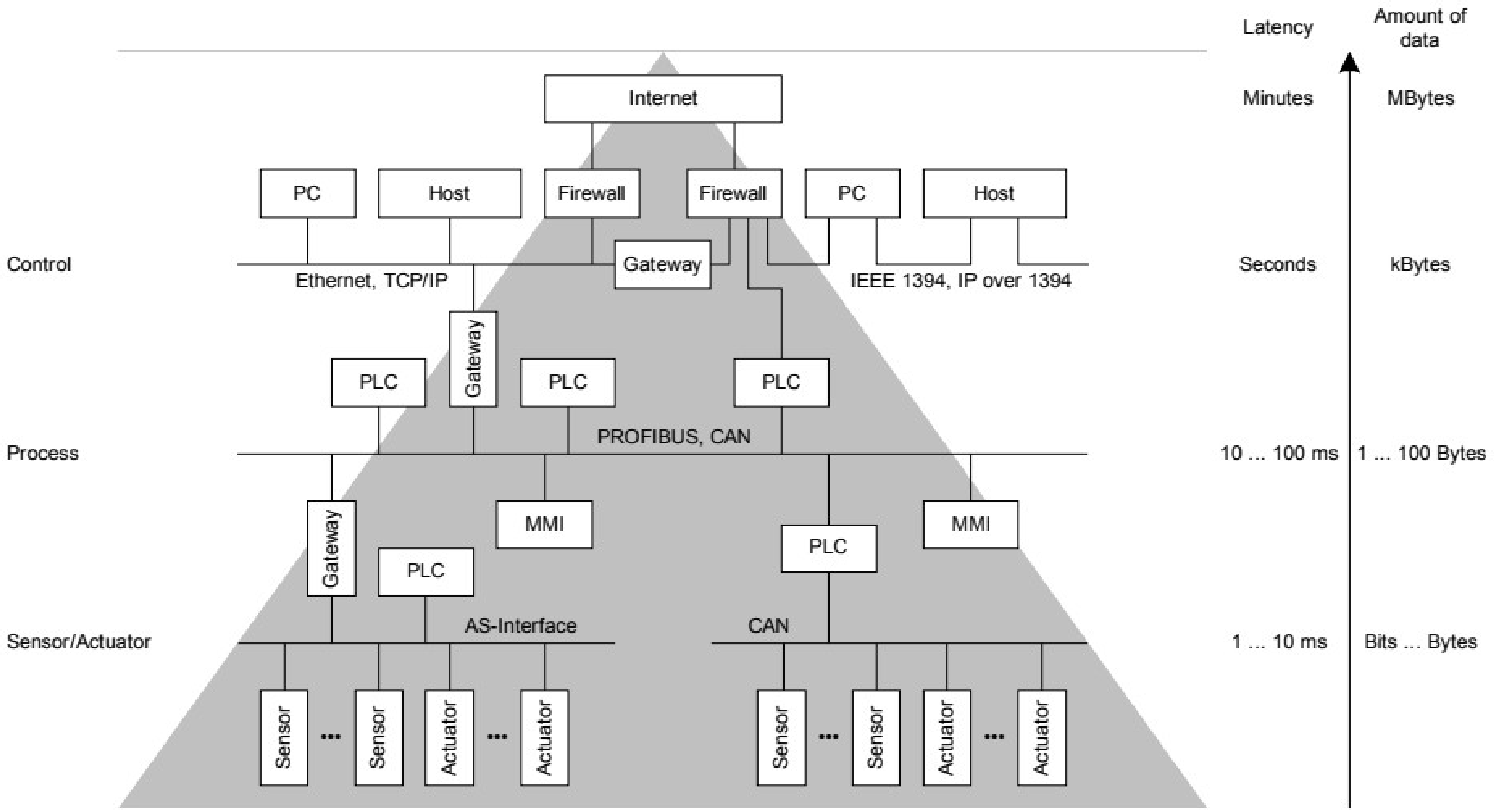
Industrial automation – CIM model



MMI – Men - Machine - Interface
PLC – Programmable Logic Controller

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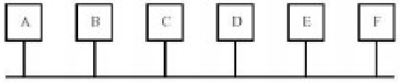
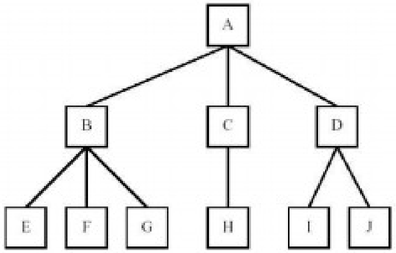
Topologies at a glance

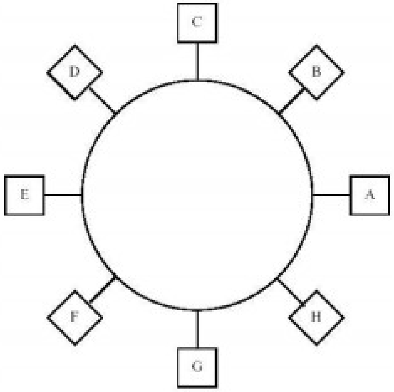
- Line, Bus



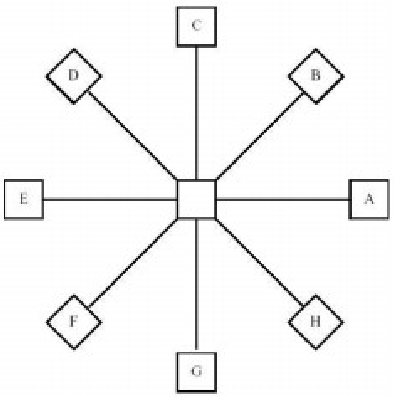
- Tree



- Ring, Token-Ring



- Star



- Open topology

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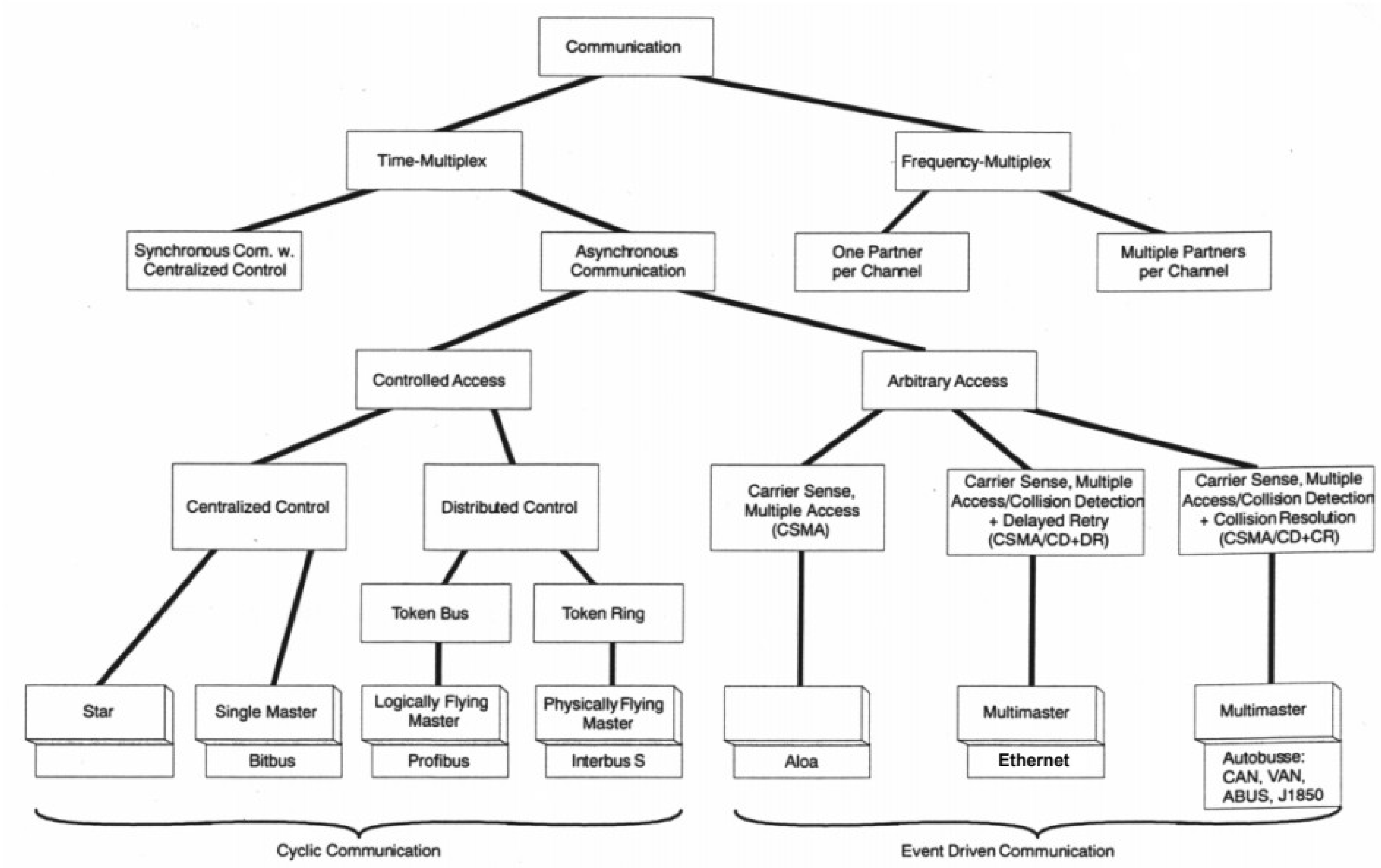
How to distinguish

Access methods at a glance



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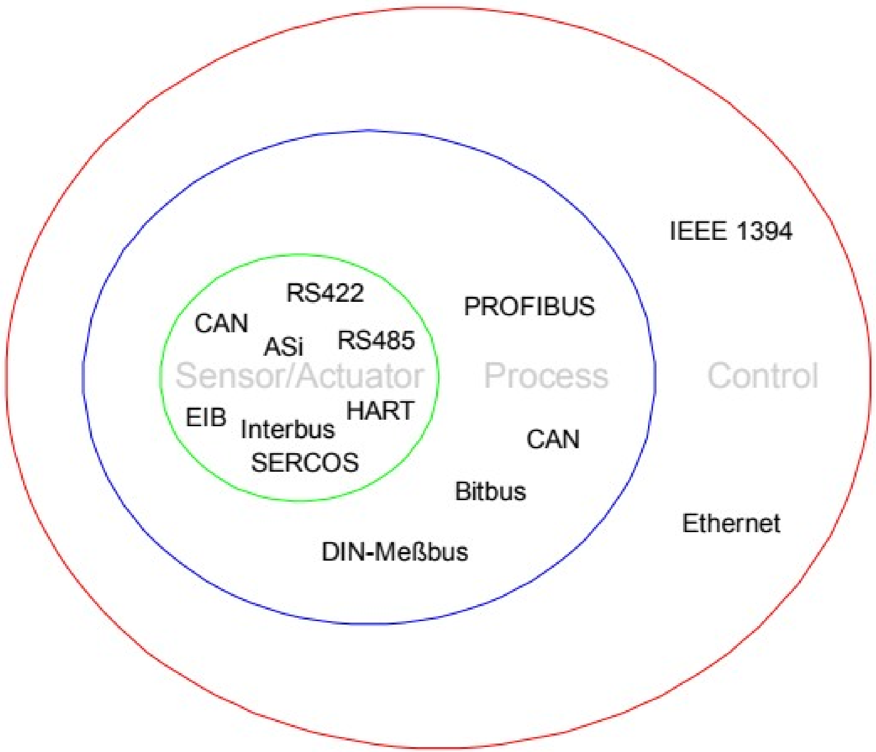
Examples

- Industrial automation



Abbreviations:

ASi – Actuator / Sensor - Interface
CAN – Controller Area Network
EIB – European Installation Bus
EHS – European Home System
HART – Highway Addressable Remote Transducer
LIN – Local Interconnect Network
LON – Local Operating Network
TTP – Time Triggered Protocol

- Automotive engineering: CAN, J1850, LIN, TTP, Byteflight, Flexray
- Building services engineering: LON, EIB, EHS

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CASE CANBUS

Overview

- CAN (Controller Area Network) is a serial bus system used to communicate between several embedded 8-bit and 16-bit microcontrollers.
- It was originally designed for use in the automotive industry but is used today in many other systems (e.g. home appliances and industrial machines).

(Nearly) all kind of medias

CAN Bus Media

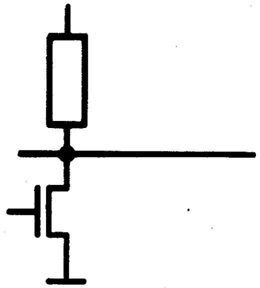
All media, supporting **dominant** and **recessive** state can be used

Examples:

Wires

recessive = pull-up

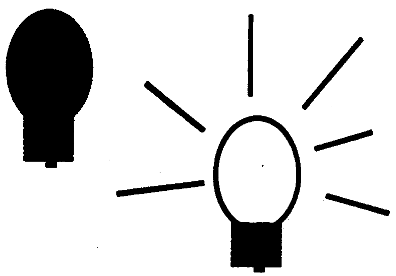
dominant = current sink to ground



Optical media

recessive = light off

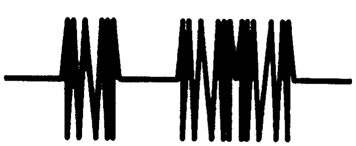
dominant = light on



RF media

recessive = RF off

dominant = RF on (spread spectrum)



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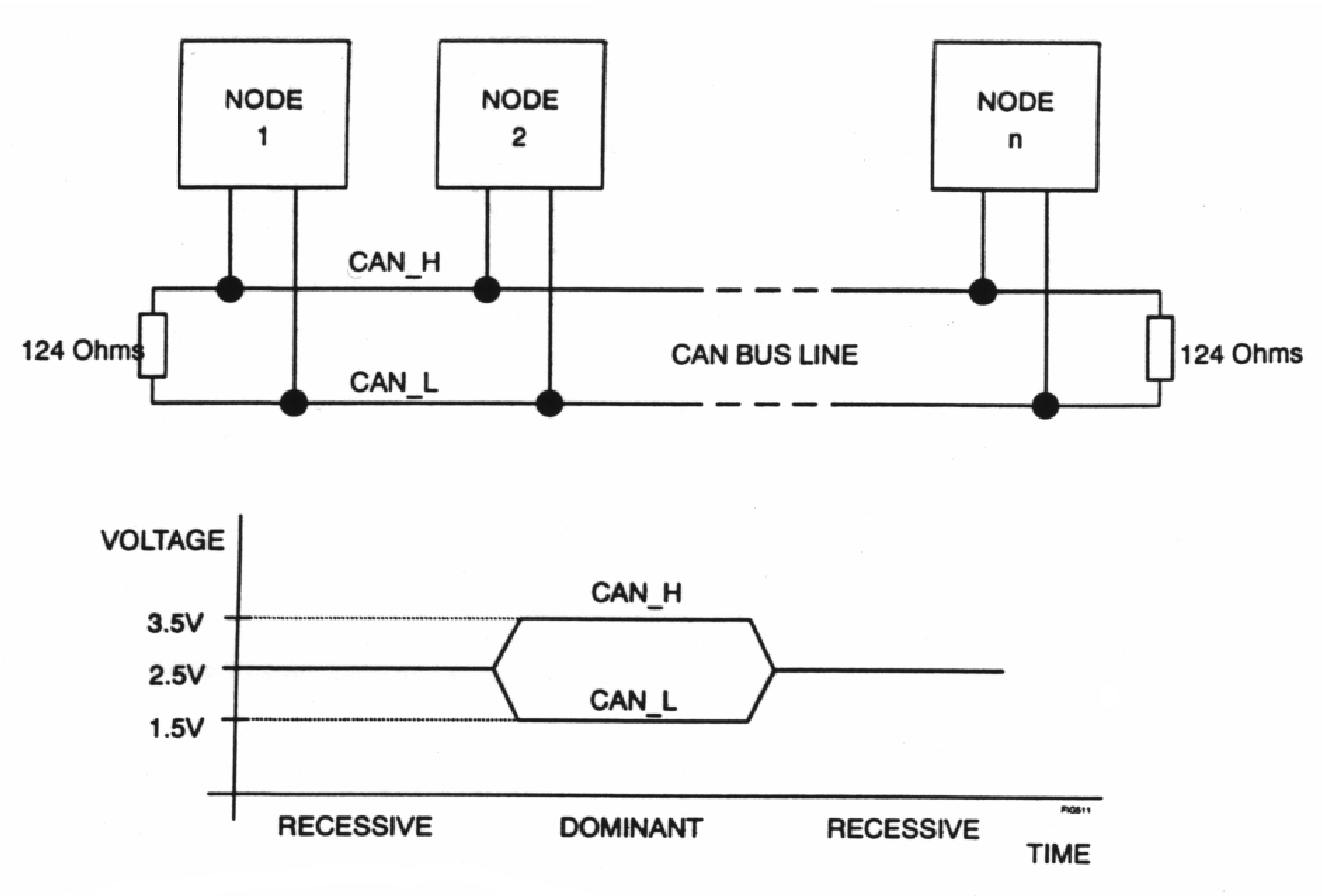
CAN Interface nach ISO 11898



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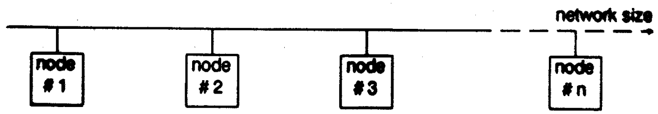
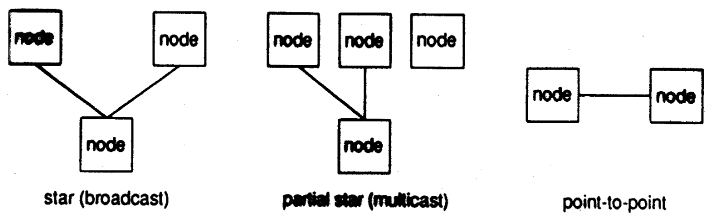
Configuration Flexibility with CAN

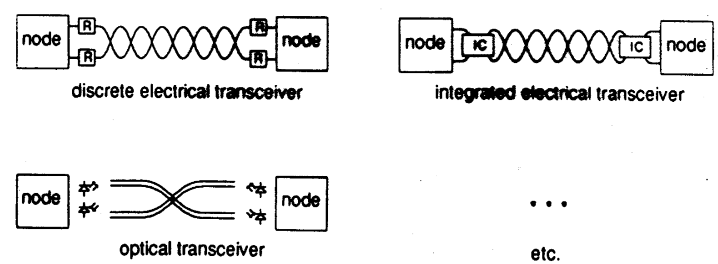
- extension



- information-oriented routing (within one bus-type network)



- application-defined transmission medium



- data rate programmable

CAN Overview

- Number of nodes
  - unlimited (dependent on physical layer)
- Type of communication
  - serial
  - asynchronous
  - object-oriented
  - multi-master
- Storing of messages
  - shared memory concept
- Topology
  - line
  - star
- Length of bus lines
  (dependent on transfer rate)
  - 40 m at 1 Mbit/s (specified)
  - 620 m at 100 kbit/s
  - 10 km at 5 kbit/s
- Number of message identifiers
  - 2^{11} (standard frame)
  - 2^{29} (extended frame)
- Data bytes per message
  - 0 ... 8
- Bus access
  - CSMA/CA through AMP
  - controlled by message priority
  - non-destructive bit-wise arbitration
- Bus throughput
  - max. 1 Mbit/s (total)
  - max. 577 kbit/s (information)
- Real-time capability
  - guaranteed latency times for high priority messages (<134 μs @ 1 Mbit/s)
- Reliability / Safety
  - acknowledgment of message
  - error detection, handling and fault confinement

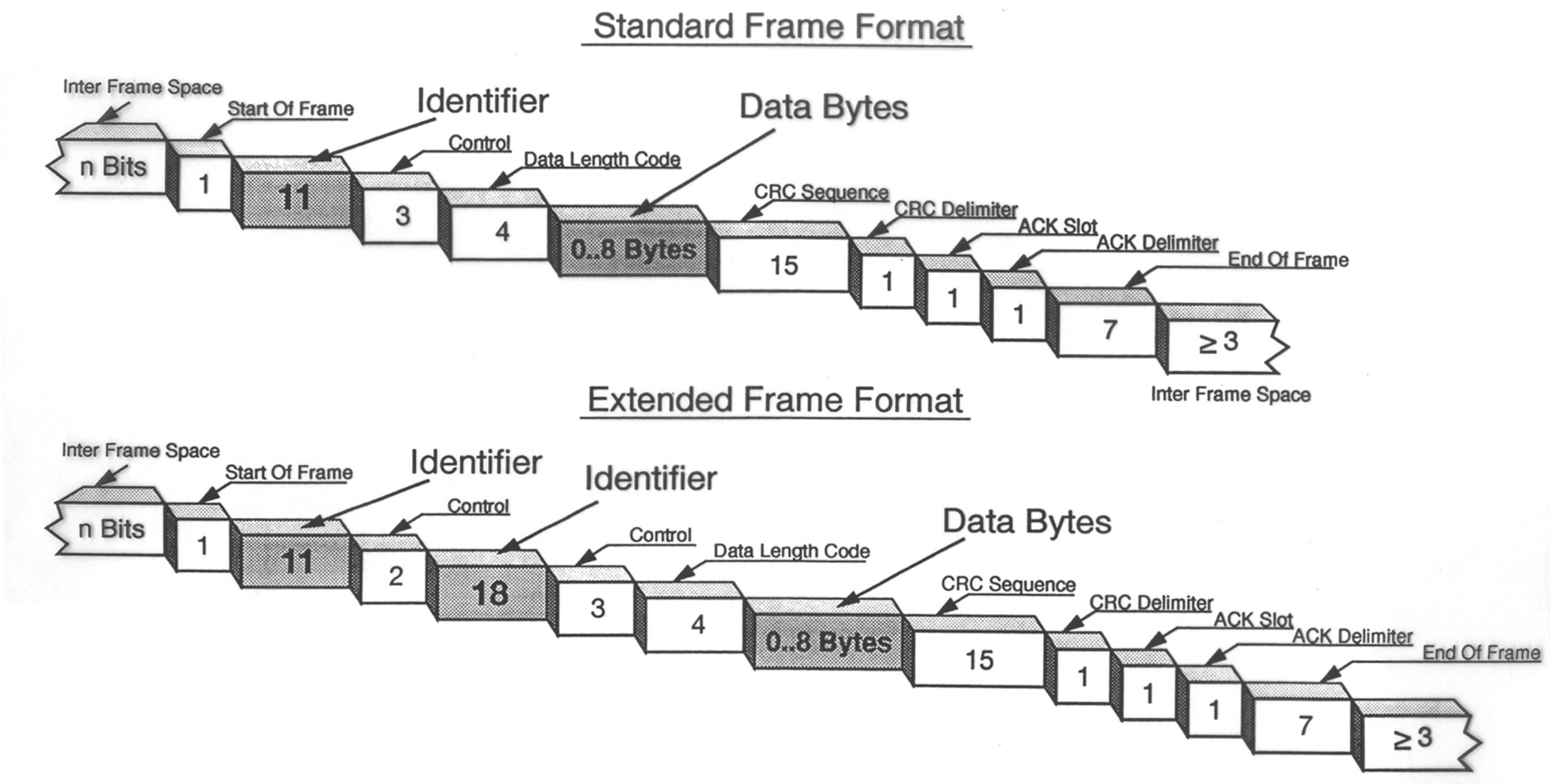
Overview (con't)

- Highest Baud Rate is 1Mbit.
- CAN uses a message oriented transmission protocol.
- There are no defined addresses, just defined messages.

Data Information – Frame Format

- SOF – Start of Frame
- Identifier – Tells the content of message and priority
- RTR – Remote Transmission Request
- IDE – Identifier extension (distinguishes between CAN standard,11 bit identifier, and CAN extended, 29 bit identifier.)
- DLC – Data Length Code
- Data – holds up to 8 bytes of data
- CRC – “Cyclic Redundant Check” sum
- ACK – Acknowledge
- EOF – End of Frame
- IFS – Intermission Frame Space. Minimum number of bits separating consecutive messages.

CAN Data Frame



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CAN vs. Ethernet 802.3

CAN Frame

SOF	Arbitration	Control	Data	CRC	ACK	EOF	IFG
	12 (Ext. 32)	6	0-64	16	2	7	3

47 Bit - 111 Bit (Ext. 67 Bit - 132 Bit)

802.3 Frame

Preamble		Destination	Source	DLC	Data	Pad	CRC
		6	6	2	0-1500	0-46	7

64 Byte - 1526 Byte

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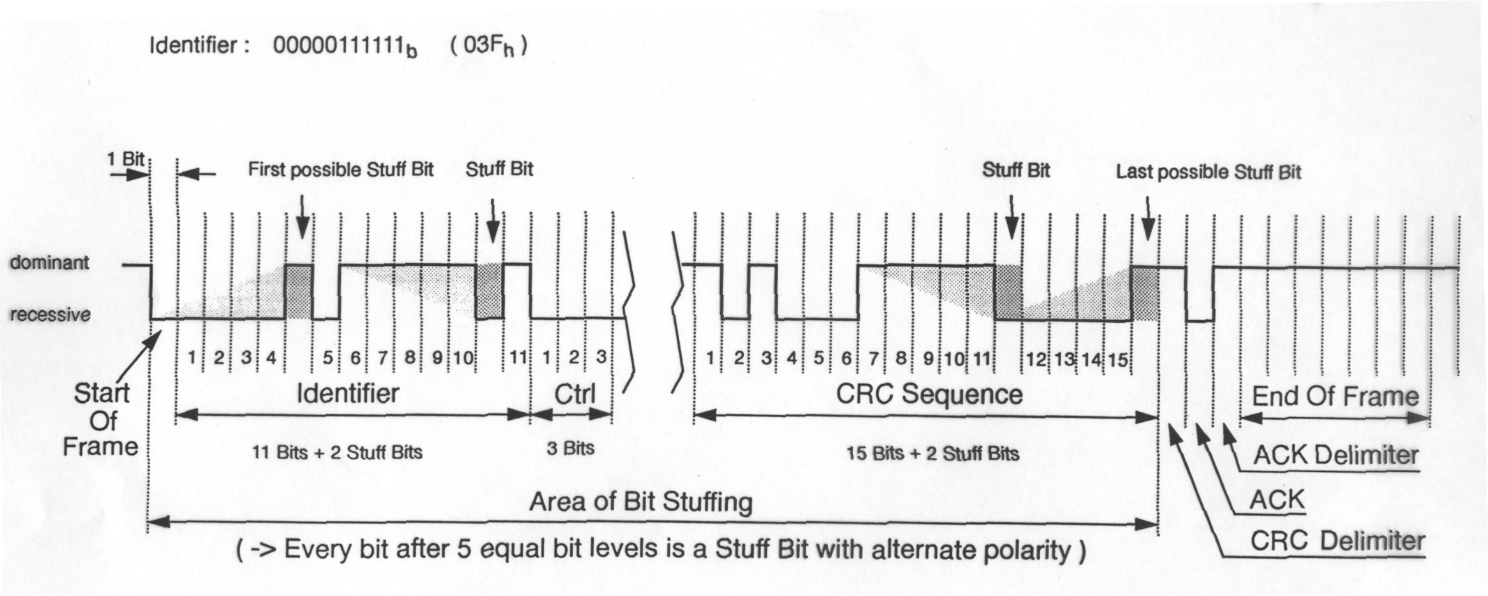
CAN Bit Stuffing



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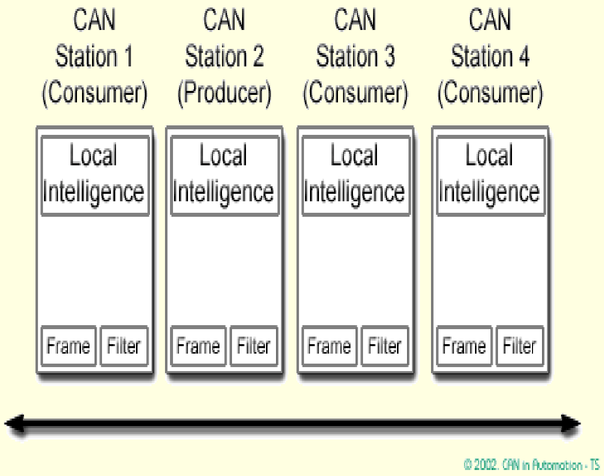
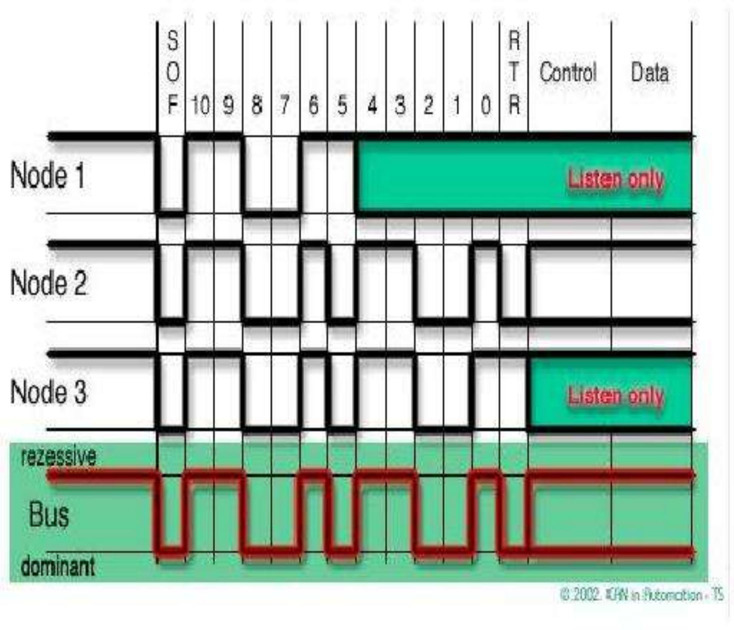
Data Information - Protocol



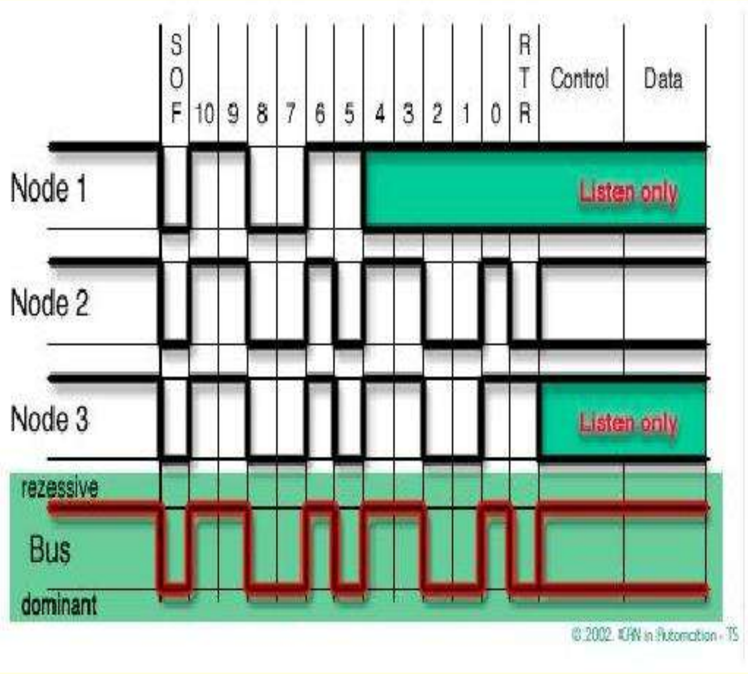
- Messages are distinguished by message identifiers.
- The identifier is unique to the network and defines the content & priority of the message.

Data Information – Protocol (con't)



- When several messages access the bus at the same time, the one with the higher priority "wins".
- The identifier with the lowest binary number has the highest priority.
- The priority are specified during system design and cannot be changed dynamically.

Data Information – Protocol (con't)



- Access conflicts on the bus are resolved by a "wired and" mechanism, where the dominate state overwrites the recessive state.
- All "losers" automatically become receivers and they won't try to send another message until the bus becomes available again.

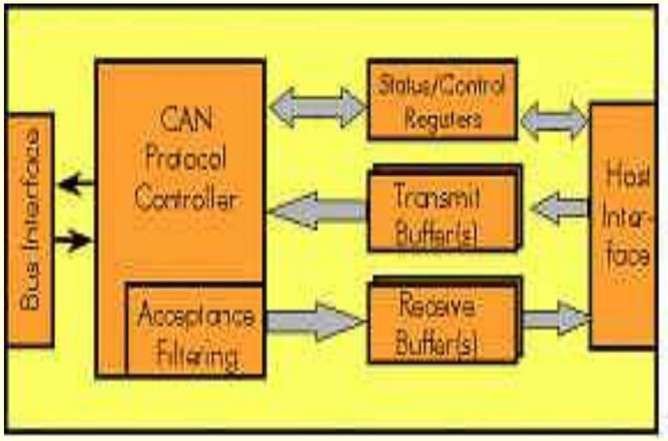
Data Information – Error detection

- If one or more errors are detected, the transmission is aborted. This prevents all other stations or nodes from accepting the message.
- Re-transmission is automatic. If errors continue, then the station or node may switch itself off to prevent the bus from being tied up.
- Error detection is done on two levels:
  - Message level
  - Bit level

Data Information – Error detection (con't)

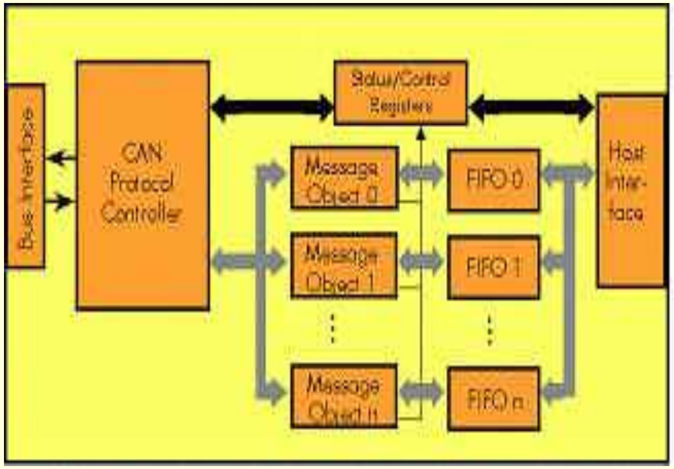
- Message Level
  - CRC = Cyclic Redundant Check sum
  - Frame Check = compares message to fixed format and frame size
  - ACK errors = if transmitter does not receive an ACK signal from the receivers
- Bit level
  - Monitoring = The transmitter monitors the bus signal as it sends the message and compares the bit sent to the bit received.
  - Bit Stuffing = After five consecutive equal bits, the transmitter inserts a stuff bit with a compliment value into the bit stream. The receivers remove this stuff bit.

Implementations



- Basic CAN
  - Limited number of receive buffers and filters
  - Can get bogged down quickly with multiple consecutive messages.

Implementation (con't)



- Enhanced Full Can
  - Dedicated FIFO for each individual message object
  - Very complicated to use
  - Less common

Prep for next week

- Install support for Teensy (3.6) in your arduino
  - Its left as an exercise
- Install flexcan for Teensy on Arduino
  - Its left as ..