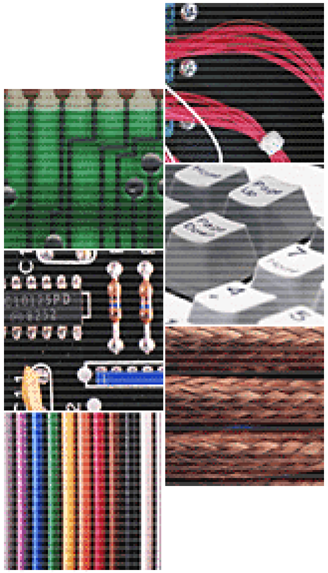
Lecture

Computer Networks

Fieldbus Systems



Prof. Dr. H. P. Großmann

Dipl.-Ing. Andreas Schmeiser

Department of Information Resource Management

University of Ulm, Germany

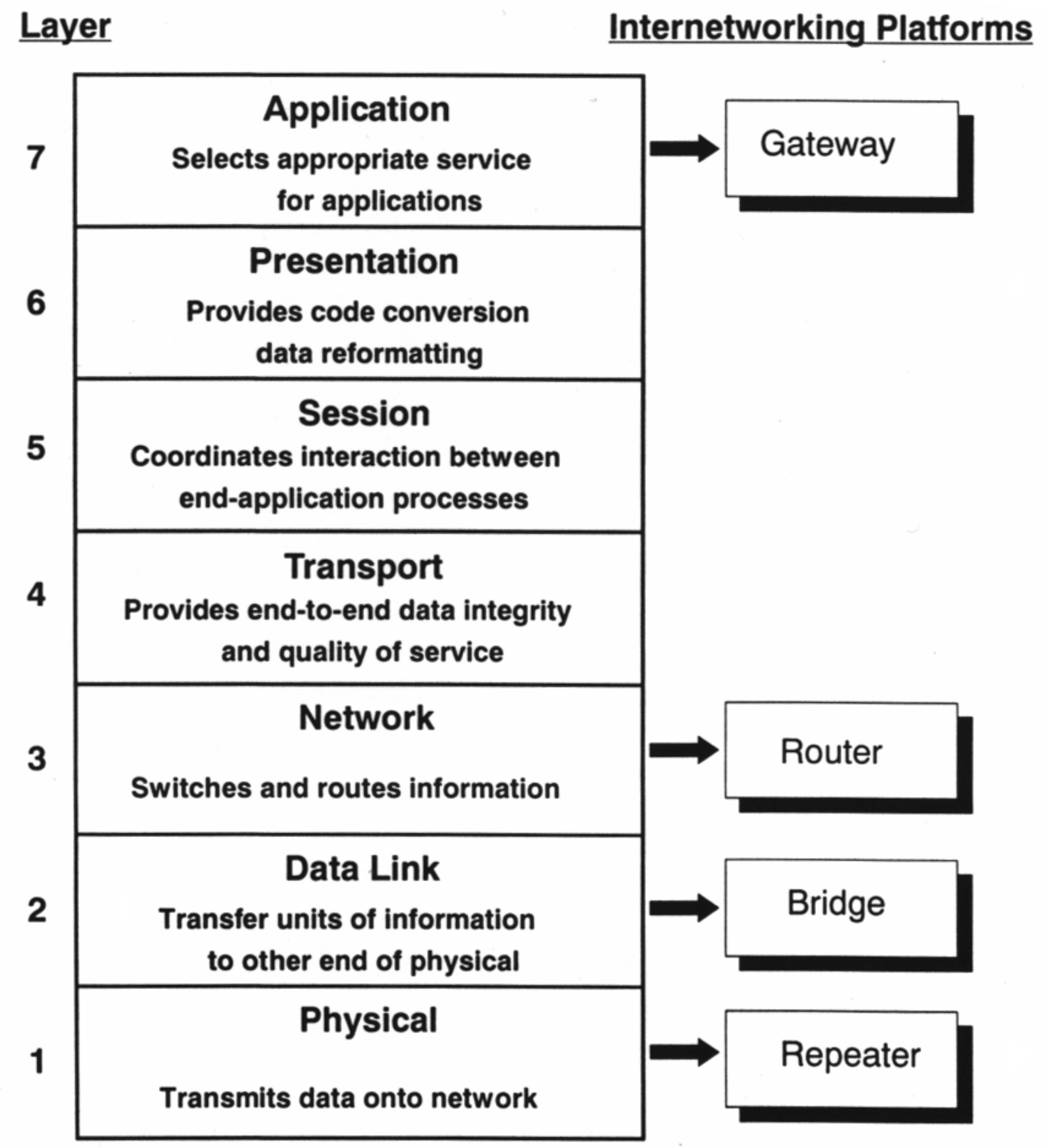
Areas of application and examples

- 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

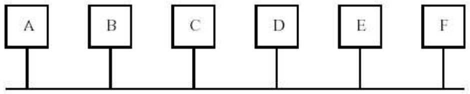
Fieldbuses and the ISO OSI reference model



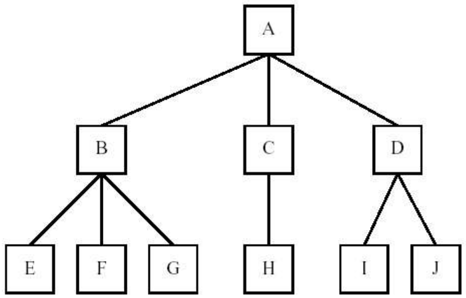
- Fieldbus systems often define several OSI layers in one standard
- Mostly layers 3 to 6 are nonexistent
  - Efficient, fast data processing
  - No routing
  - No fragmentation
- In the majority only layers 1-2 or layers 1-2-7 are defined

Topologies at a glance

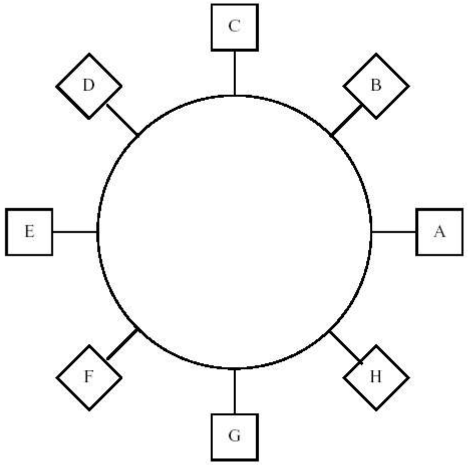
- Line, Bus



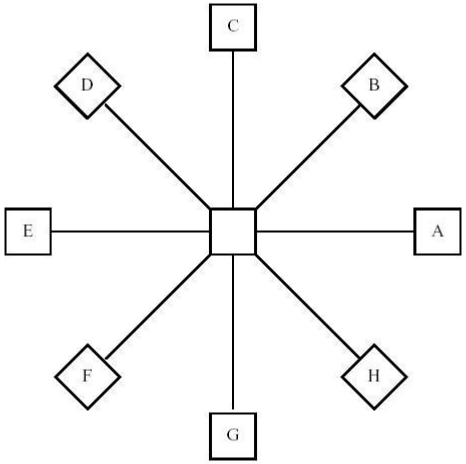
- Tree



- Ring, Token-Ring

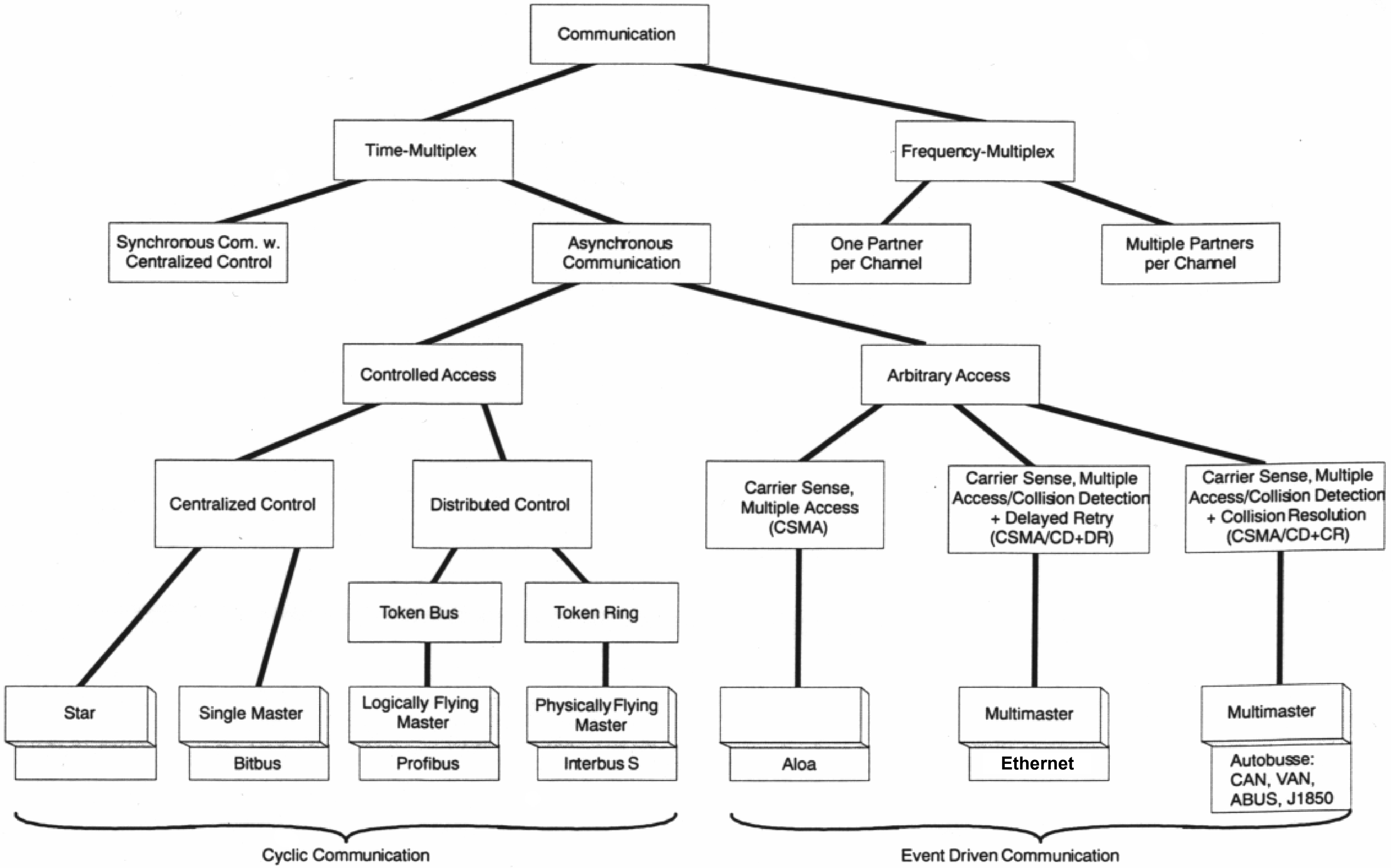


- Star



- Open topology

Access methods at a glance



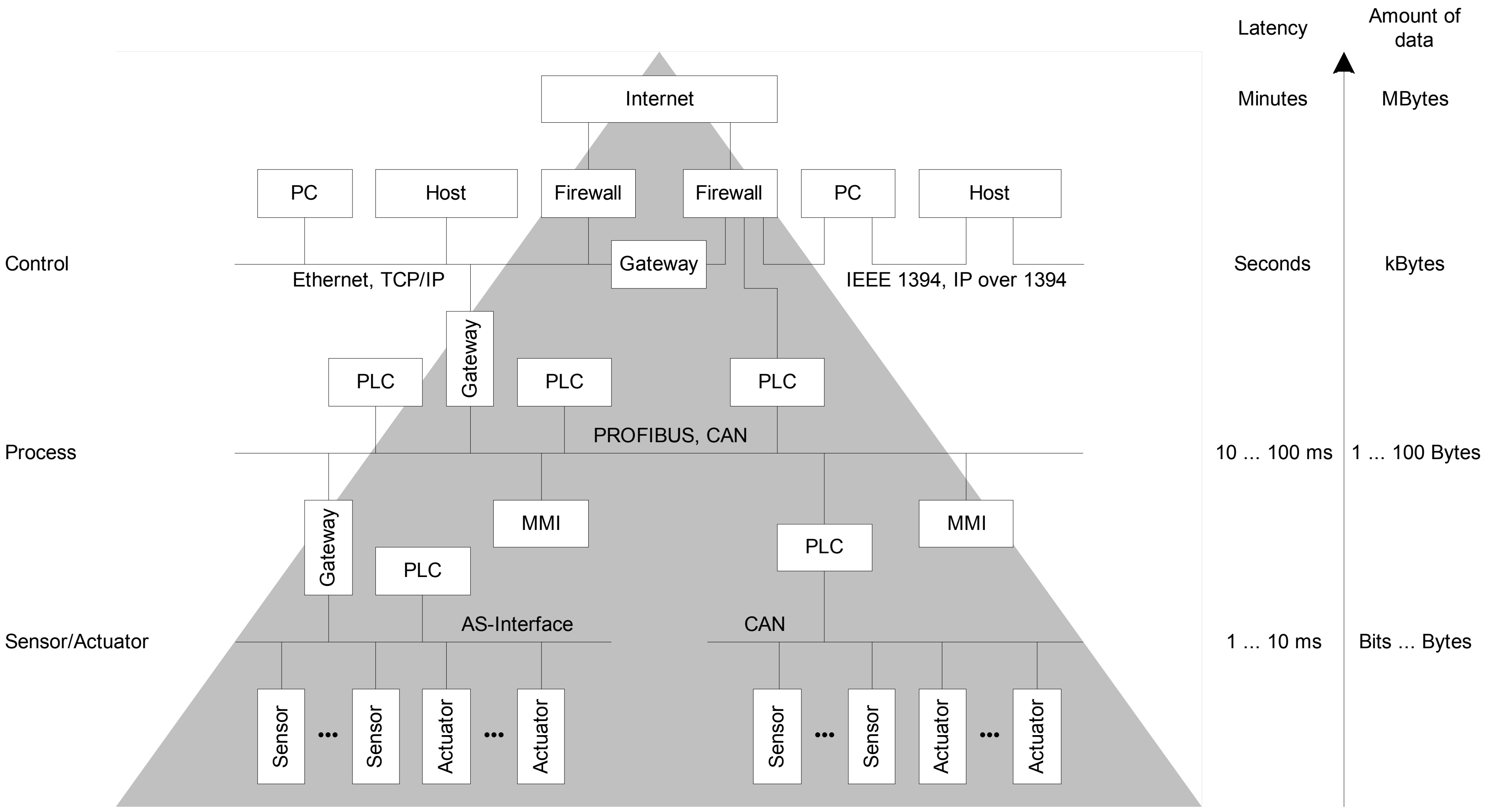
LOMI Universität Ulm, 2004

Comparison of amount of data

	ASi	CAN 2.0A	 2.0B	IEEE 1394 S100	IPv6
Addressing	5 Bits	11 Bits	29 Bits	16 + 48 Bit	128 Bits
User data	9 Bits	0 ... 8 Bytes	0 ... 8 Bytes	4 … 512 Bytes	Max. 64 kBytes
Efficiency	32 %	14 ... 57 %	11 … 48 %	20 … 96 %	Max. 99 %

ASi – Actuator / Sensor - Interface
CAN – Controller Area Network

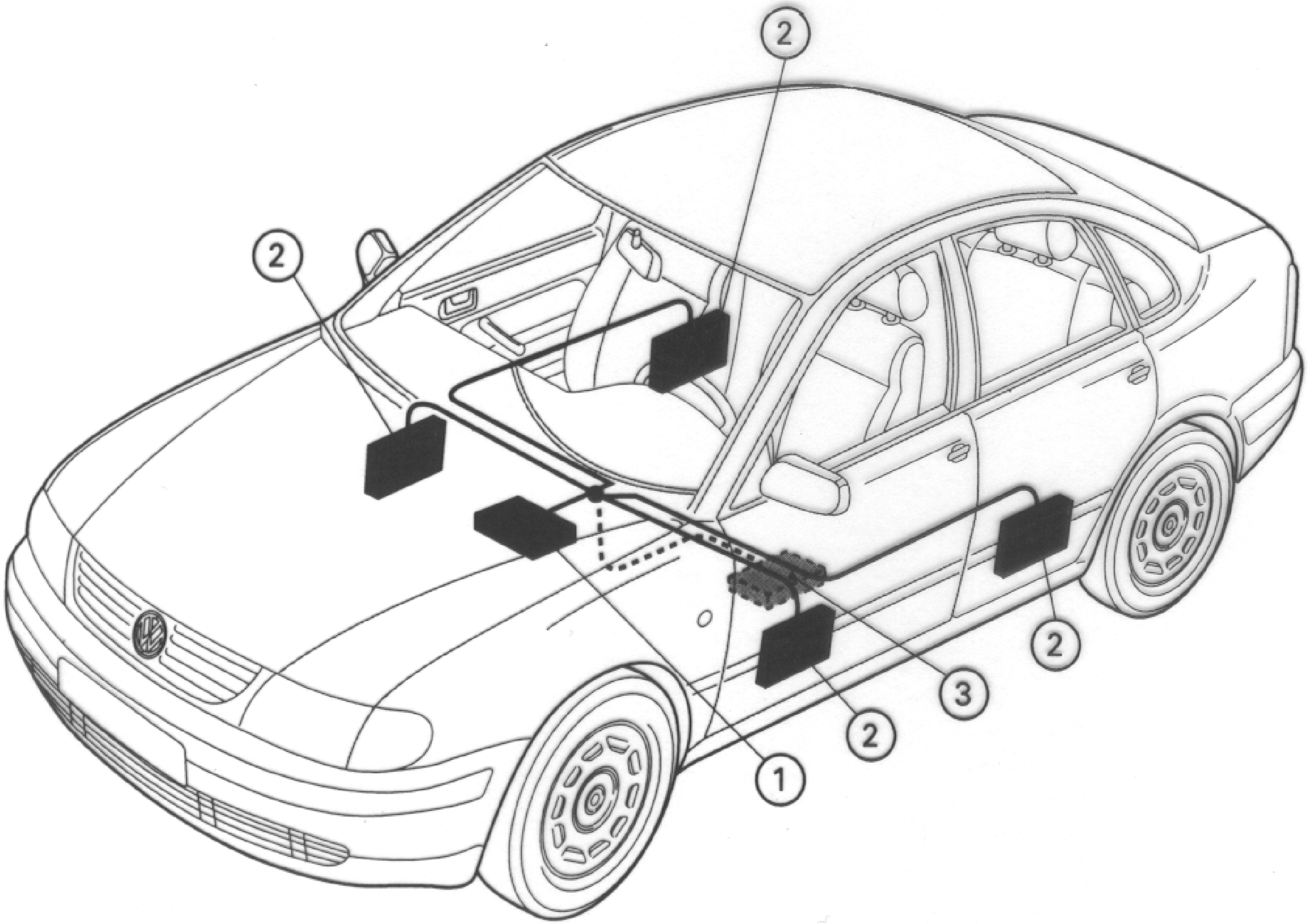
Industrial automation – CIM model



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

LOMI Universität Ulm, 2004

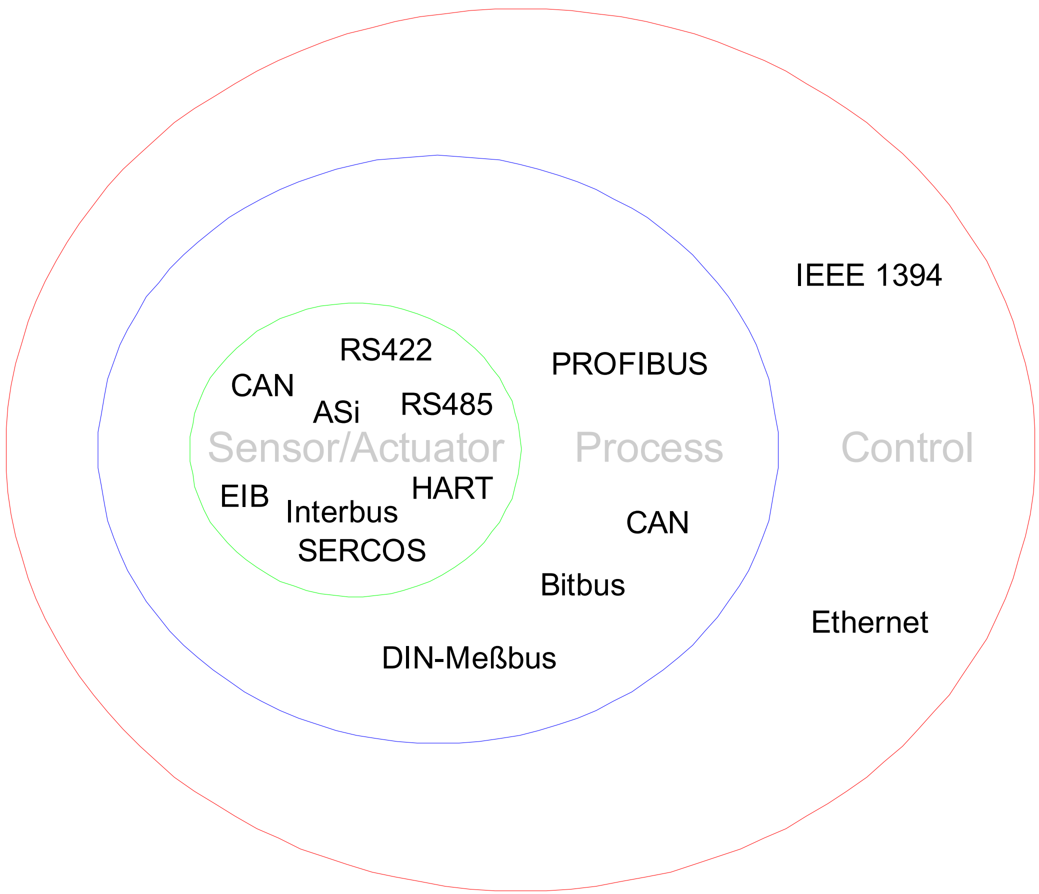
Automotive engineering



① Zentralmodul (ZM) Central Control Unit ② Türsteuergerät (TSG) Door Control Unit ③ Memory-Steuergerät Memory Control Unit

Examples

- Industrial automation



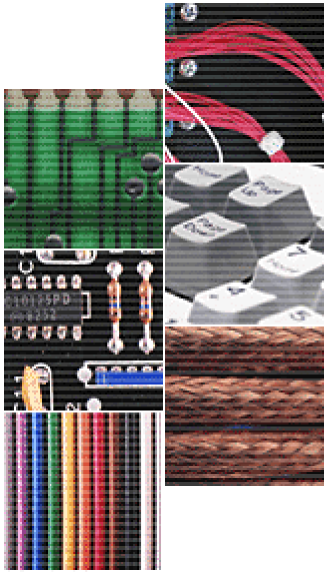
Abbreviations:
ASi – Actuator / Sensor - Interface
CAN – Controller Area Network
EIB – European Installation Bus
EHS – European Home System
HART – Highway Addressable Remote Transducer
LIN – Local Interconnect Network
LON – Local Operating Network
TTP – Time Triggered Protocol

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

Lecture

Computer Networks

Controller Area Network (CAN)



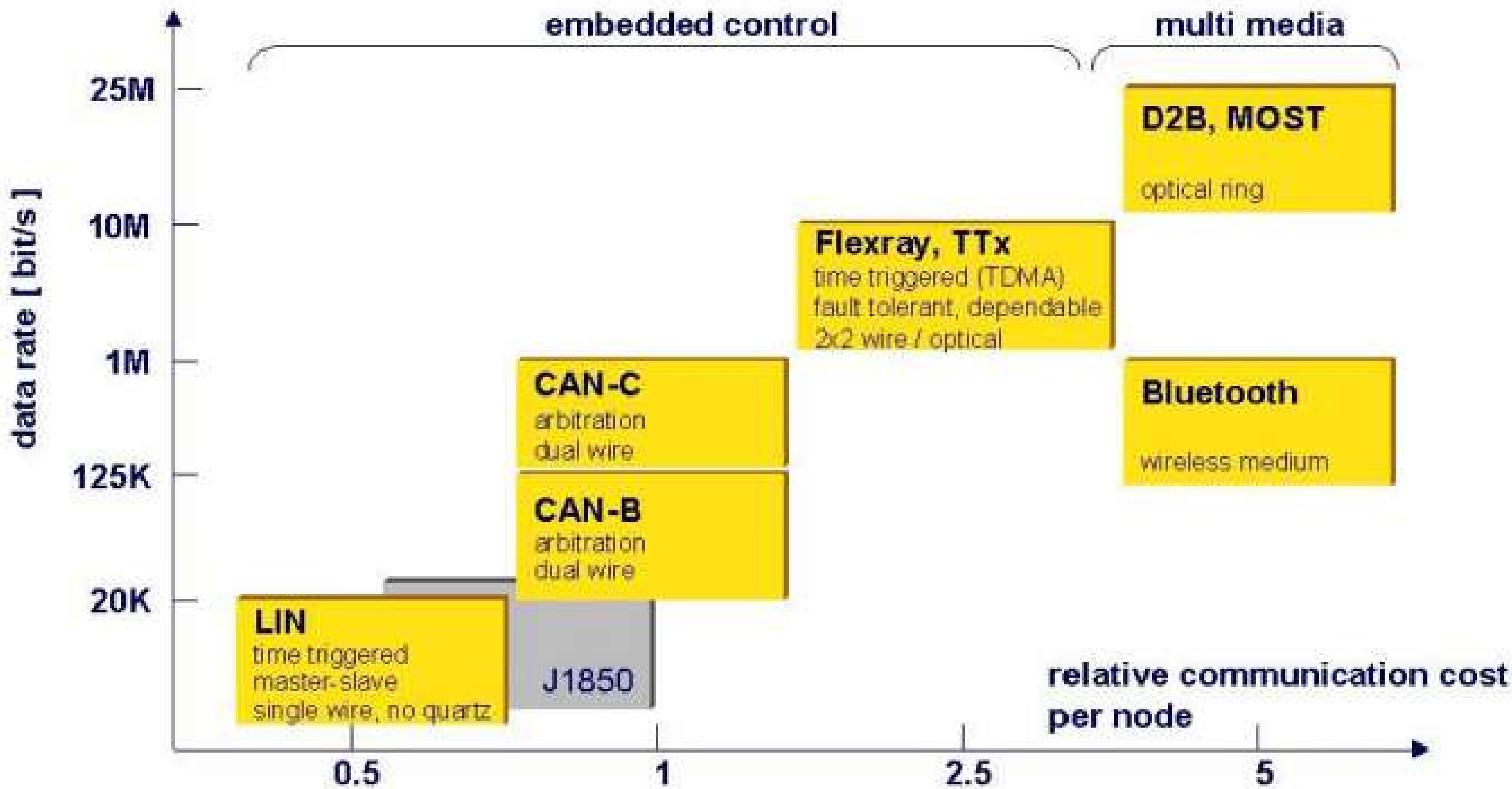
Prof. Dr. H. P. Großmann

Dipl.-Ing. Andreas Schmeiser

Department of Information Resource Management

University of Ulm, Germany

Automotive Bus Systems



D2B – Digital Data Bus
MOST – Media Oriented Systems Transport

LOMI Universität Ulm, 2004

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

CAN ISO OSI Layer 1 and 2

OSI Layer 2 Data Link

LLC (Logical Link Control)

Acceptance Filtering
Overload Notification
Recovery Managment

MAC (Medium Access Control)

Data Encapsulation
/Decapsulation
Frame Coding (Stuffing, Destuffing)
Medium Access Management
Error Detection
Error Signalling
Acknowledgement
Serialization/Deserialization

OSI Layer 1 Physical

PLS (Physical Signalling)

Bit Encoding/Decoding
Bit Timing
Synchronization

PMA (Physical Medium Attachment)

Driver/Receiver Characteristics

MDI (Medium Dependent Interface)

Connectors

CAN Bus Media

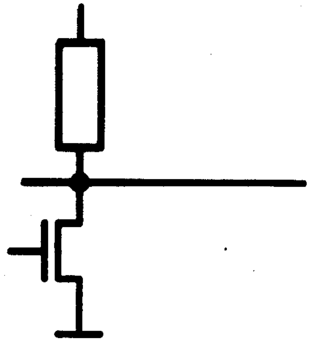
All media, supporting **dominant** and **recessive** state can be used

Examples:

Wires

recessive = pull-up

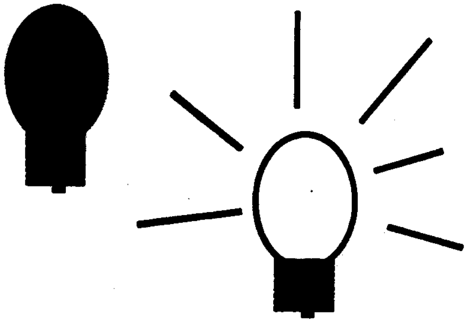
dominant = current sink to ground



Optical media

recessive = light off

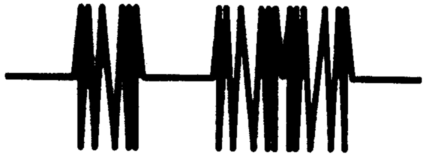
dominant = light on



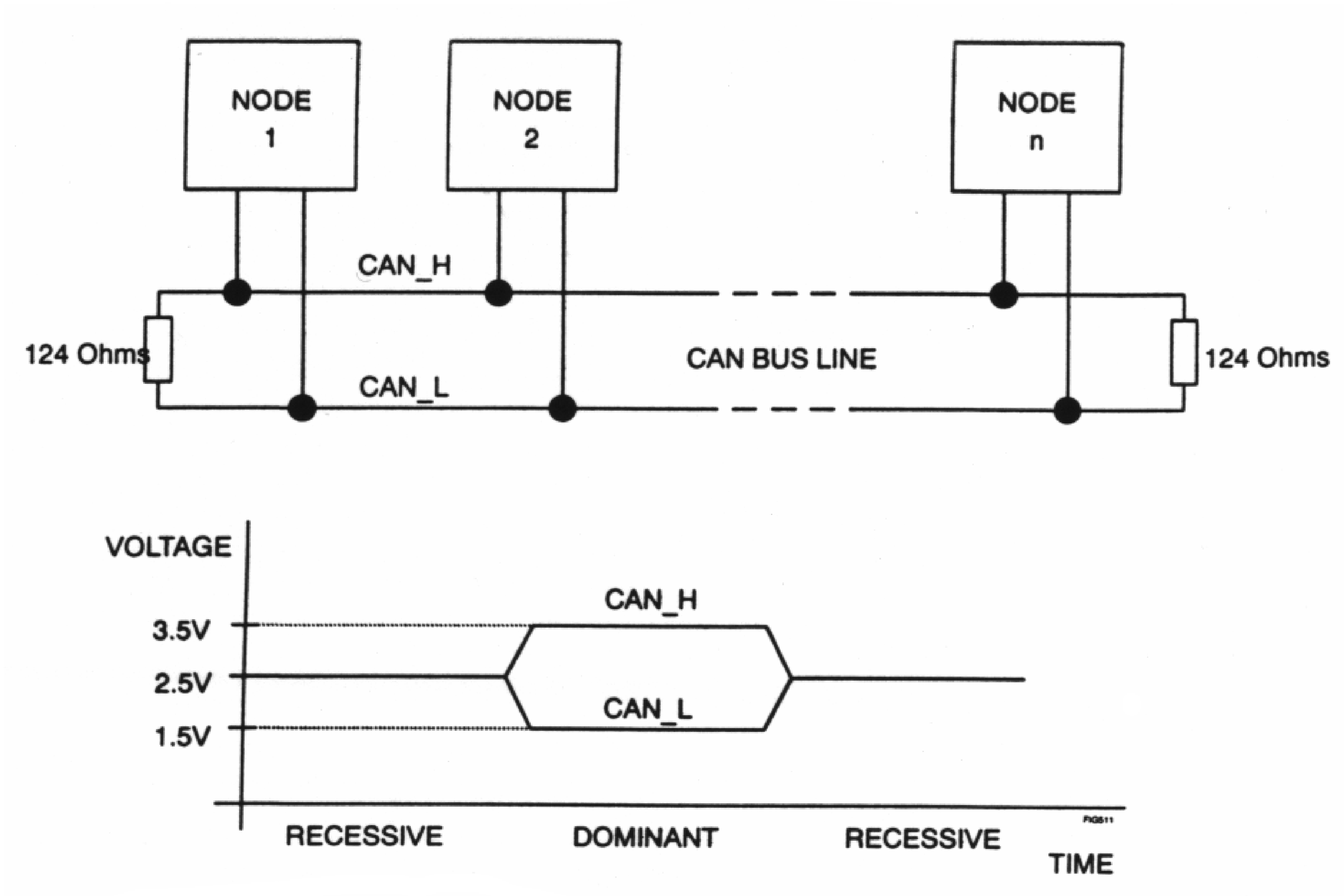
RF media

recessive = RF off

dominant = RF on
(spread spectrum)

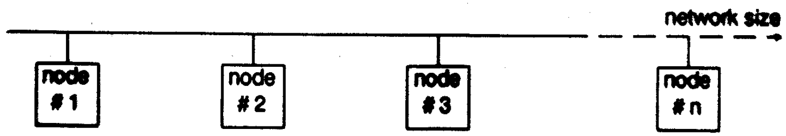


CAN Interface nach ISO 11898

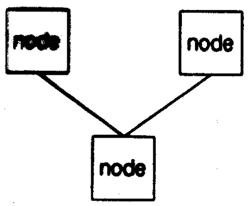


Configuration Flexibility with CAN

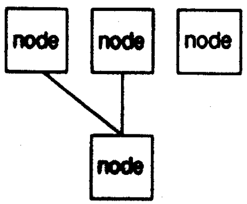
- extension



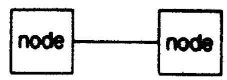
- information-oriented routing (within one bus-type network)



star (broadcast)

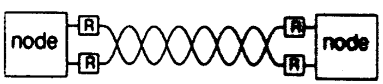


partial star (multicast)

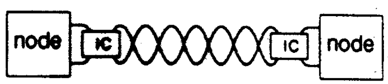


point-to-point

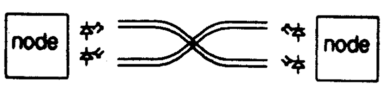
- application-defined transmission medium



discrete electrical transceiver



integrated electrical transceiver

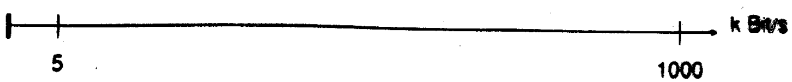


optical transceiver

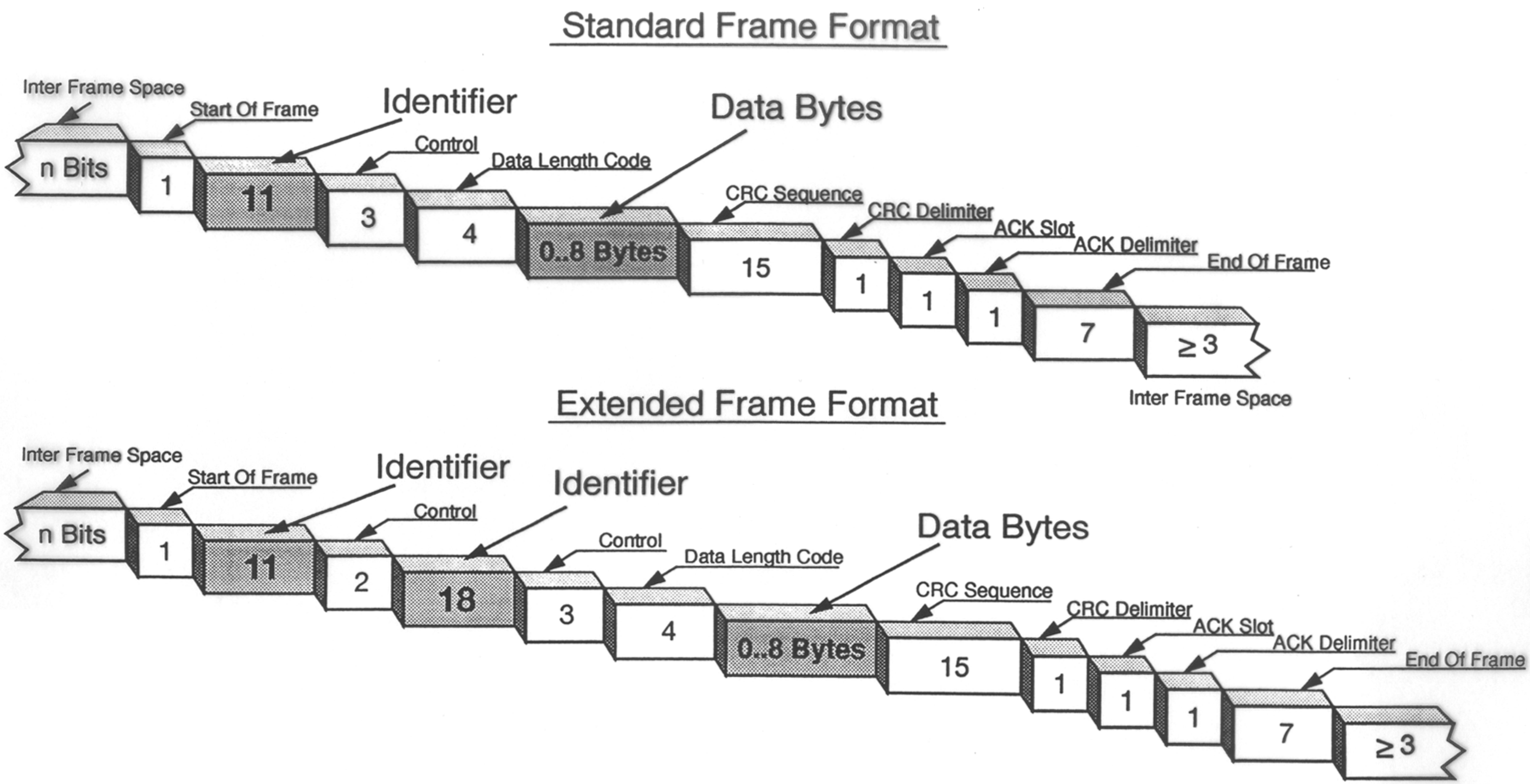
. . .

etc.

- data rate programmable

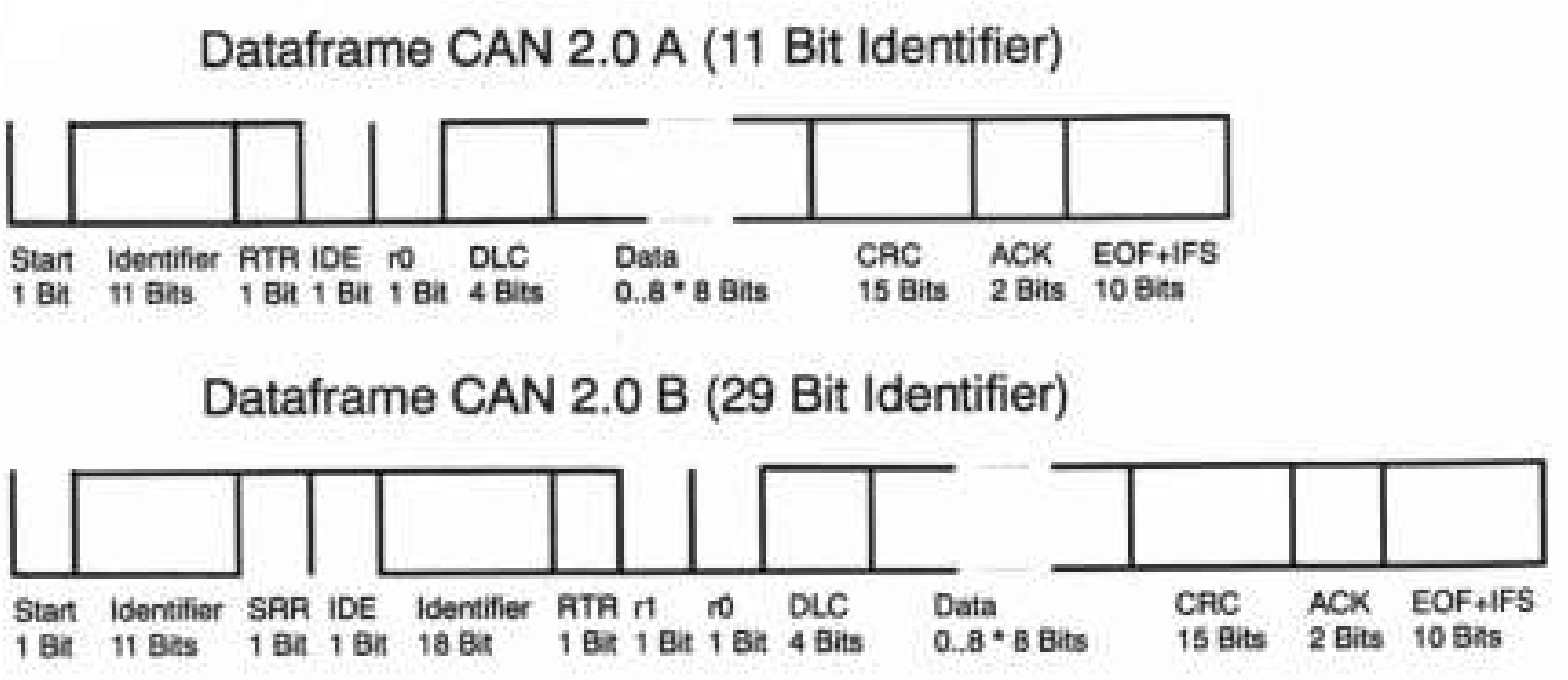


CAN Data Frame

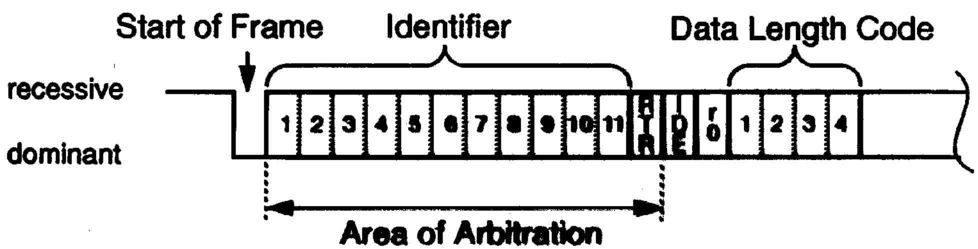


LOMI Universität Ulm, 2004

CAN Data Frame

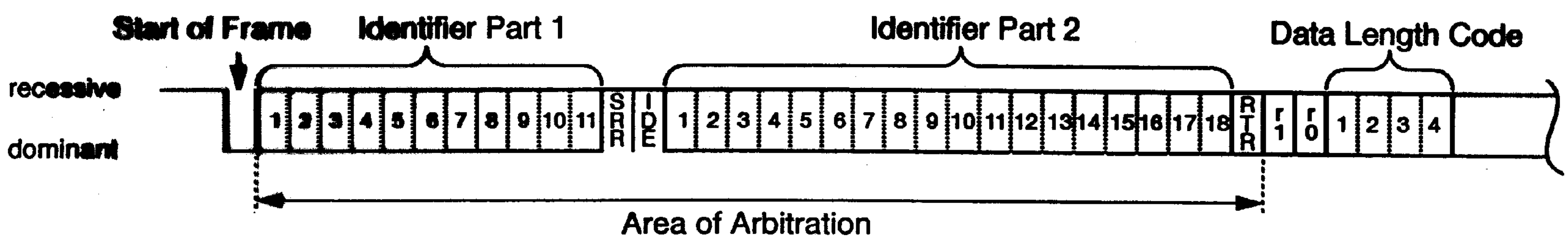


CAN Arbitration

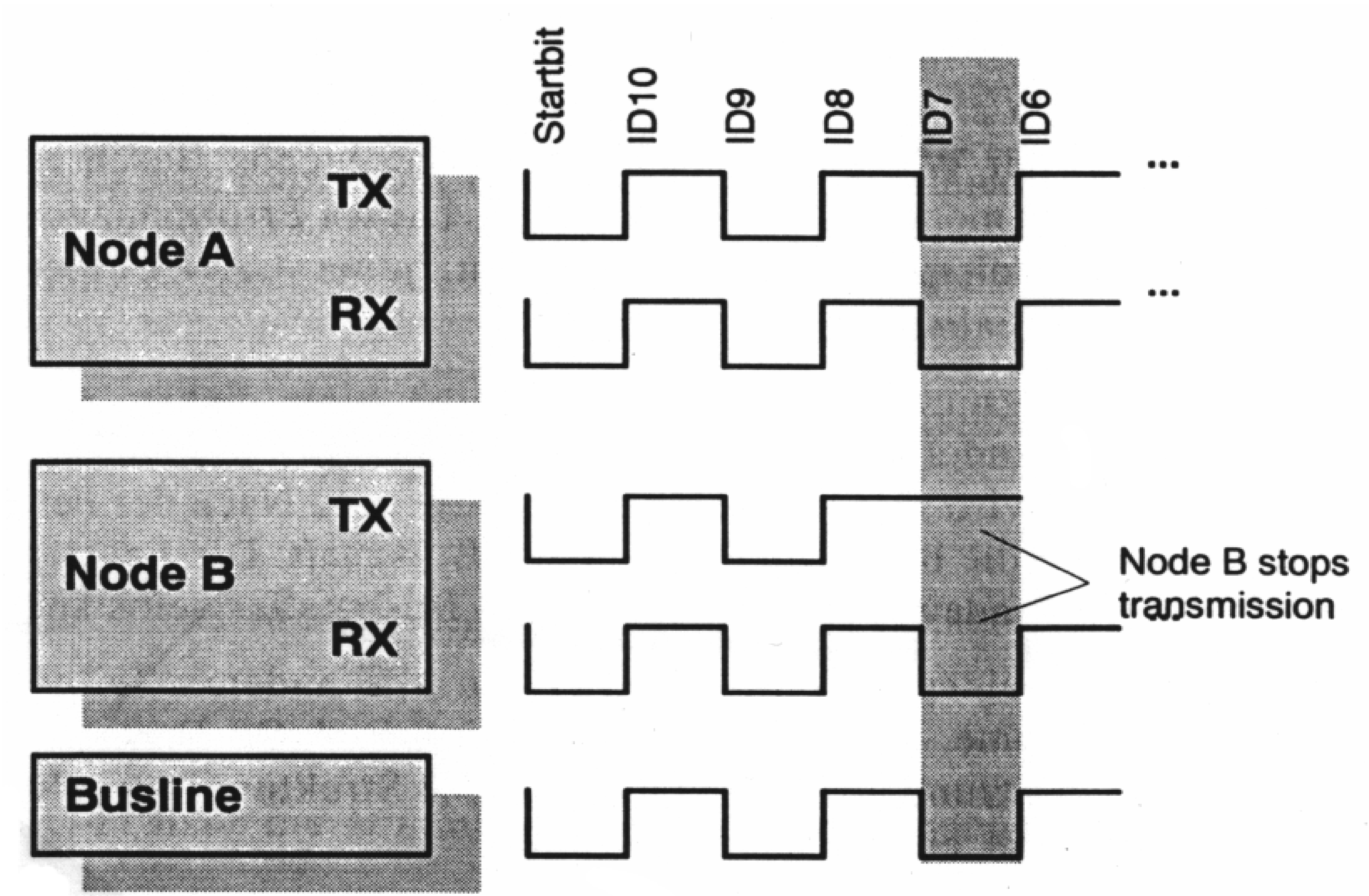


TX	Bus (RX)	Action
rec.	rec.	proceed with arbitration
dom.	dom.	proceed with arbitration
rec.	dom.	arbitration lost
dom.	rec.	bit error

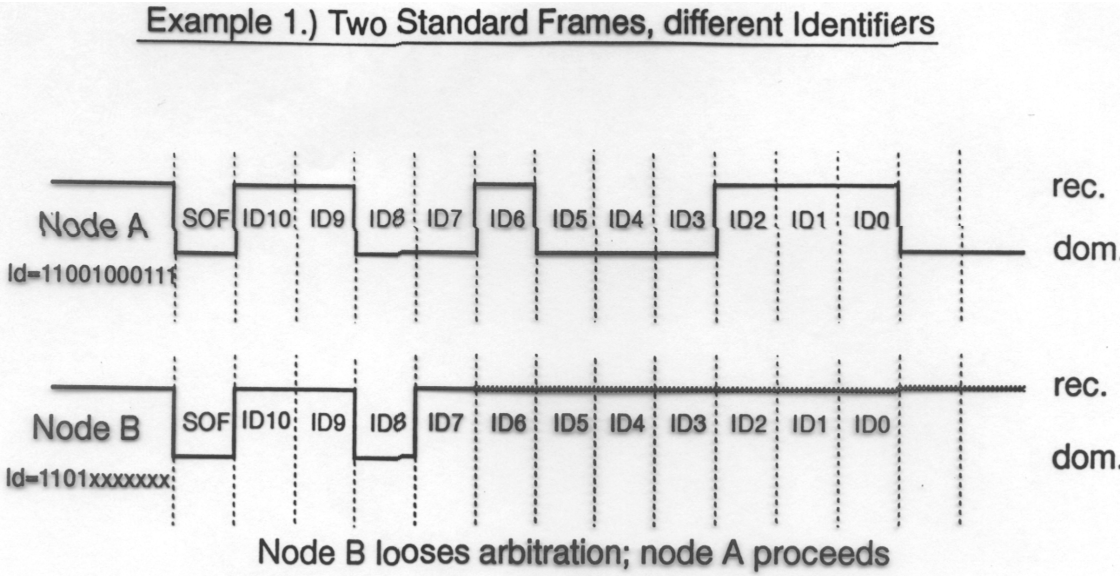
Extended Frame Format

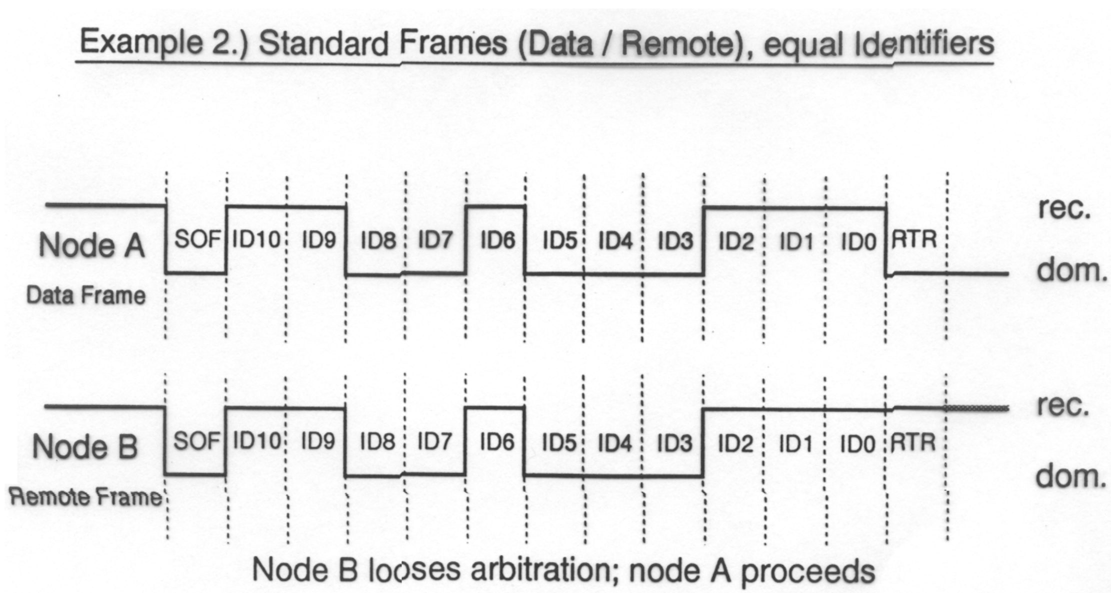


CAN Arbitration



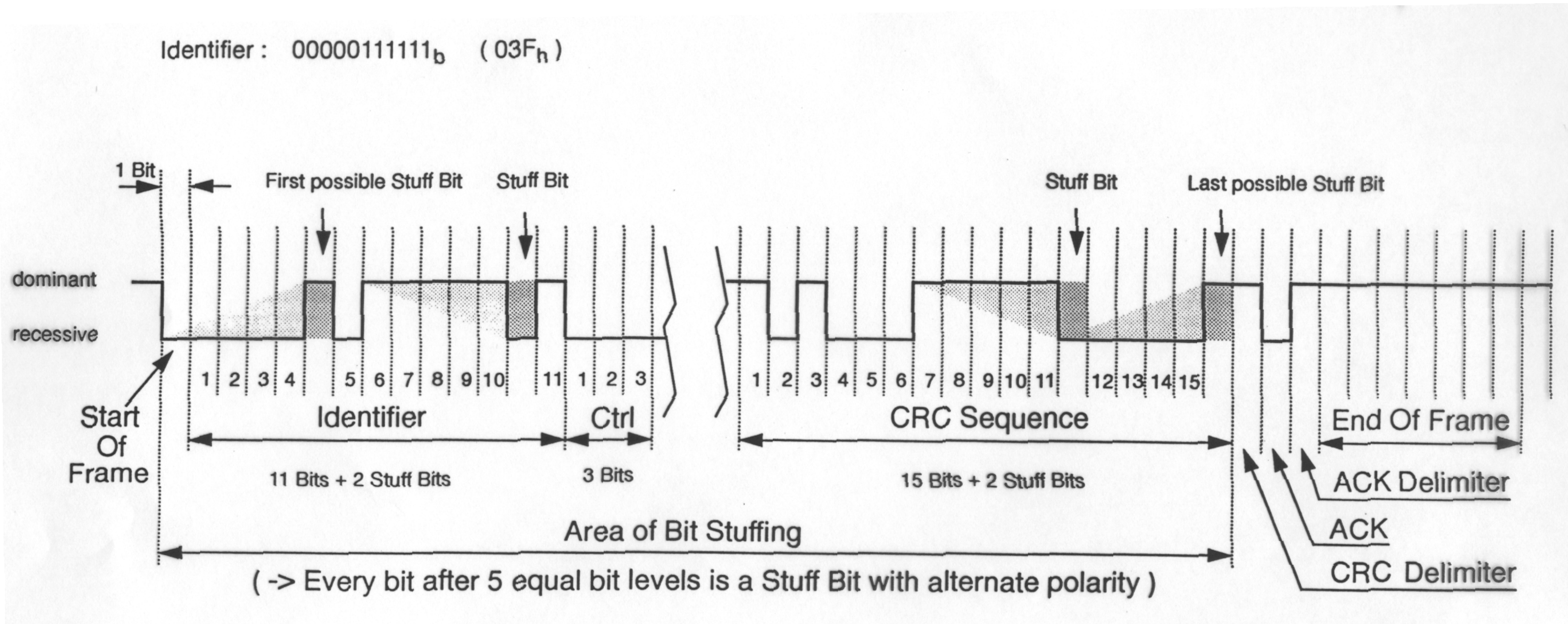
CAN Arbitration



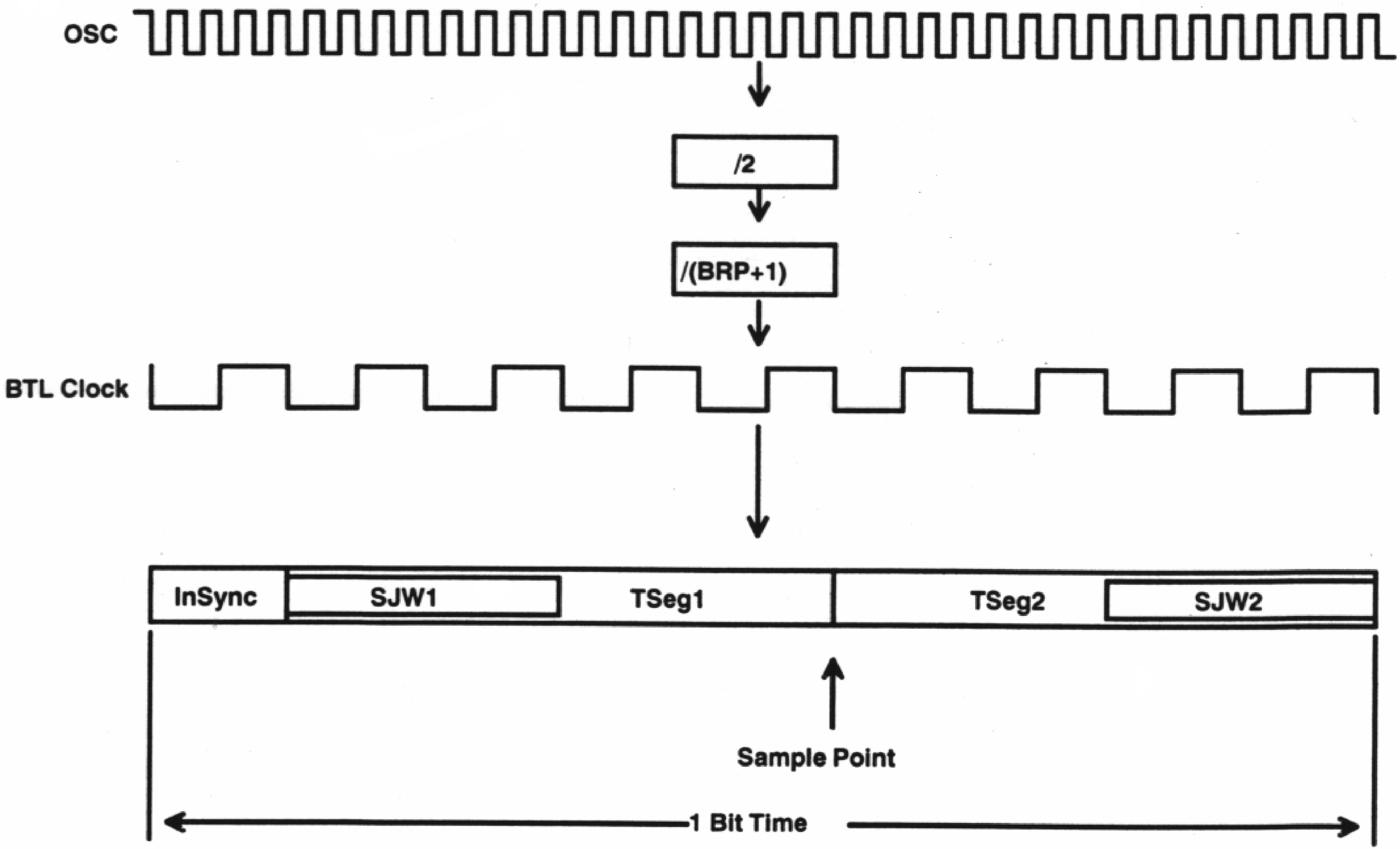


LOMI Universität Ulm, 2004

CAN Bit Stuffing



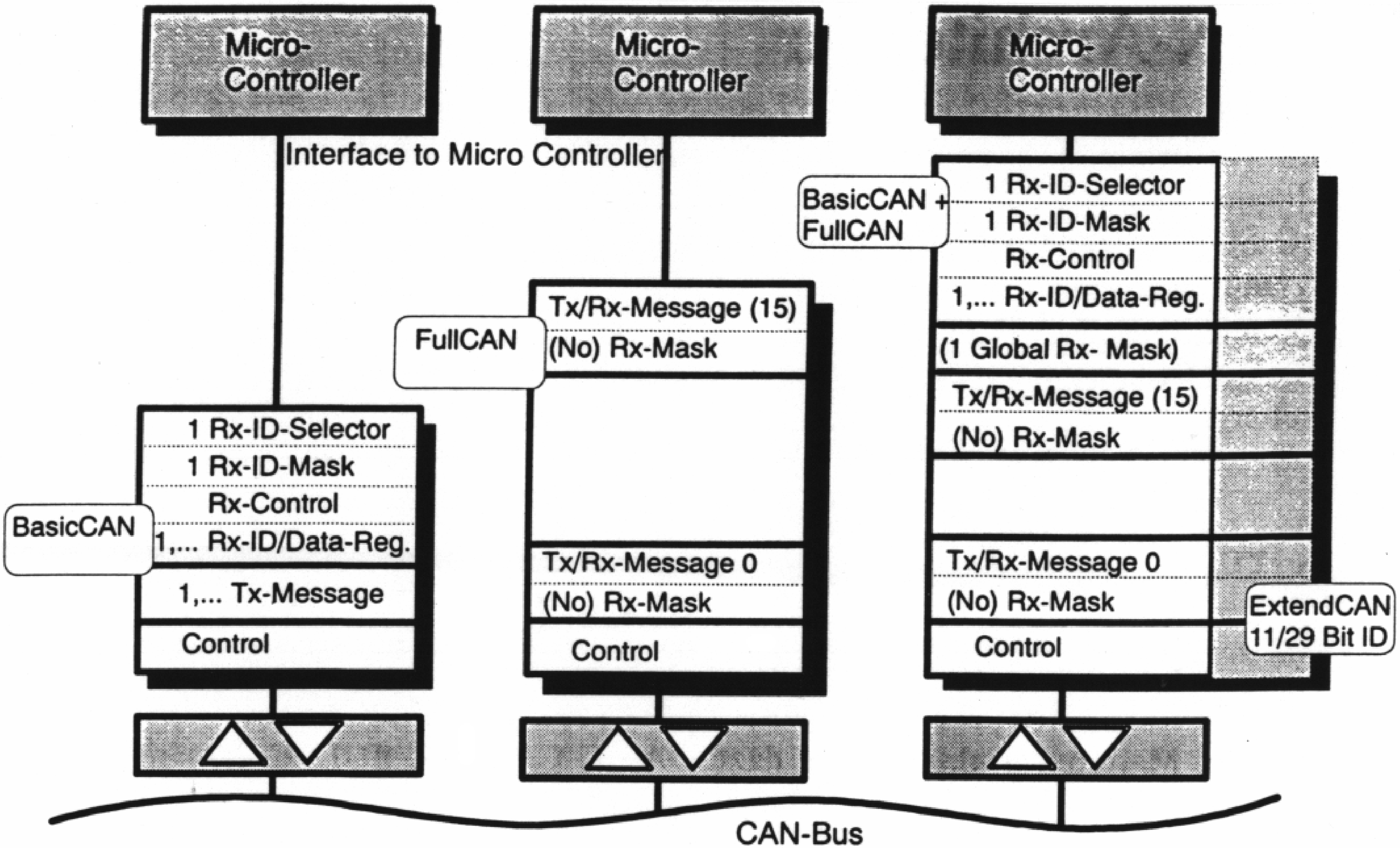
CAN Bit Timing



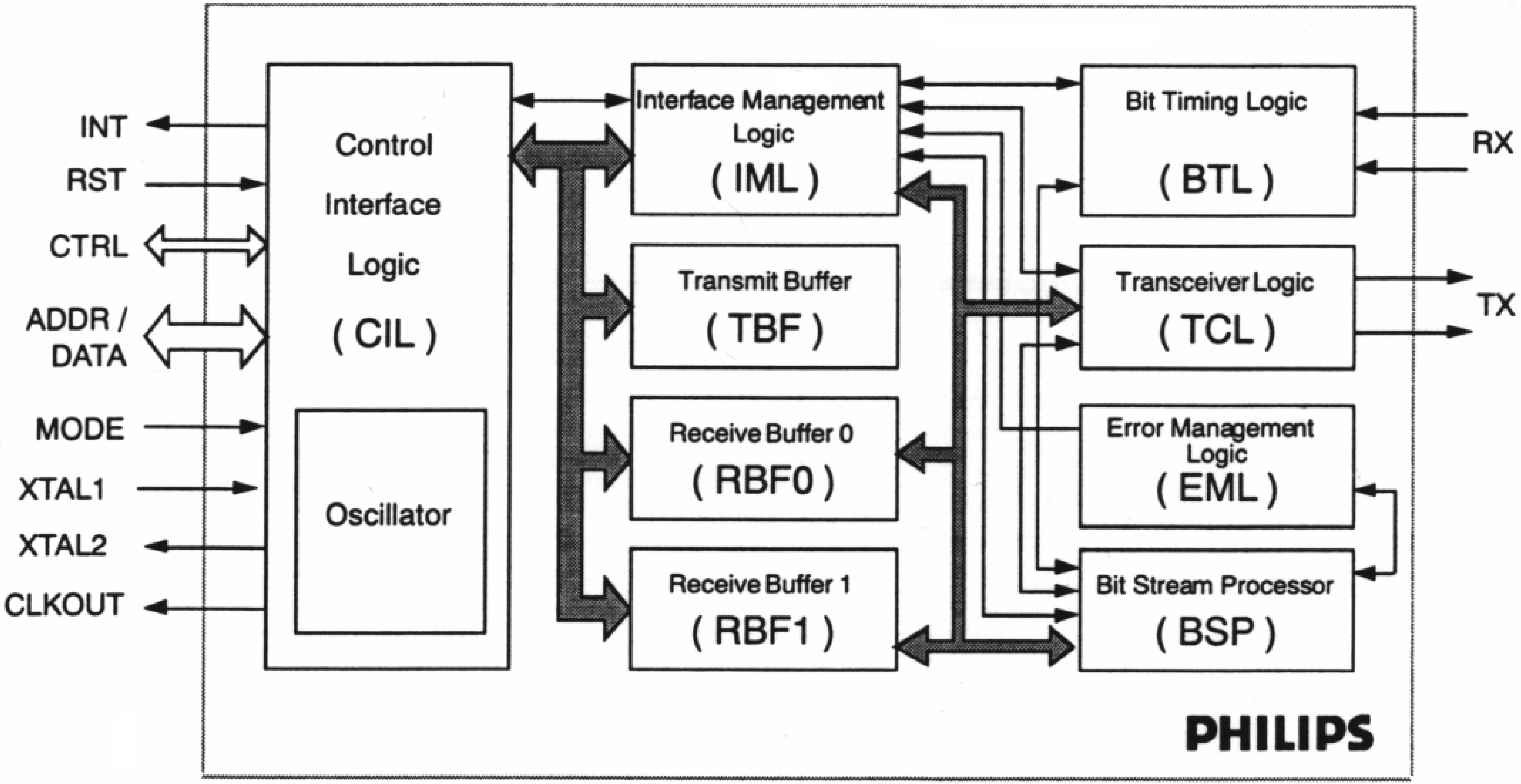
CAN Data Rates

Datenlänge	Nettodatenrate bei	
	Std. Frame	Ext. Frame
0	–	–
1	72,1 kBit/s	61,1 kBit/s
2	144,1 kBit/s	122,1 kBit/s
3	216,2 kBit/s	183,2 kBit/s
4	288,3 kBit/s	244,3 kBit/s
5	360,4 kBit/s	305,3 kBit/s
6	432,4 kBit/s	366,4 kBit/s
7	504,5 kBit/s	427,5 kBit/s
8	576,6 kBit/s	488,5 kBit/s

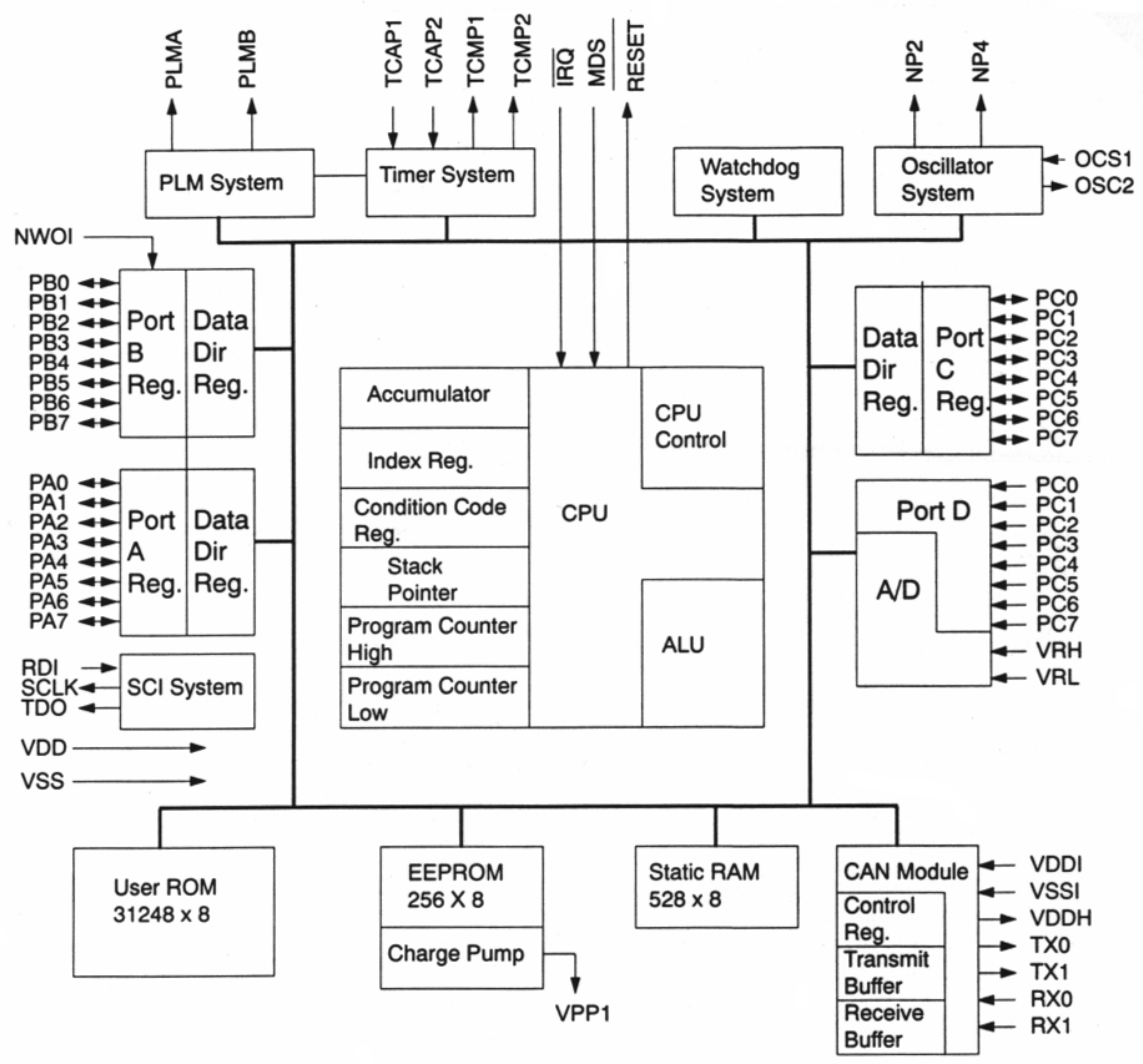
CAN Hardware: Basic- und Full-CAN



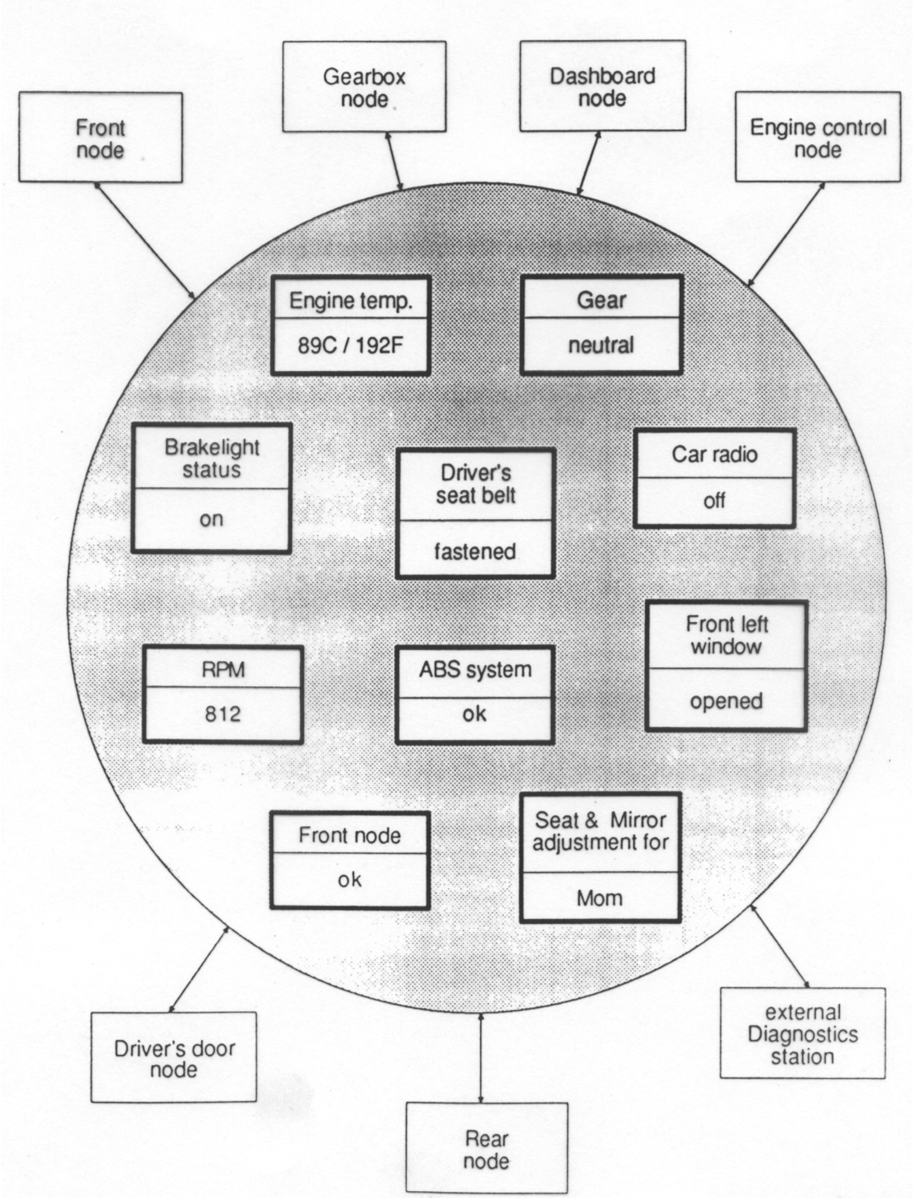
CAN Hardware: Basic-CAN-Controller 82C200



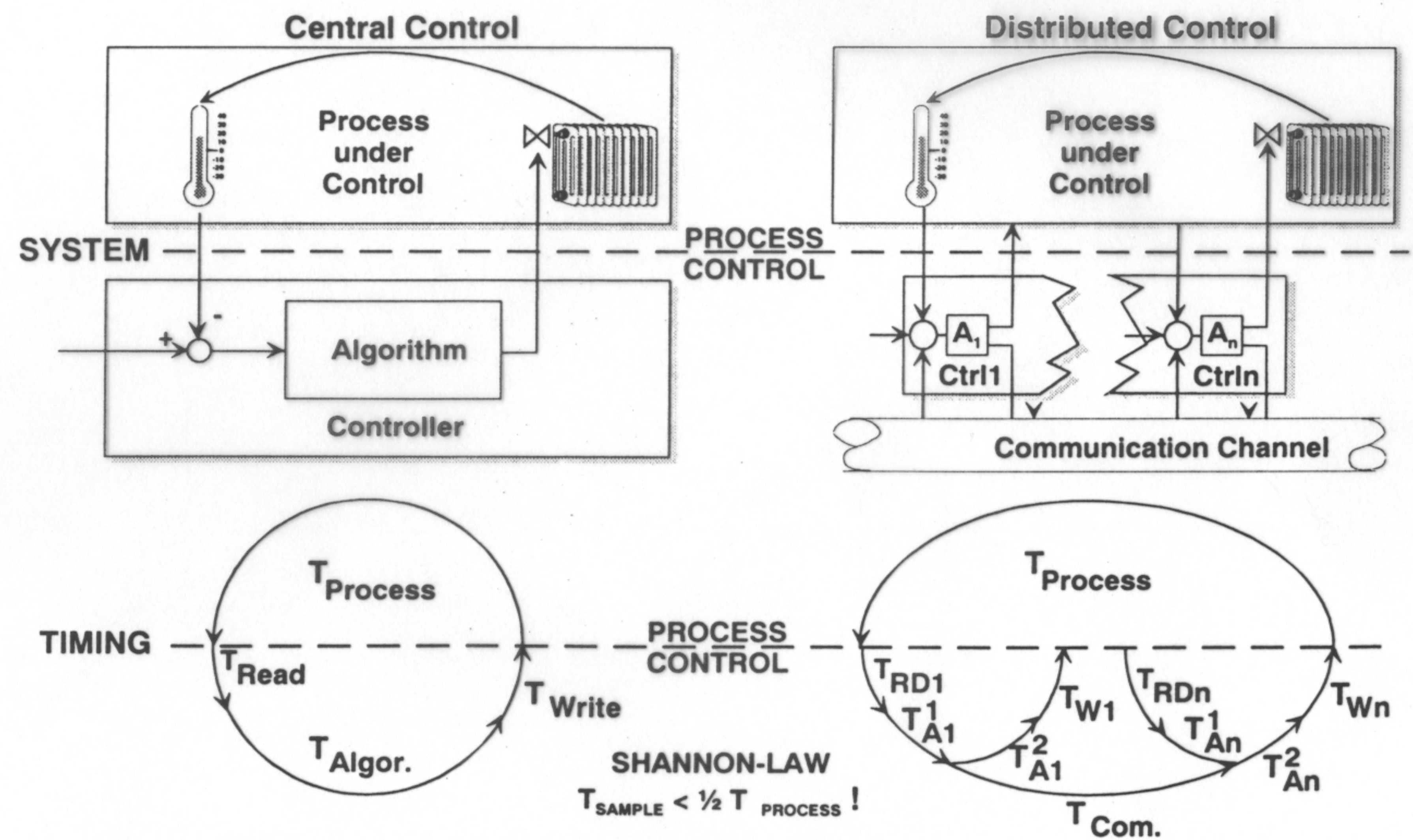
CAN Hardware: Full-CAN-Controller in C167 Microcontroller



Shared Memory Concept



Timing in distributed Systems



CAN vs. Ethernet 802.3

CAN Frame

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

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

802.3 Frame

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

64 Byte - 1526 Byte

Higher layer protocols on OSI layer 7

- CANopen
- OSEK / VDX (Offene Systeme und deren Schnittstellen für die Elektronik im Kraftfahrzeug / Vehicle Distributed eXecutive)
- DeviceNet
- CAN Kingdom

CANopen

- Object dictionary

Index (hex)	Object
0000	not used
0001-001F	Static Data Types
0020-003F	Complex Data Types
0040-005F	Manufacture Specific Data Types
0060-007F	Device Profile Specific Static Data Types
0080-009F	Device Profile Specific Complex Data Types
00A0-0FFF	Reserved for further use
1000-1FFF	Communication Profile Area
2000-5FFF	Manufacturer Specific Profile Area
6000-9FFF	Standardised Device Profile Area
A000-FFFF	Reserved for further use

- Master/Slave COB-IDs

Object	resultierende COB-IDs
NMT	0
GFC	1
SYNC	128
EMERGENCY	129-255
TIME STAMP	256
SRDO (tx)	257-320
SRDO (rx)	321-384
PDO1(tx)	385-511
PDO1(rx)	513-639
PDO2(tx)	641-767
PDO2(rx)	769-895
PDO3(tx)	897-1023
PDO3(rx)	1025-1151
PDO4(tx)	1153-1279
PDO4(rx)	1281-1407
SDO (tx)	1409-1535
SDO (rx)	1537-1663
NMT Error Control	1793-1919

CANopen

- Service Data Object (SDO)

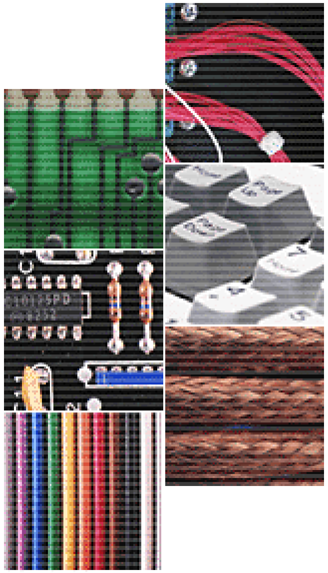
COB-ID	CS	Index (lsb msb)	Sub-Index	D	A	T	A

- Process Data Object (PDO)
  - Uses all 8 data bytes of a CAN message

Lecture

Computer Networks

PROFIBUS



Prof. Dr. H. P. Großmann

Dipl.-Ing. Andreas Schmeiser

Department of Information Resource Management

University of Ulm, Germany

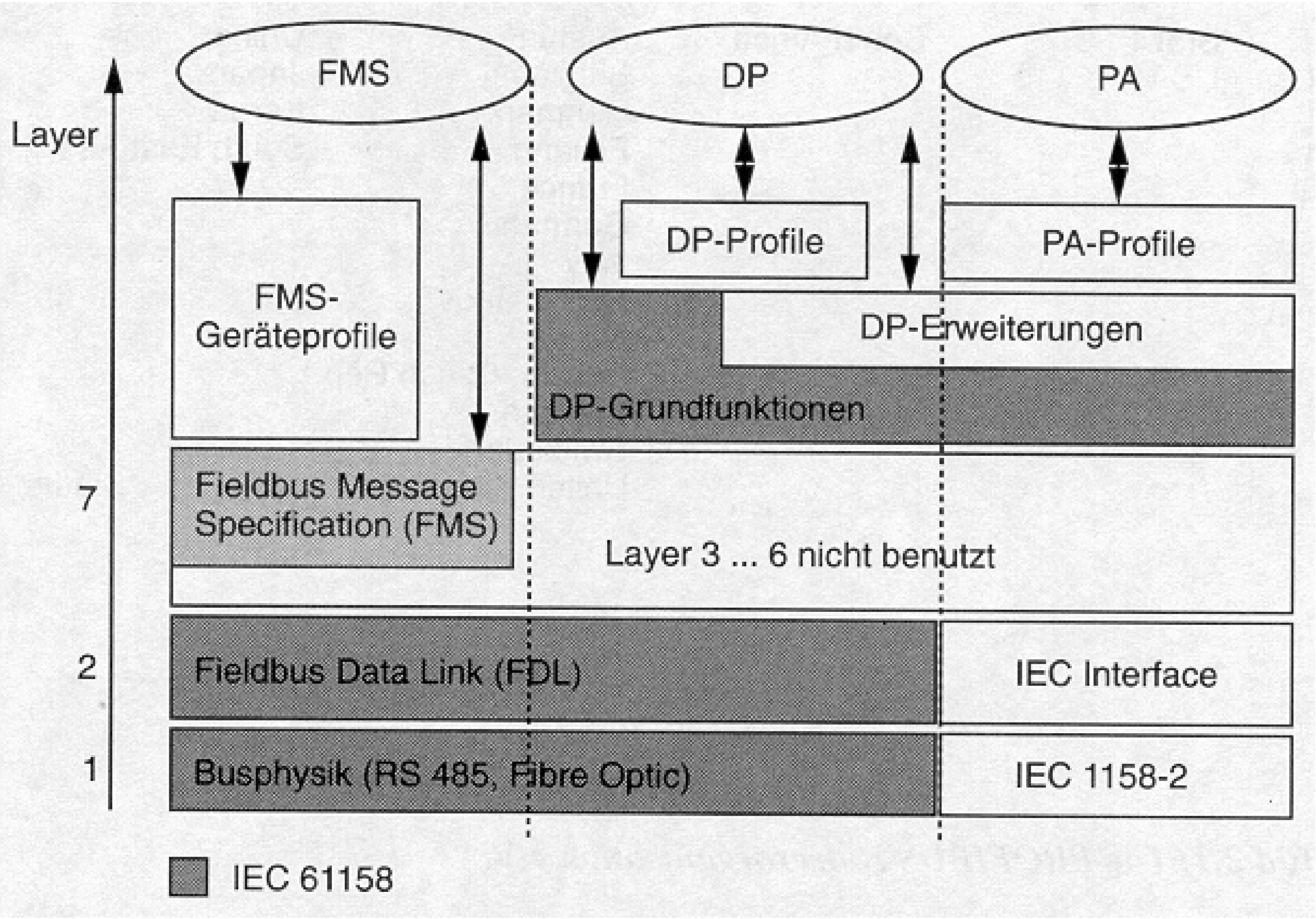
The 3 types of PROFIBUS according to IEC 61158

- PROFIBUS-FMS
  - FMS – Fieldbus Message Specification
  - Object oriented, universal exchange of data on process layer
- PROFIBUS-DP
  - DP – Dezentrale Peripherie
  - Fast exchange of data in the manufacturing area or facility management
- PROFIBUS-PA
  - PA – Process Automation
  - Suitable for explosive environment, for example chemical industry
  - Power supply over the bus,
    sensors/actors do not need separate power supply

PROFIBUS at a glance

- Number of nodes
  - max. 32 per segment
  - max. 126 in case of using repeaters
- Communication
  - serial
  - asynchronous
- Topology
  - line, bus
  - tree
- Length of bus lines
  (dependent on transfer rate)
  - 100 m at 3 … 12 MBit/s
  - 200 m at 1,5 MBit/s
  - 400 m at 500 kBit/s
  - 1200 m at 9,6 … 93,75 kBit/s
- User data per message
  - 1 ... 246 Bytes
- Bus access
  - master/slave
  - multi master by using a token

PROFIBUS at ISO OSI model



References

- Robert Bosch GmbH (1991): CAN Specification, Version 2.0, Stuttgart
- Lawrenz, W. (Hrsg.) (1994): CAN Controller Area Network, Grundlagen und Praxis, Hüthig, Heidelberg
- Zeltwanger, H. (Hrsg.) (2001): CANopen, VDE Verlag, Berlin
- CAN in Automation (CiA), http://www.can-cia.org
- DIN Deutsches Institut für Normung e. V. (Juli 1997): DIN EN 50170/2 – Universelles Feldkommunikationssystem (PROFIBUS), Berlin
- Popp, M. (2000): PROFIBUS-DP/DPV1, Grundlagen, Tipps und Tricks für Anwender, Hüthig, Heidelberg, 2. Auflage
- Kriesel, Werner R. / Madelung, Otto W. (1999): AS-Interface, Das Aktuator-Sensor-Interface für die Automation, Carl Hanser Verlag, München/Wien, 2. Auflage
- Dietrich / Kastner / Sauter (Hrsg.) (2000): EIB Gebäudebussystem, Hüthig, Heidelberg
- Rose, M. (1995): Gebäudesystemtechnik in Wohn- und Zweckbau mit dem EIB, Hüthig, Heidelberg, 2. Auflage