Networking
Fieldbuses

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Standards for machine communication

- In the industrial context there is a strong need for collecting of control information and distributing control commands
- Traditional choice: star topology with point to point connections from control to peripherals (e.g. PLC); data is exchanged by means of dedicated signal lines or wires
- Links underutilized: a lot of "useless" cabling
- This solution is becoming increasingly difficult and expensive as systems and control functions become ever more complex
- In the case of complex control systems in particular, the number of connections cannot be increased much further

Solution: **Fieldbus networks** for connecting the control devices

What is a fieldbus?

A fieldbus is a data network, interconnecting an automation system, characterized by:

- Many small data items (process variables) with bounded delay (1ms to 1s)
- Transmission of non-real-time traffic for commissioning and diagnostics
- Harsh environment (temperature, vibrations, EM-disturbances, water, salt, etc.)
- Robust and easy installation by skilled people
- High integrity (no undetected errors) and high availability (redundant layout)
- Intrinsic safety (for oil & gas, mining, chemicals, etc.)
- Clock synchronization (milliseconds to microseconds)
- Continuous supervision and diagnostics
- Low attachment costs (from 5€ to 50€ per node)
- Moderate data rates (50 kbit/s to 5 Mbit/s), large distance range (10m - 4km)

Closed vs open fieldbuses

Fieldbuses are communication technologies and products used in vehicular, automation and process control industries.

Closed (Proprietary) Fieldbuses

Proprietary Fieldbuses are an intellectual property of a particular company or body.

Open Fieldbuses

An Open Fieldbus must satisfy the following criteria:

- The full Fieldbus Specification must be published and available at a reasonable price.
- Critical ASIC components must be available, also at a reasonable price.
- Well defined validation process, open to all of the Fieldbus users.

Advantages of fieldbuses

- Reduces the complexity of the control system in terms of hardware outlay.
- Resulting in the reduced complexity of the control system, project design engineering is made simpler, more efficient and conversely less expensive.
- By selecting a recognized and well established system, this will make the Fieldbus equipment in you plant or plants interchangeable between suppliers.
- The need to be concerned about connections, compatibility and other potential problems is eradicated.

(Some) available fieldbuses

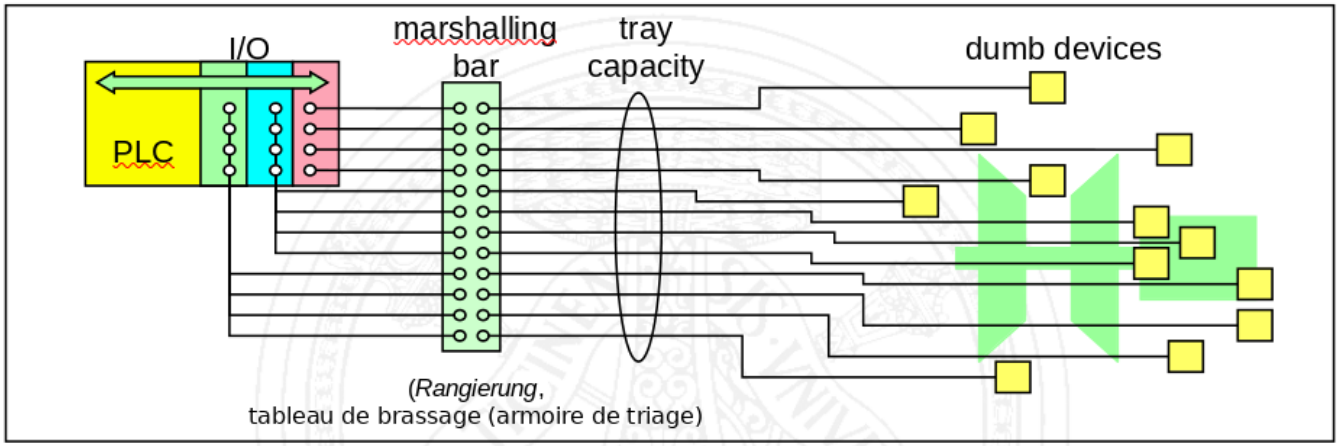
Some of the Fieldbus technologies currently on the market:

- AS-Interface (Europe)
- CAN (German, Bosch)
- Interbus (German, Phoenix Contract)
- ModBus (America, Modicon)
- Profibus (German, Siemens)
- EtherNet (America, AB)
- ControlNet (America, AB)

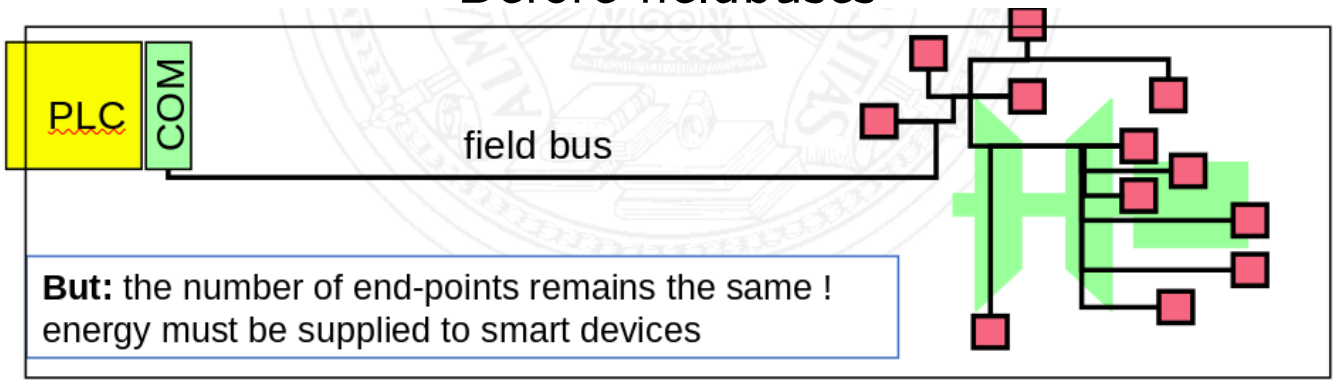
Expectations

- Reduce cabling.
- Increased modularity of plant (each object comes with its computer).
- Easy fault location and maintenance.
- Simplify commissioning (mise en service, IBS = Inbetriebssetzung).
- Simplify extension and retrofit.
- Off-the-shelf standard products to build “Lego”-control systems.

The original idea: save wiring

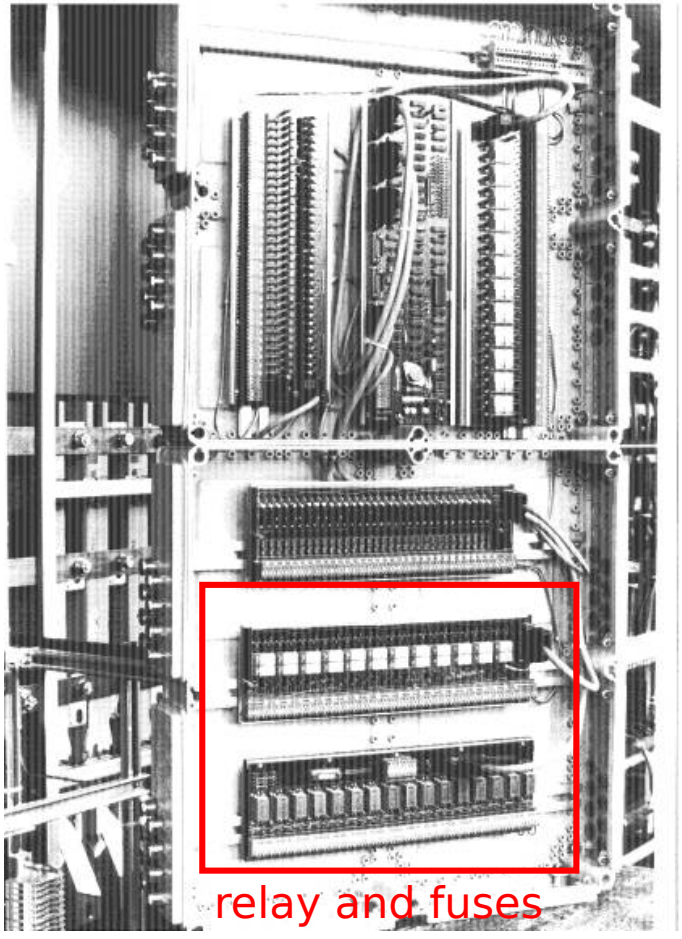


Before fieldbuses



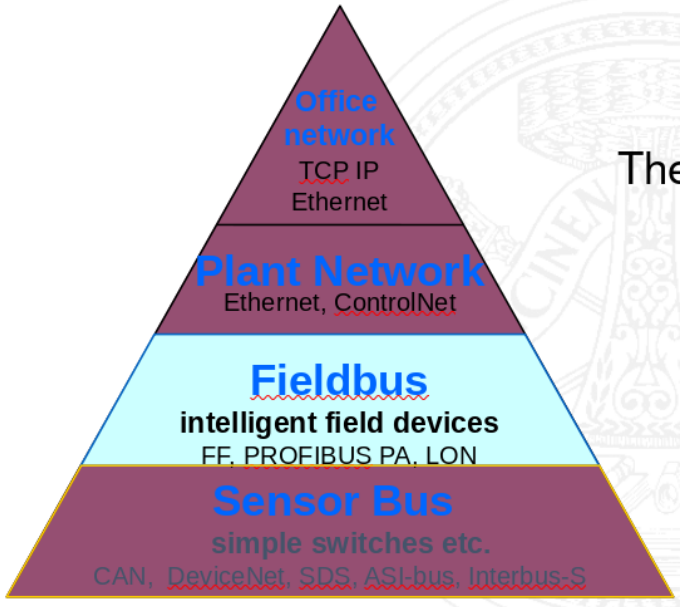
After fieldbuses

Distributed peripherals



Many field busses are just extensions of the PLC's inputs and outputs, field devices are data concentrators.
Devices are only visible to the PLC that controls them.

Field busses classes



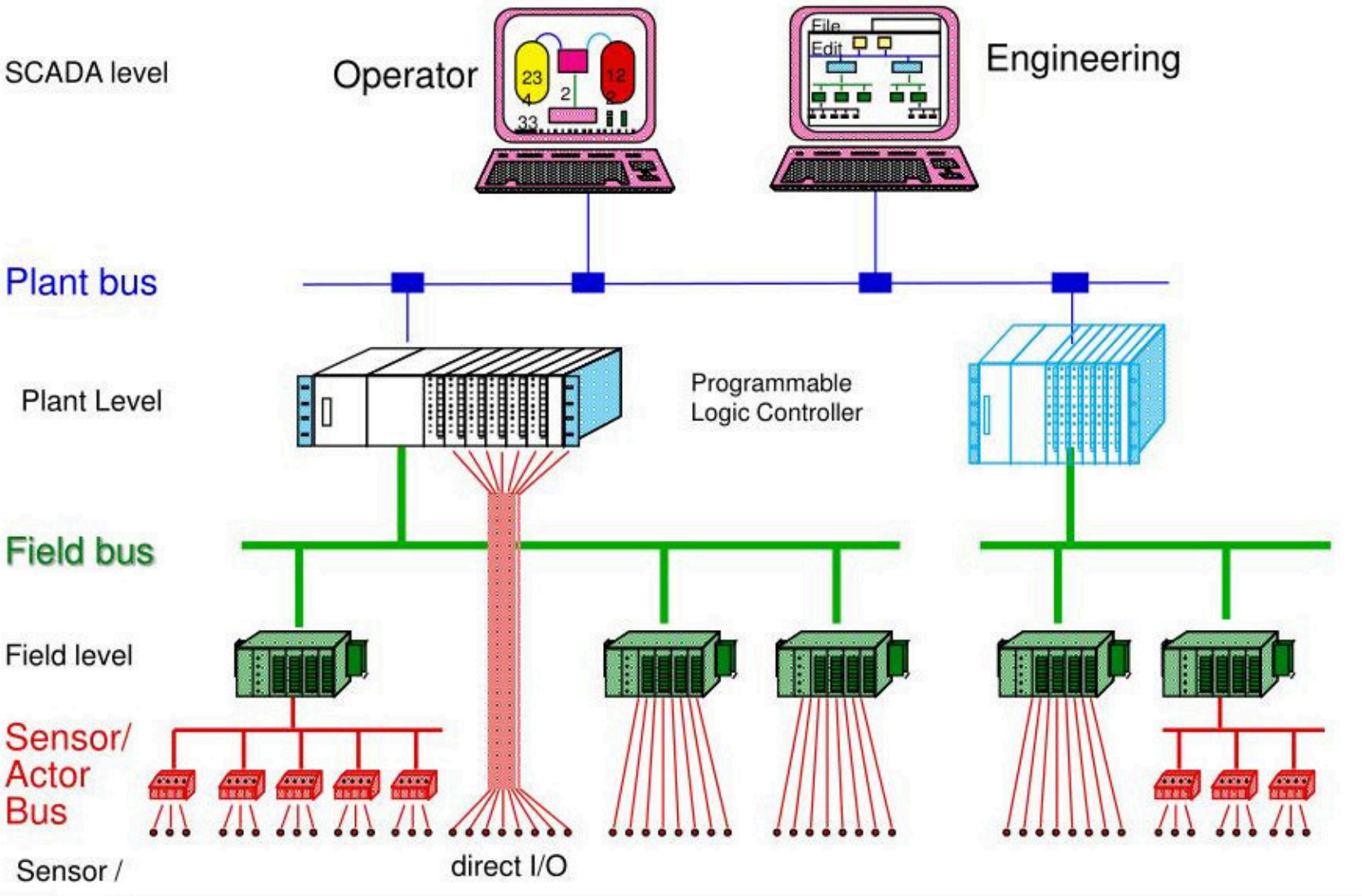
The field bus depends on:

- its function in the hierarchy
- the distance it should cover
- the data it should gather

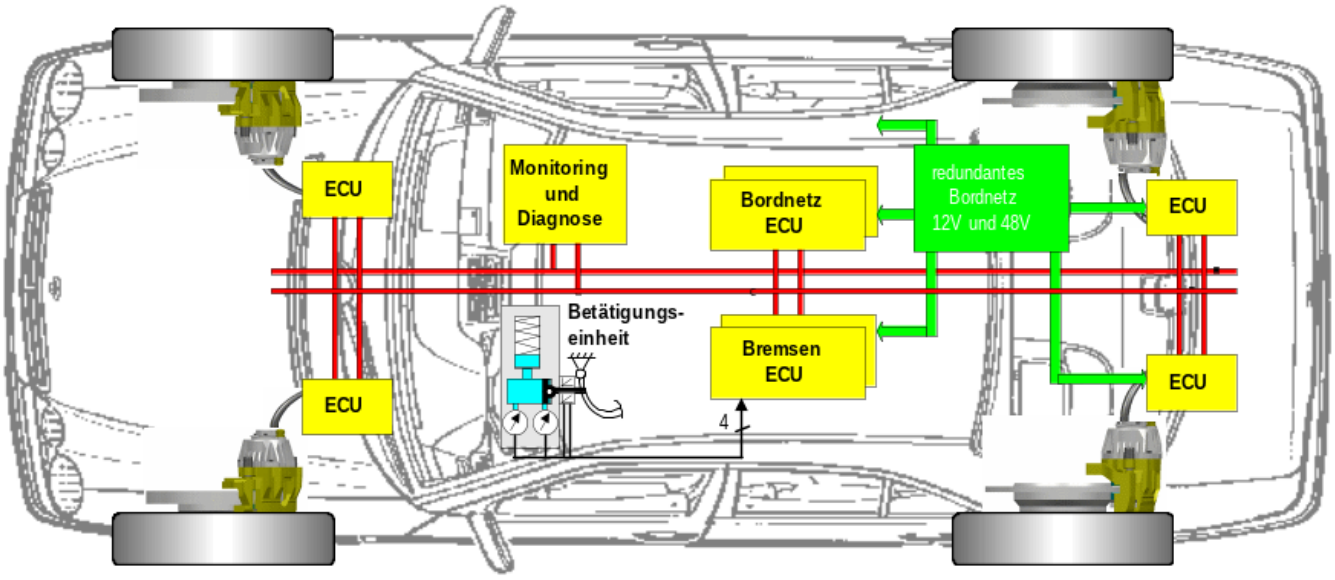
Geographical extension of industrial plants

1 km .. 1000 km	Transmission & Distribution : Control and supervision of large distribution networks: water - gas - oil - electricity - ...
1 km .. 5 km	Power Generation : Out of primary energy sources: waterfalls - coal - gas - oil - nuclear - solar - ...
50 m .. 3 km	Industrial Plants : Manufacturing and transformation plants: cement / steel works - food silos - printing - paper pulp processing - glass plants - harbors - ...
500m .. 2 km	Building Automation : energy - air conditioning - fire - intrusion - repair - ...
1 m .. 1 km	Manufacturing : flexible manufacturing cells - robots
1 m .. 800 m	Vehicles : locomotives - trains - streetcars - trolley buses - vans - buses - cars - airplanes - spacecraft - ...

The fieldbus in the plant system



Fieldbus application: automotive



- Electromechanical wheel brakes
- Redundant Engine Control Units
- Pedal simulator
- Fault-tolerant 2-voltage on-board power supply
- Diagnostic System

Engineering a fieldbus: consider data density

- Acceleration limiter and prime mover: 1 kbit in 5 ms
- Burner Control: 2 kbit in 10 ms
- For each 30 m of plant: 200 kbit/s
- Fast controllers: at least 16 Mbit/s over distances of 2 m
- Data are transmitted from the periphery or from fast controllers to higher level, but slower links to the control level through field busses over distances of 1-2 km. The control stations gather data at rates of about 200 kbit/s over distances of 30 m.
- The control room computers are interconnected by a bus of at least 10 Mbit/s, over distances of several 100 m.

Field bus planning: estimate data density per unit of length or surface, response time and throughput over each link.

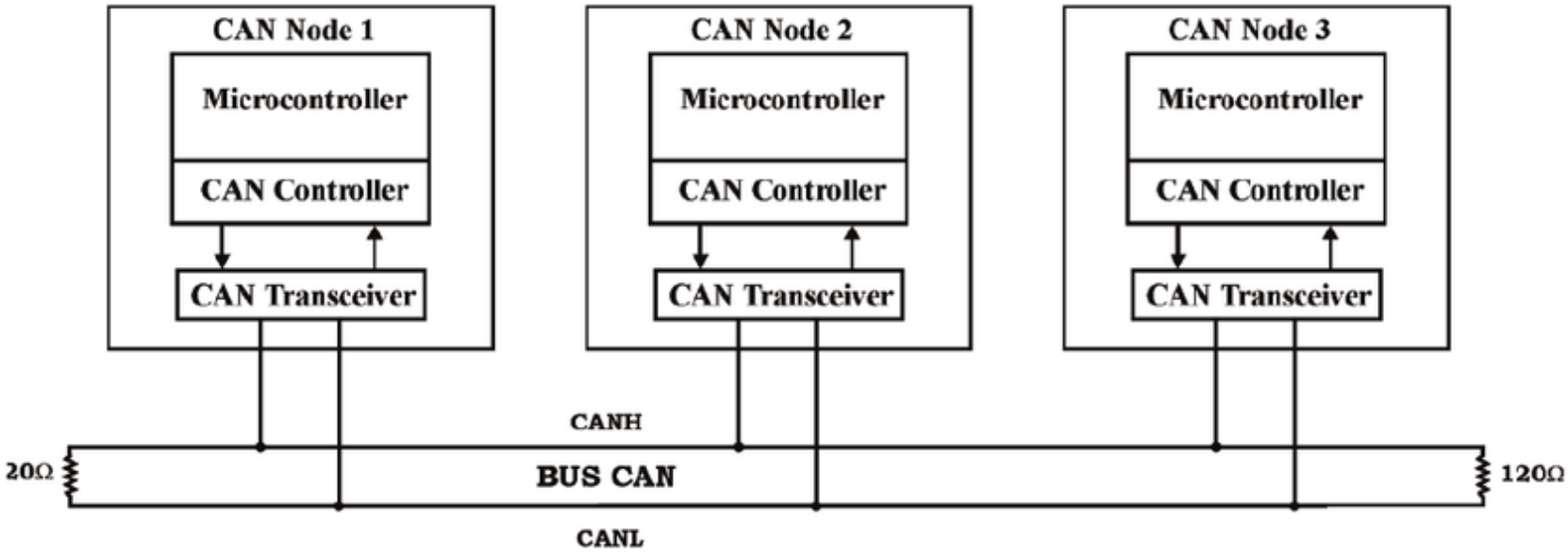
Controller Area Network (CAN)

- Controller Area Network (CAN) is a fast serial bus that is designed to provide an efficient, reliable and very economical link between sensors and actuators.
- CAN uses a twisted pair cable (dual-wire) to communicate at speeds up to 1Mbit/s (max) with up to 40 devices.
- It originally developed to simplify the wiring in automobiles.
- CAN (fieldbus) are now used in machine and factory automation products as well.

Features of the CAN bus

- Any node can access the bus when the bus is quiet.
- Non-destructive bit-wise arbitration to allow 100% use of the bandwidth without loss of data
- Variable message priority based on 11-bit / 29 bit packet identifier
- Peer-to-peer and multi-cast reception
- Automatic error detection, signaling and retries
- Data packets 8 bytes long
- Asynchronous communication (Even Triggered)

Architecture of the CAN bus



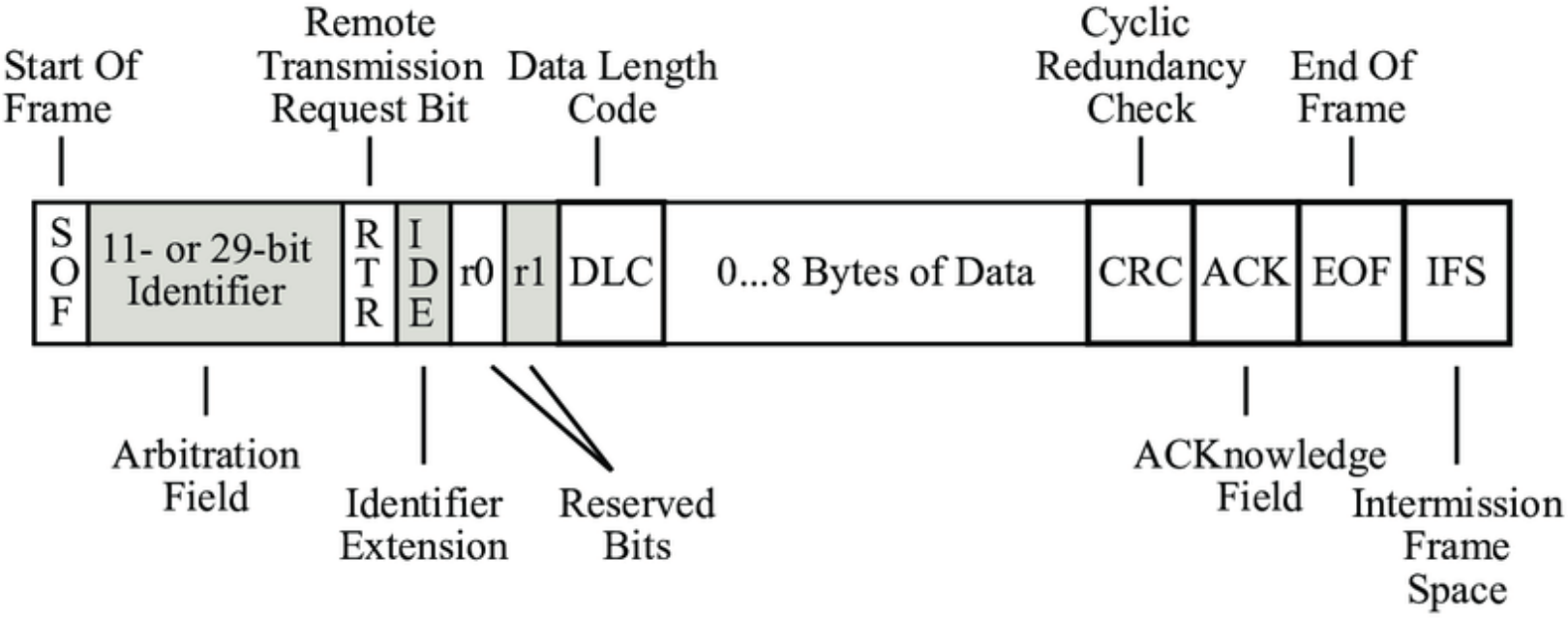
Architecture of the CAN bus according to the ISO 11898 standard.

The standard allows up to 40 nodes to be connected to the same wire.

Tradeoff: CAN bus versus point-to-point

- By introducing one single bus as the only means of communication as opposed to the point-to-point network, we traded off the channel access simplicity for the circuit simplicity.
- Since two devices might want to transmit simultaneously, we need to have a MAC protocol to handle the situation.
- CAN manages MAC issues by using a unique identifier for each of the outgoing messages.
- Identifier of a message represents its priority.

CAN message format



The identifier can use 11 bits (standard lenght) or 29 bits (extended length).

The identifier is used to arbitrate the access to the same shared channel.

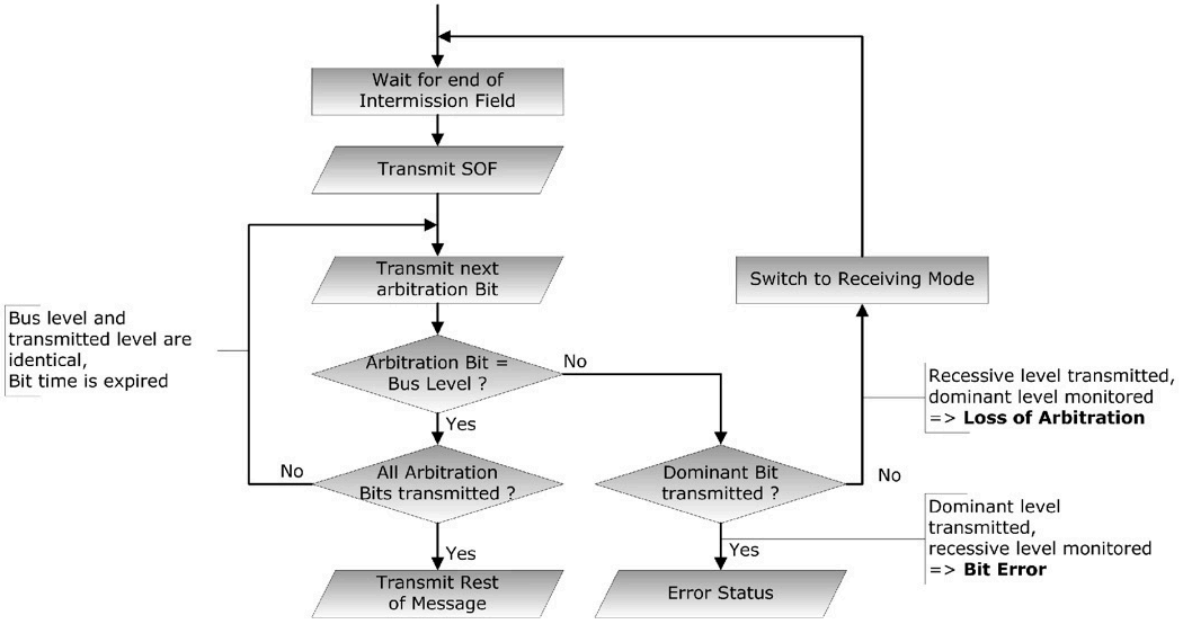
Implicit collision handling in the CAN bus

Arbitration: in general, it is the process of gathering access to the shared communication medium.

- If two messages are simultaneously sent over the CAN bus, the bus takes the "logical AND" of all them.
- Hence, the messages identifiers with the identifier corresponding to the lowest binary number gets the highest priority.
- Every device listens on the channel and backs off when it notices a mismatch between the bus's bit and its identifier's bit.

The arbitration in the CAN bus is very clever, and represents a distinguishing aspect of the technology.

CAN arbitration procedure in details



Zero Bit = Dominant bus level

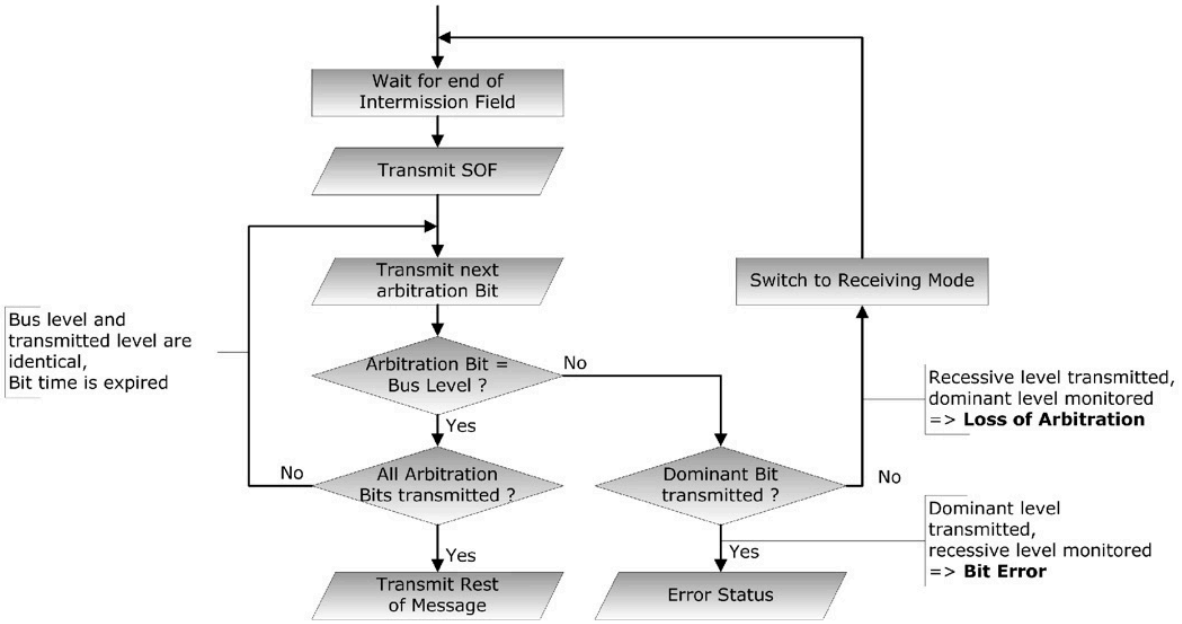
One Bit =

Recessive bus level $\rightarrow$ dominant bit

overrides recessive bit

	bit $\rightarrow$										
node	10	9	8	7	6	5	4	3	2	1	0
sender 1	1	~~0~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	1
sender 2	0	0	1	1	1	0	0	1	0	1	1
sender 3	0	0	1	1	1	0	1	~~0~~	~~0~~	~~1~~	~~0~~
bus level	0	0	1	1	1	0	0	1	0	1	1

CAN arbitration procedure in details



(1) The CAN node (CAN controller) waits for the end of the intermission field.

(2) As soon as the bus is being detected as idle, the node signals an SOF (Start of Frame) by putting a dominant (low) level onto the bus. Every other node, which did not request bus access, immediately switches to a receiving mode.

Ethernet as a fieldbus

Determinism and Qos with Ethernet

- "Vintage" Ethernet
- Switched Ethernet (Which QoS implementation?)

But not so simple...

- Can I support IP applications on the fieldbus, without disturbing real time traffic?
- Can I forward fieldbus protocol messages through Ethernet segments?
- Can I have an integrated solution for the networks management?
- Delays introduced by proxies and gateway

Idea and some proposals

A very simple idea:

"I take my classic Fieldbus protocol and carry it on Ethernet with TCP or UDP"

... leads to several commercial solutions:

- Modbus/TCP (Schneider)
- Ethernet/IP (Rockwell, IAONA)
- HSE (Fieldbus Foundation)
- WorldFIP EtherFIP
- ...

Problems

- TCP/IP protocol stack is designed for Client/server application, not for 1 producer/N Consumers exchanges
- Needs switched Ethernet to insure determinism
- Needs QoS management if mixed traffic with other IP applications is needed
- How manage full redundancy if needed?
- How manage station synchronization if needed?

The protocol encapsulation specification is not enough!

EtherCAT

- EtherCAT enabled devices don't require a central switch
- Master sends a unique frame containing datagrams for all slaves
- Dynamic TDMA mode "on the fly"