Communication Systems in Automobiles

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Outline

- Historical development of automobiles and the growing necessity of communication systems

- In-Car communication systems
  - Safety-Critical Systems
    - CAN, FlexRay
  - Auxilliary Systems
    - LIN
  - Infotainment Systems
    - MOST

- Car-2-Car and Car-2-Infrastructure communication systems
  - WIFI, Bluetooth, RFID

- Future prospects and outlook

Historical Development (i)

- First electric device in car
  - 1915: Ford includes electric lights in cars
- Electric schematic of VW Beetle fitted on 1 page
- First electronic circuit
  - ASIC (Application Specific Integrated Circuit) for wiper control
- Integration of Microcontrollers
  - 1980s
- Grouping of electronic components
  - Engine electronics, auxiliary systems

Historical Development (ii)

- Control of grouped electronic devices via Control Units (CUs)
- Control Units were linked via single wires that were bunched together in a cable harness
  - During 1980 an extrapolation foretold that in the beginning of 1990s the harness will consist of more then 4000 cables
  - high costs, high weight
- Bosch developed CAN (Controller Area Network)
  - Mid 1980s
  - Integrated in Mercedes production in early 1990s
- Vienna University of Technology developed TTP
  - 1980s, TTTech continued development and commercialization 1998

Historical Development (iii)

- Different applications have very different requirements
- LIN consortium (VW, BMW, Volvo, etc.) defined an open standard for automotive communication at low cost in 98/99
  - For applications where bandwidth and versatility of CAN is not needed
- MOST Cooperation started developing standard for interconnection of multimedia equipment in 1998
- ByteFlight was proposed for safety critical applications
  - Integrated in BMW 5, 6 and 7 series
    - Nowadays replaced by TTCAN and FlexRay

Historical Development (iv)

- In 2000 the development of FlexRay began driven by a consortium consisting of Daimler Chrysler, BMW, Phillips, etc.
  - FlexRay is told to be the next generation automotive network system
  - It was first integrated in 2005 in the BMW X5 suspension system

Reasons for the development of bus systems

- Guaranteed communication between different modules and control units with little wiring
- Easy update of software, during production and maintenance
- Easy integration of new/replaced components
- Increasing the reliability by means of redundancy
- Diagnostic tools, implementation of error log memory in Control Units
- Decreasing wiring and therefore costs and weight

Current challenges concerning also automotive bus systems

- Reduction of emissions – more influence in engine control
- Increasing active and passive safety
- Increasing driver assistance
- Replacement of mechanical systems by X-by-Wire systems
- Decreasing complexity of production (Hard- and Software) and programming despite increasing number of components

Choosing a bus system (i)

- Bandwidth
- Error Tolerance
- Number of nodes
- Real time capabilities
- Topology of wiring

Choosing a bus system (ii)

- Electromagnetic compatibility
- Electromagnetic radiation
- Voltage tolerances
- Temperature tolerances
- Reliability at high accelerations/decelerations

Choosing a bus system (iii)

- Costs of wiring
- Costs of components/nodes
- Costs of assembly
- Costs of diagnostics and maintenance

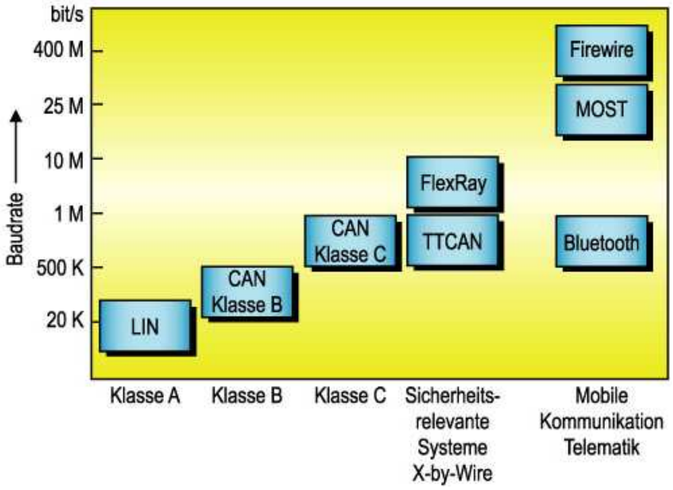
SAE – Classification of Bus systems (i)

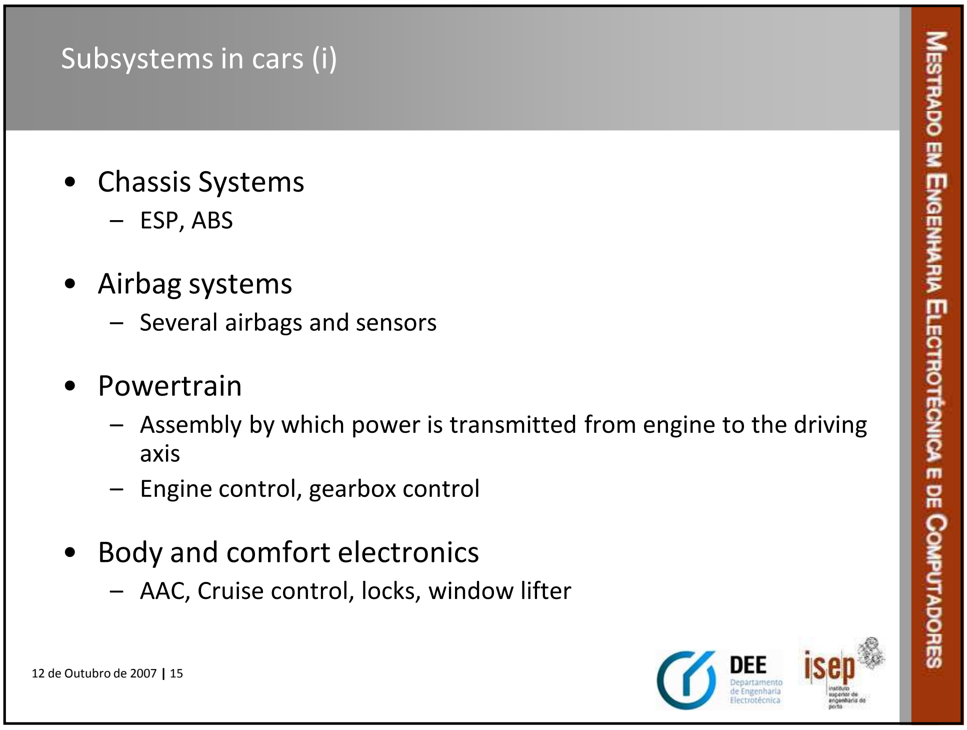
- Class A
  - Up to 10 kbit/s
  - Price per node: ~USD 4$
  - LIN, TTP/A, J1850
  - Class of Subbus systems
- Class B
  - 10 kbit/s to 100 kbit/s
  - Price per node: ~USD 5$
  - Safety relevant applications with error tolerance
  - Powertrain, Byteflight, TTCAN
  - Class of car body electronics

SAE – Classification of Bus systems (ii)

- Class C
  - 100 kbit/s and higher
  - Price per node: ~USD 10$
  - Distributed real time systems, Multimedia
  - MOST, D2B
  - Class of engine electronics
- Two additional differentiations
  - Safety critical systems
    - High redundancy, highly deterministic (FlexRay, TTCAN)
  - Mobile communication
    - High bandwidth for multimedia (MOST)

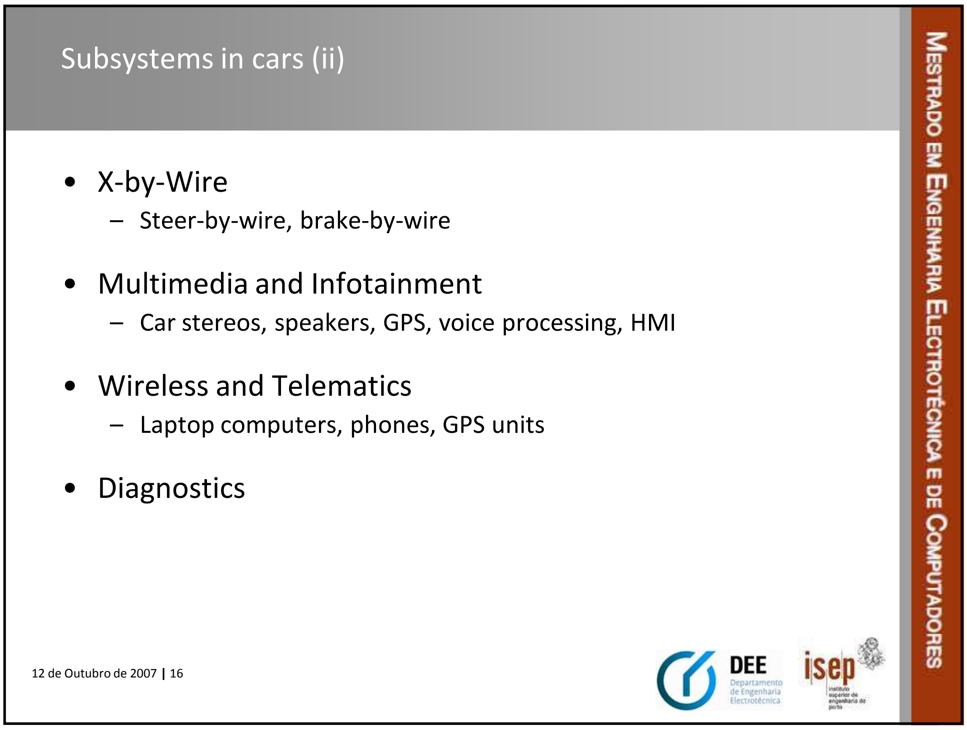
SAE – Classification of Bus systems (iii)





Subsystems in cars (i)

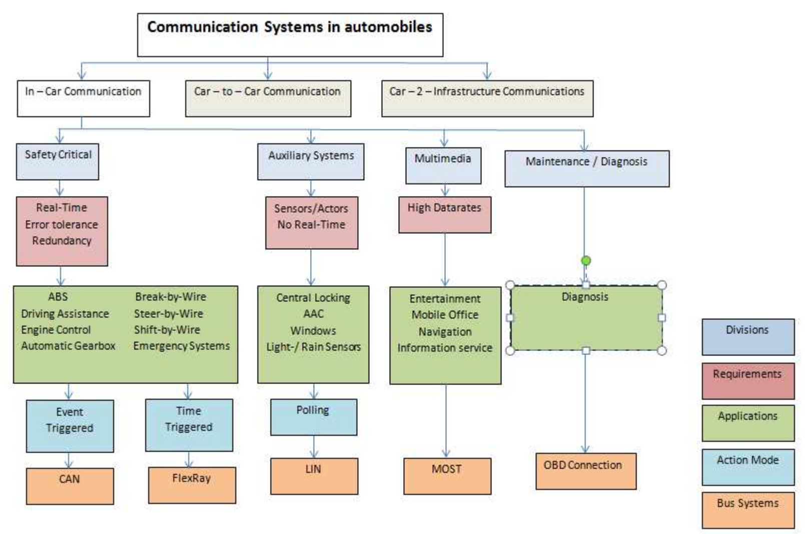
- Chassis Systems
  - ESP, ABS
- Airbag systems
  - Several airbags and sensors
- Powertrain
  - Assembly by which power is transmitted from engine to the driving axis
  - Engine control, gearbox control
- Body and comfort electronics
  - AAC, Cruise control, locks, window lifter



Subsystems in cars (ii)

- X-by-Wire
  - Steer-by-wire, brake-by-wire
- Multimedia and Infotainment
  - Car stereos, speakers, GPS, voice processing, HMI
- Wireless and Telematics
  - Laptop computers, phones, GPS units
- Diagnostics

Overview – In-Car-Communications



Communication Systems in automobiles

In – Car Communication

Car – to – Car Communication

Car – 2 – Infrastructure Communications

Safety Critical

Auxiliary Systems

Multimedia

Maintenance / Diagnosis

Real-Time
Error tolerance
Redundancy

Sensors/Actors
No Real-Time

High Datarates

ABS
Driving Assistance
Engine Control
Automatic Gearbox

Break-by-Wire
Steer-by-Wire
Shift-by-Wire
Emergency Systems

Central Locking
AAC
Windows
Light-/ Rain Sensors

Entertainment
Mobile Office
Navigation
Information service

Diagnosis

Event Triggered

Time Triggered

Polling

CAN

FlexRay

LIN

MOST

OBD Connection

Divisions

Requirements

Applications

Action Mode

Bus Systems

CAN – “Philosophy”

- If a module has information that is needed in a system, it makes it available via the CAN bus
- All nodes will have identical information
- Receiving nodes will store all needed data
- A “global database” where all nodes have the same information
- Source and destination of information is of no importance

CAN – General Information

- History
  - 1981 by Bosch and Intel
  - Since 1990s more and more common in automotive systems
  - Additionally used in industry automation, elevators etc.
  - CAN is standardized in ISO 11898 and specifies the two bottom layers of the ISO OSI Model (Physical Layer and Data Link Layer)
- Characteristics
  - Data rates of 10 kbit/s to 1Mbit/s (theoretical value) and length of 1 km
  - Physical medium is Twisted Pair (also single wire if dysfunction)
  - Multi-Master bus system
  - Transmission is event-triggered
  - Every node “hears” every message

CAN – Communication (i)

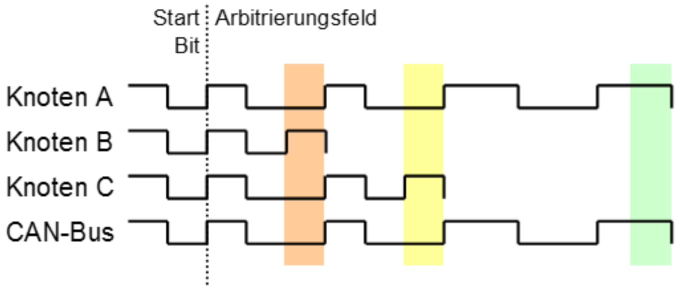
- Bit Levels
  - Dominant (Bit 0)
  - Recessive (Bit 1)
- Frames
  - Data Frame
    - Sending data
  - Remote Frame
    - Requesting data
  - Error Frame
    - Data error
  - Overload Frame
    - Protocol error

CAN – Communication (ii) – Frame Layout

Bits	Name	Description
1	Start of Frame	Marks the beginning of a frame via a dominant bit
12	Arbitration Field	11 bit identifier and 1 RTR bit. The identifier is used for deciding whether a message shall be accepted by a node. Furthermore the identifier implments a prioritisation. The RTR bit marks a data frame (dominant) or a remote frame.
6	Control Field	4 bits to define length of following data field.
0 .. 64	Data Field	Actual data. For remote frames data field length is 0.
16	CRC Field	15 bit checksum and 1 bit CRC delimiter
2	ACK Field	Used for acknowledging the received data.
7	End of Frame	7 rezessive bits.

CAN – Communication (iii) – Bit Arbitration

- When bus is free,
  - Each node can send – Collisions can occur
  - Dominant bits overwrite recessive bits → Prioritisation is implicitely dependent on identifier
  - Advantages: no capacity is lost, prioritisation
  - Disadvantages: frames with low priority have to wait long



CAN – Communication (iv) – Error Detection

- CRC
  - Checksum is sent with each frame. Receiver calculates new checksum and compares it with received checksum
- Frame Check
  - Length and structure of Frame are checked
- ACK Error
  - Sender does not receive ACK of receiver
- Bit stuffing
  - Only for Data, and remote frames. After every 5th bit of same value a complementary bit is “stuffed” at the sender and deleted at the receiver

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CAN – Communication (v) – Error Detection

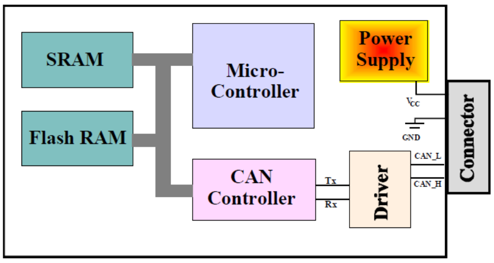
- To ensure the use of CAN also in areas with high electromagnetic influences
  - If error is detected, error flag is sent
    - New transmission is initialized
    - Use of erroneous frame by other nodes is avoided
- In worst case CAN can even disable erroneous control units

CAN – Nodes (i)

- Host processor (Micro Controller)
  - The host processor decides what received messages mean and which messages it wants to transmit itself.
  - Sensors, actuators and control devices can be connected to the host processor.
- CAN Controller
  - *Receiving*: the CAN controller stores received bits serially from the bus until an entire message is available, which can then be fetched by the host processor (usually after the CAN controller has triggered an interrupt).
  - *Sending*: the host processor stores its transmit messages to a CAN controller, which transmits the bits serially onto the bus.

CAN – Nodes (ii)

- Transceiver (can also be integrated in CAN Controller)
  - *Receiving*: it adapts signal levels from the bus to levels that the CAN controller expects and has protective circuitry that protects the CAN controller.
  - *Sending*: it converts the transmit-bit signal received from the CAN controller into a signal that is sent onto the bus.



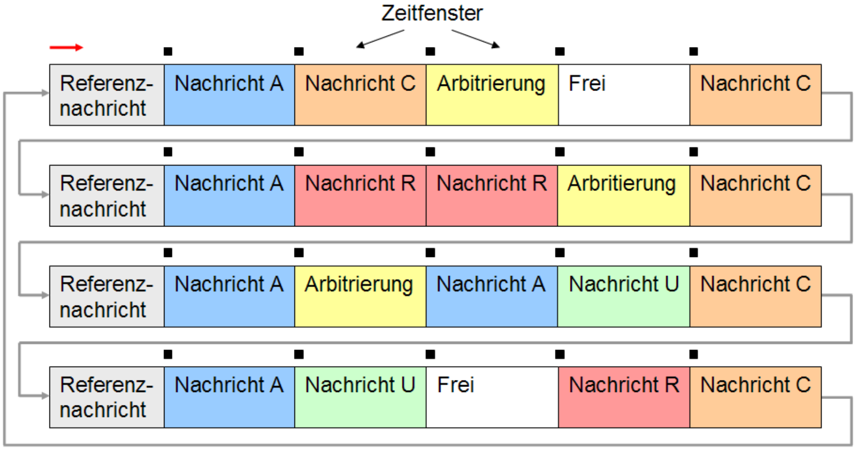
CAN – ID Filtering

- All CAN controllers will receive all frames
  - Decision, whether frame is useful or not
  - Most commonly using ID filtering hardware
- Filter Masking
  - Must-match/Don't-care Masks
  - CAN Controller interrupts the CPU only if ID matches mask:
    XXXXXXXX1001
- Choosing IDs for frames with a priori information
  - Allows to select filter bits for filter masking

Time Triggered CAN (i)

- CAN is not completely deterministic because of event triggered communication
- Time triggered communication is deterministic and suits better for safety relevant systems
- TTCAN is based on CAN protocol but uses a system matrix to define time slots and synchronization points
- Need for time master (redundantly integrated in bus system)
- Each node saves the relevant timing information
  - Support of additional timeslots
  - Support of integration of common CAN (with bitwise arbitration)

Time Triggered CAN (ii)



Zeitfenster

Referenz-nachricht	Nachricht A	Nachricht C	Arbitrierung	Frei	Nachricht C
Referenz-nachricht	Nachricht A	Nachricht R	Nachricht R	Arbritierung	Nachricht C
Referenz-nachricht	Nachricht A	Arbitrierung	Nachricht A	Nachricht U	Nachricht C
Referenz-nachricht	Nachricht A	Nachricht U	Frei	Nachricht R	Nachricht C

FlexRay – Challenges

FlexRay – Principles

- Provide a communication infrastructure for future generation high speed control applications in vehicles.
- Provide architectural flexibility as key enabler to serve the diverse requirements ranging from flexible to restrictive
  - Provide functional alternatives within one conceptual framework
    - Reuse of understanding, tools, concepts, system architectures for different applications
- Provide architecture level support for the integration process to address migration over different platforms

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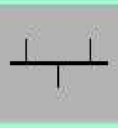
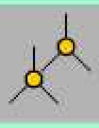
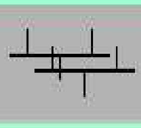
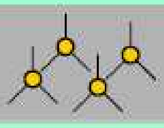
FlexRay – General Information

- History
  - Development started in 1998/99 initiated by BMW, DaimlerChrysler
  - Designed to be communication system of the future
    - E.g. X-by-Wire Applications
  - Main requirements were higher data rates, deterministic communication, high error tolerance and high flexibility
- Characteristics
  - Configurable synchronous and asynchronous transmission with bandwidths of 10 Mbit/s
  - FlexRay does not specify a Physical Layer (electrical AND optical medias)
  - Support of different topologies
  - Global timing for synchronous transfer and deterministic behaviour

FlexRay – Topologies (i)

	Bus	Multiple star	
Single channel			reduced wire-harness, experience, cost
Dual channel			tolerates one faulty channel
	passive medium, most experience, cost efficient	allows for high data rates, increases error containment	Electrical & optical physical layer

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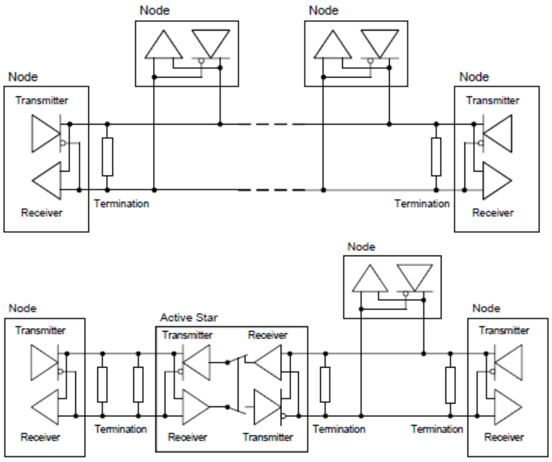
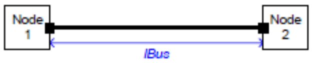
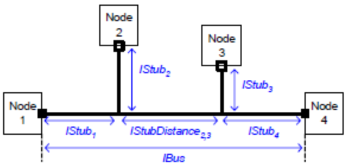
FlexRay – Topologies (ii)



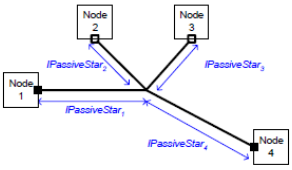
FlexRay – Topologies (iii)



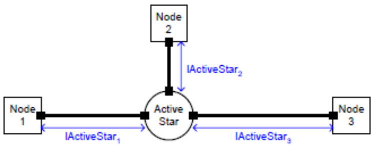


Name	Description	Min	Max	Unit
lBus	Maximum electrical distance between two nodes in the system		24	m
lStubDistance$_{M,N}$	Distance between two network splices (*)	150		mm
nStubNodes	Number of stub nodes		22	

FlexRay – Topologies (iv)

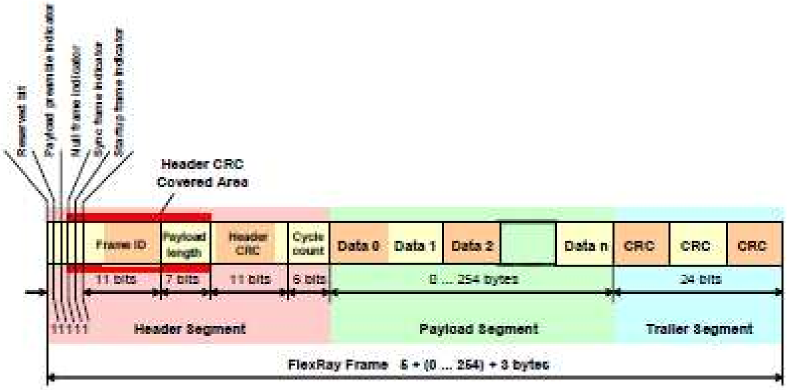


Name	Description	Min	Max	Unit
lPassiveStar$_N$+lPassiveStar$_M$	Maximum electrical distance between two nodes in the system		24	m
nStarNodes	Maximum number of nodes in a passive star network.		22	

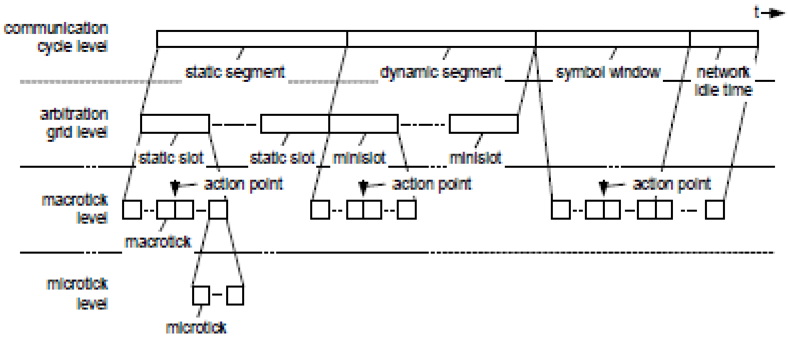


Name	Description	Min	Max	Unit
lActiveStar$_N$	Length of a branch from node N to the star		24	m
nActiveBranches	Number of branches at an active star	2		-

FlexRay – Communication (i) – Frame Format

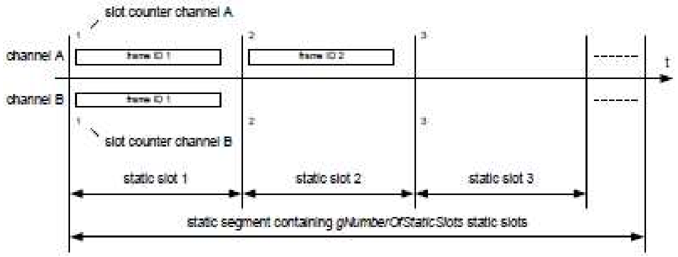


FlexRay – Communication (ii) – Communication Cycle



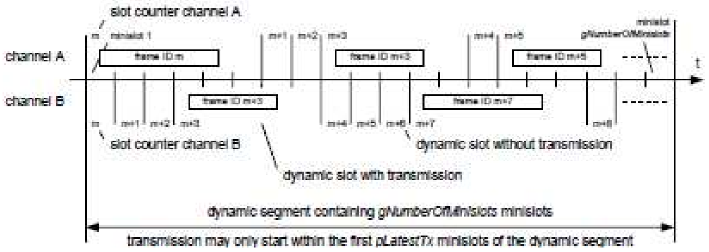
FlexRay – Communication (iii) – Static Segments

- Static Time division multiple access scheme
- All communication slots are of equal, statistically configured duration, and all frames are of equal length.
- To schedule transmissions each node requires a slot counter



FlexRay – Communication (iv) – Dynamic Segments

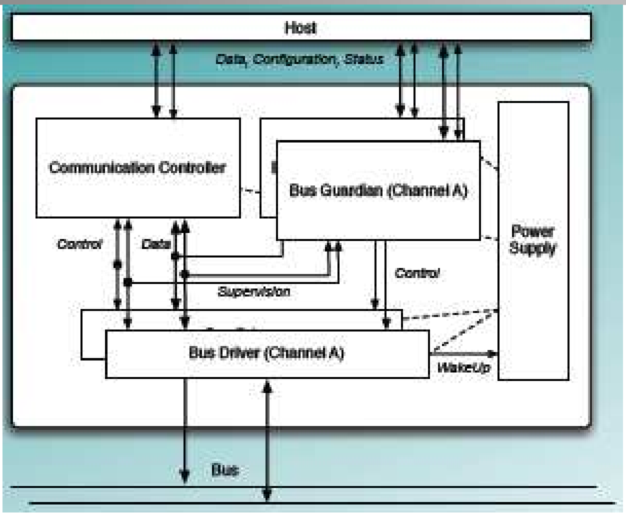
- Dynamic mini-slotting based scheme
- Duration of communication slots may vary in order to accommodate frames of varying lengths



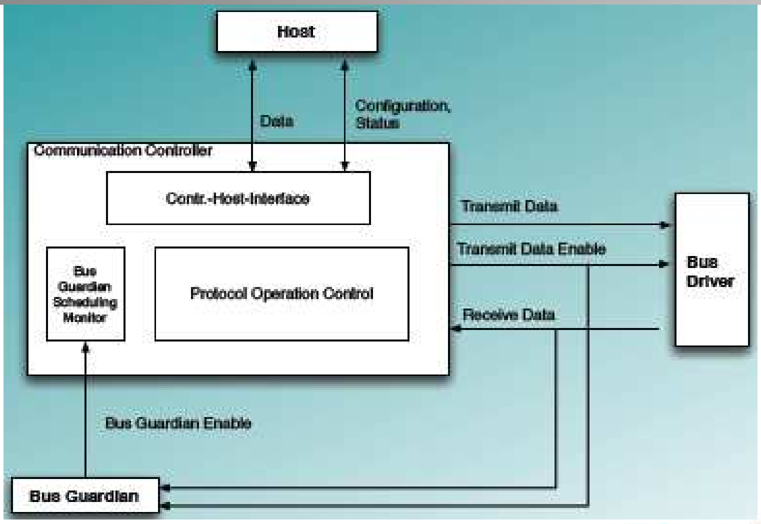
FlexRay – Communication (iv) – Synchronisation

- To ensure that the time differences between nodes stay within a specified precision.
- Two types of differences
  - Offset (Phase)
  - Rate (Frequency)
- FlexRay uses combination of methods to correct Offset and Rate
  - Offset correction is done during Network Idle Time
  - Rate correction is performed over the entire cycle

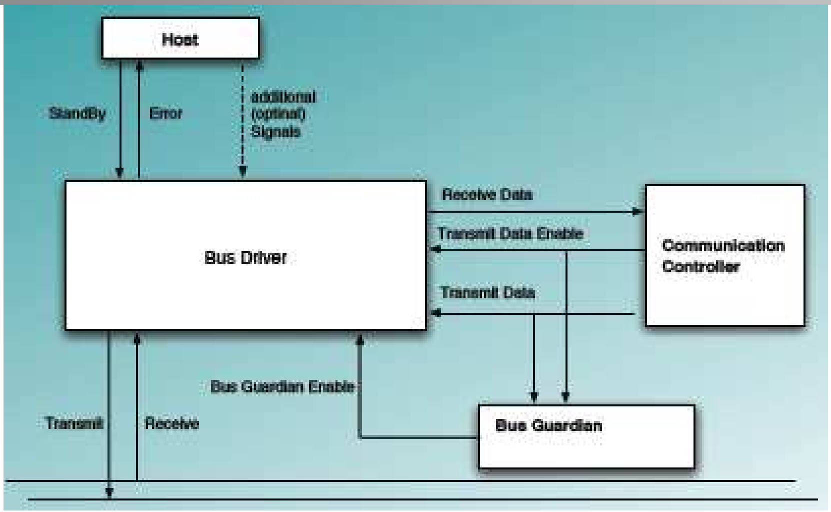
FlexRay – Nodes (i) – General



FlexRay – Nodes (ii) – Communication Controller



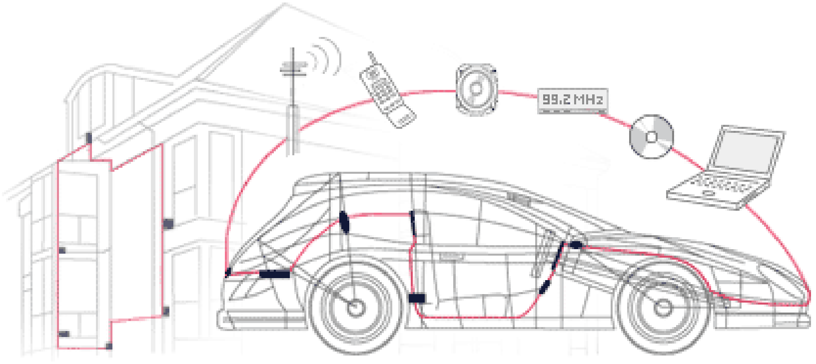
FlexRay – Nodes (iii) – Bus Driver



FlexRay – Nodes (iv) – Further Components

- Bus Guardian
  - Local Bus Guardian
    - Same functionality as CC with its own clock synchronisation
    - Supervises transmission from CC to Bus Driver
    - If error occurs it sends a stop signal to Bus Driver and a Error message to CC and Host
  - Central Bus Guardian
    - Separate device on bus
    - Analyses all messages (can also act as a repeater)
    - Supervises scheduling
    - Filters unscheduled messages

MOST



Media Oriented Systems Transport

MOST – General Information

- Media Oriented Systems Transport (MOST)
- History
  - Developed since 1998 by MOST Cooperation (BMW, DaimlerChrysler)
- Application field
  - Multimedia Applications: Audio, Video, Navigation, Telecommunication
- High Bandwidth at low cost

MOST – Principles

- Function oriented high-speed multimedia technology to network a variety of devices
- Defines mechanisms for sending Streaming Data and packet-based data
- Supports different speed grades and physical layers
- MOST is a network that has mechanisms to transport all the various signals and data streams that occur in multimedia and infotainment systems

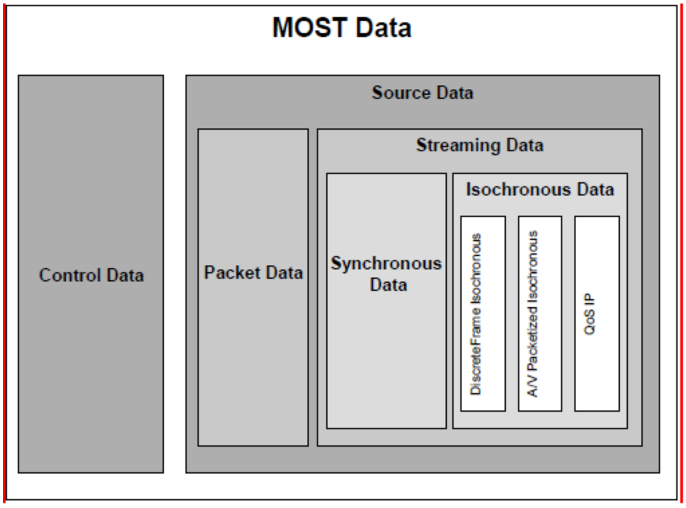
MOST – Characteristics

- Up to 64 nodes
- Up to 24.8 Mb/s
- No basic topology but usually implemented as Ring
- Optical and electrical network supported
- Streaming Data and Packet-based Data

MOST – Communication (i) – Data Transport mechanisms

- Control Channel
  - Control messages transported to specific addresses
  - Event-oriented transmissions at low bandwidth
- Streaming Data
  - Continuous data streams that demand high bandwidth and synchronized transmission
- Packet Data Channel
  - Specified for transmissions requiring high bandwidth in a burst-like manner
  - Mainly for data with large block size (graphics, navigation maps)

MOST – Communication (ii) – Data Transport mechanisms



MOST Data

Control Data

Source Data

Packet Data

Streaming Data

Synchronous Data

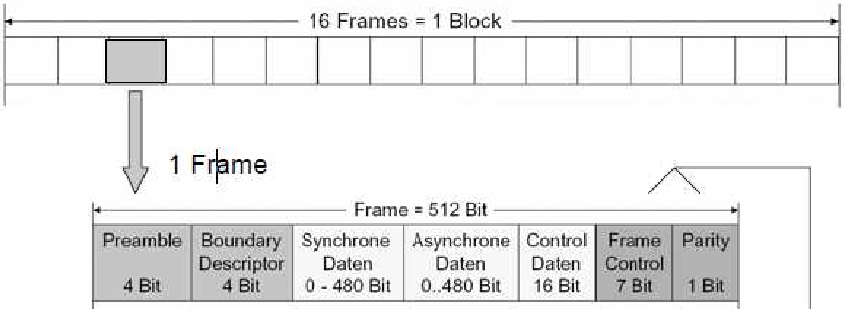
Isochronous Data

DiscreteFrame Isochronous

A/V Packetized Isochronous

QoS IP

MOST – Communication (iii) – Frame Format



16 Frames = 1 Block

1 Frame

Frame = 512 Bit

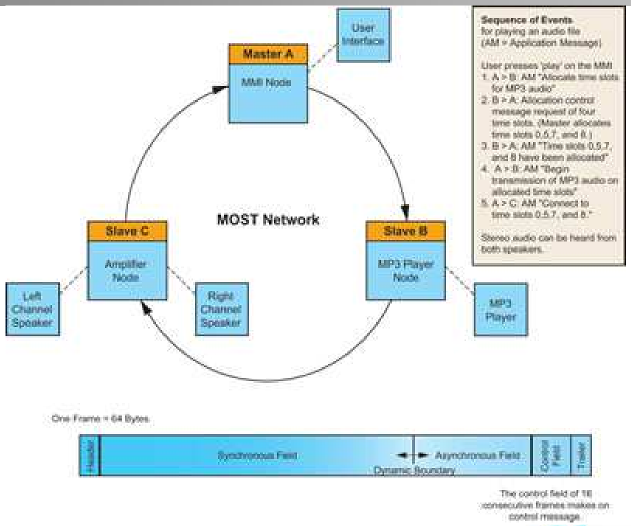
Preamble	Boundary Descriptor	Synchrone Daten	Asynchrone Daten	Control Daten	Frame Control	Parity
4 Bit	4 Bit	0 - 480 Bit	0..480 Bit	16 Bit	7 Bit	1 Bit

MOST – Communication (iv) – Frame Format

- Synchronous area
  - Real time audio-/ video stream data
  - Sender allocates a channel with max. 60 bytes/Frame
- Asynchronous area
  - Special message format
  - Message can be divided over more frames
  - „alternative data link layer“ supports much higher data lengths

Bits	Name
8	Arbitration
16	Target Address
8	Length
16	Source Address
0..384	Data Area
32	CRC

MOST – Topology



Sequence of Events
for playing an audio file
(AM = Application Message)

User presses 'play' on the MMI
1. A > B: AM "Allocate time slots for MP3 audio"
2. B > A: Allocation control message request of four time slots. (Master allocates time slots 0,5,7, and 8.)
3. B > A: AM "Time slots 0,5,7, and 8 have been allocated"
4. A > B: AM "Begin transmission of MP3 audio on allocated time slots"
5. A > C: AM "Connect to time slots 0,5,7, and 8."

Stereo audio can be heard from both speakers.

The control field of 16 consecutive frames makes on control message

MOST – Error Management

- Performed by MOST System Services
- Functionblocks for error managment at application layer
- If an error occurs, nodes can be checked remotely
- In case of node failures, nodes can be excluded from the network
- Others
  - Parity, Status Flags, CRC checksums and ACK-Flags

LIN – General Information

- History
  - First developments in 1998 by BMW, Audi, VW etc.
  - Goal to design a bussystem that is a much cheaper solution for simpler applications within the car
  - In 2000 Version 1 was presented and in 2001 included in mass production by DaimlerChrysler
- Characteristics
  - SingleMaster /MultipleSlave concept
  - Cheap implementation of Hard and Software
  - Deterministic signal transmission
  - Data rate of 20kbit/s
  - Maximum number of nodes: 16

LIN - Topology

- 1 Master and multiple Slaves define a Subbus that can be connected via a Gateway to a „higher“ bus
- Exact Topology is not specified, but a maximum capacity is defined
- Usually bus topology is used and the nodes are connectd via single wires

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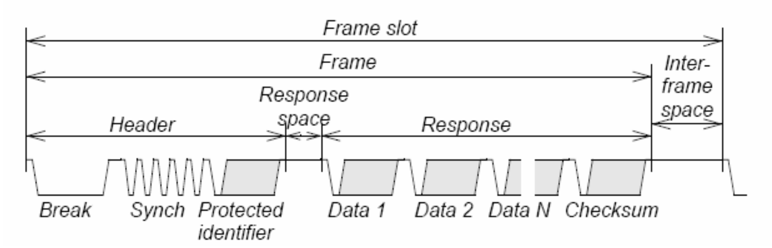
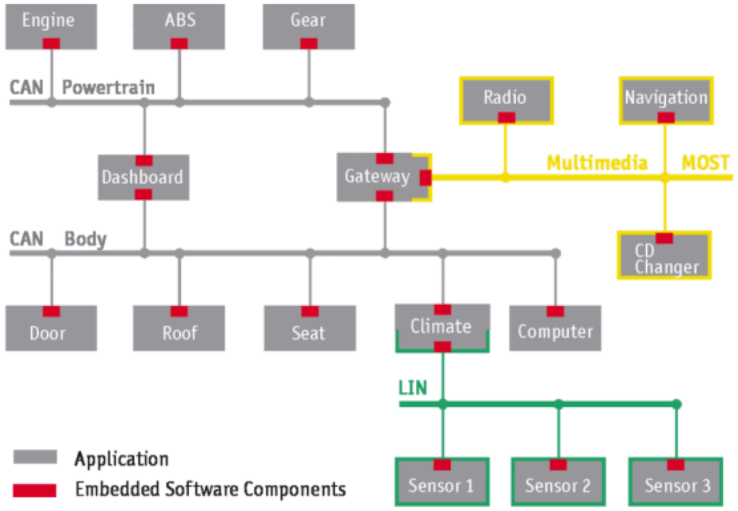
LIN – Communication (i) – Frame Format



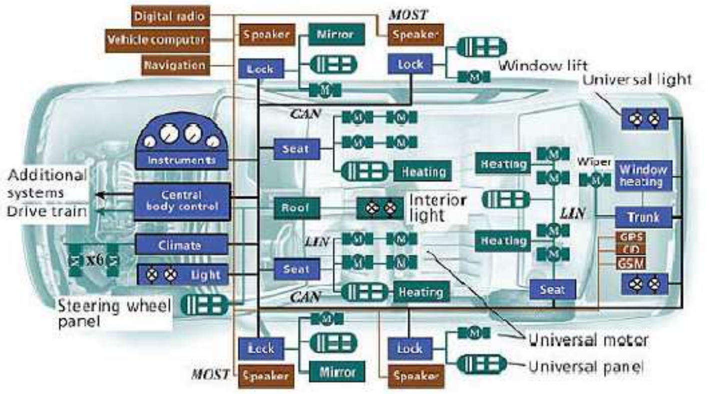
LIN – Communication (ii) – Basic Communication

- Complete communication is initiated by Master
- Master possesses LIN Description File (LDF)
  - Timeslots, Schedule, Identifier etc.
  - Allows deterministic transmission
- Header of Frame is always sent by Master, one or more slaves can reply
  - Master requests data of one or more slaves
  - Master sends control messages to one or more slaves
  - Master initiates communication between slaves

Connecting Networks (i)



Connecting Networks (ii)

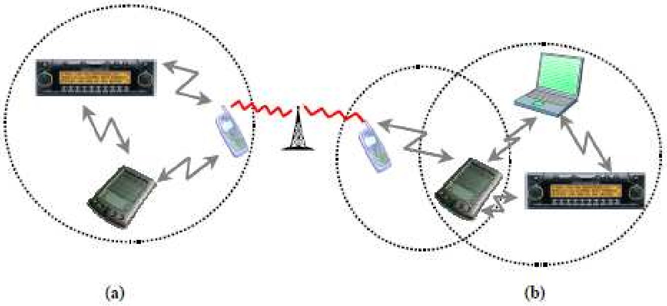


CAN	Controller Area Network
GPS	Global Positioning System
GSM	Global System for Mobile Communications
LIN	Local Interconnect Network
MOST	Media-oriented Systems Transport

■ CAN
▨ LIN
▨ MOST

Wireless Communications in Cars (i)

- Allowing communications with surrounding devices
  - Mobile phones
  - Laptops
- Recent applications in car-2-car and car-2-infrastructure


(a)

(b)

Wireless Communications in Cars (ii)

- Two alternatives
  - Infrastructure based networks
  - Ad-hoc networks
- Infrastructure based network
  - Access point has to be set up within the car
  - Each device is connected to the AP and can exchange data only via the AP
  - E.g. IEEE 802.11
- Ad-hoc network
  - Do not rely on infrastructure
  - Mobile devices organize network themselves
  - E.g. Bluetooth

Wireless Communications in Cars (iv) – Bluetooth (i)

- IEEE 802.15.1
- Personal network of low cost, low power and low range
- 1999 Car Working Group by the Bluetooth Special Interest Group
- Main priority was to develop a hands free profile
- Products that use Bluetooth technology can automatically connect to car network and are controllable via main display in car

Wireless Communications in Cars (v) – Bluetooth (ii)

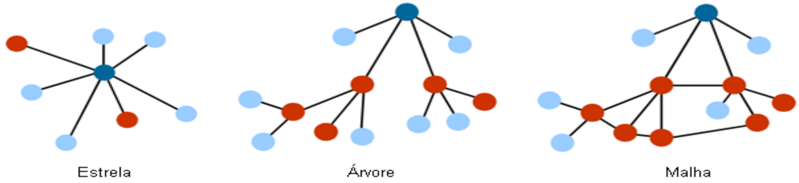
- Advantages
  - Adapts power consumption according to network usage
  - Creates automatically PAN network (Personal Area network) when other device comes in reach
- Secure wireless connection
  - Frequency hopping so that communication can not be intercepted
  - 128-bit encryption

Wireless Communications in Cars (vi) – ZigBee (i)

- IEEE 802.15.4
- Wireless network with low cost and low power consumption
- Suited to meet requirements of sensors and control devices
- Usually used for control and monitoring applications that don’t need high bandwidths
  - Also many proprietary systems but not standardized (interconnection with other networks in car)
- Speeds up to 250kb/s
- Applications in cars: sensors, monitoring and control (AC, lights, etc.)

Wireless Communications in Cars (vii) – ZigBee (ii) - Topology

- Components
  - ZigBee Coordinator
    - Able to create network
    - Stores information of network
  - ZigBee Router
    - Routes data between devices
  - ZigBee End Device
    - Can only exchange information with its parent node



Wireless Communications in Cars (viii) – ZigBee (iii)

- Operates in ISM bands (free bands)
  - 2.4 GHz, 915 MHz, 868 MHz
- Speeds between 10kb/s up to 115kb/s
- Ranges from 10m to 100m
- Large number of devices is allowed
- Simple protocol that allows reliable transfer of data with appropriate levels of security

Wireless Communications in Cars (vi) - WiFi

- IEEE 802.11
- Car2Car Consortium
- Connect devices ad-hoc or providing an access point within cars but also for communication to the cars environment
  - Establishing connection to other cars or infrastructure to get or send information

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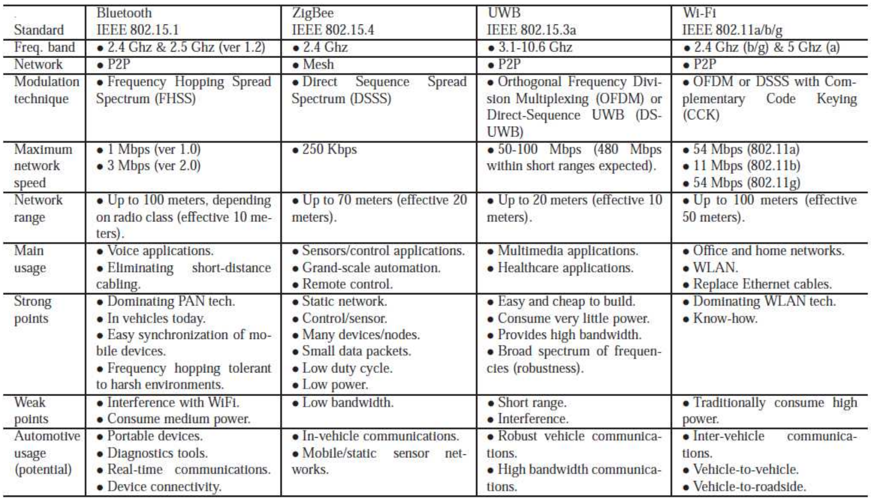
Summary of Wireless Communication Standards



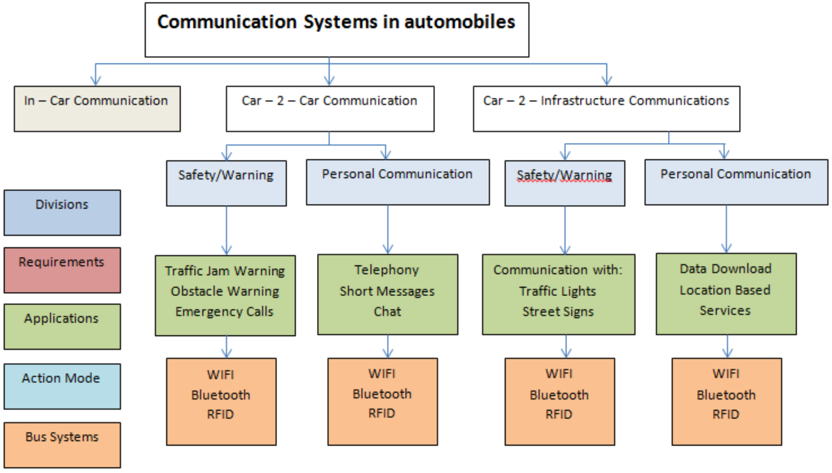
Standard	Bluetooth IEEE 802.15.1	ZigBee IEEE 802.15.4	UWB IEEE 802.15.3a	Wi-Fi IEEE 802.11a/b/g
Freq. band	• 2.4 Ghz & 2.5 Ghz (ver 1.2)	• 2.4 Ghz	• 3.1-10.6 Ghz	• 2.4 Ghz (b/g) & 5 Ghz (a)
Network	• P2P	• Mesh	• P2P	• P2P
Modulation technique	• Frequency Hopping Spread Spectrum (FHSS)	• Direct Sequence Spread Spectrum (DSSS)	• Orthogonal Frequency Division Multiplexing (OFDM) or Direct-Sequence UWB (DS-UWB)	• OFDM or DSSS with Complementary Code Keying (CCK)
Maximum network speed	• 1 Mbps (ver 1.0) • 3 Mbps (ver 2.0)	• 250 Kbps	• 50-100 Mbps (480 Mbps within short ranges expected).	• 54 Mbps (802.11a) • 11 Mbps (802.11b) • 54 Mbps (802.11g)
Network range	• Up to 100 meters, depending on radio class (effective 10 meters).	• Up to 70 meters (effective 20 meters).	• Up to 20 meters (effective 10 meters).	• Up to 100 meters (effective 50 meters).
Main usage	• Voice applications. • Eliminating short-distance cabling.	• Sensors/control applications. • Grand-scale automation. • Remote control.	• Multimedia applications. • Healthcare applications.	• Office and home networks. • WLAN. • Replace Ethernet cables.
Strong points	• Dominating PAN tech. • In vehicles today. • Easy synchronization of mobile devices. • Frequency hopping tolerant to harsh environments.	• Static network. • Control/sensor. • Many devices/nodes. • Small data packets. • Low duty cycle. • Low power.	• Easy and cheap to build. • Consume very little power. • Provides high bandwidth. • Broad spectrum of frequencies (robustness).	• Dominating WLAN tech. • Know-how.
Weak points	• Interference with WiFi. • Consume medium power.	• Low bandwidth.	• Short range. • Interference.	• Traditionally consume high power.
Automotive usage (potential)	• Portable devices. • Diagnostics tools. • Real-time communications. • Device connectivity.	• In-vehicle communications. • Mobile/static sensor networks.	• Robust vehicle communications. • High bandwidth communications.	• Inter-vehicle communications. • Vehicle-to-vehicle. • Vehicle-to-roadside.

On-Board Diagnosis

- Vehicle diagnosis system
- Supervises control devices
- Errors are indicated by control lamps and are saved in control unit
- Error codes can be downloaded via specified connection in the garage
  - Normed interface
  - Serial interface
  - CAN

- Codes are normed in ISO 15031-6

Overview – Car 2 Car and Car 2 Infrastructure Communication



Communication Systems in automobiles

In – Car Communication

Car – 2 – Car Communication

Car – 2 – Infrastructure Communications

Safety/Warning

Personal Communication

Safety/Warning

Personal Communication

Traffic Jam Warning
Obstacle Warning
Emergency Calls

Telephony
Short Messages
Chat

Communication with:
Traffic Lights
Street Signs

Data Download
Location Based
Services

WIFI
Bluetooth
RFID

WIFI
Bluetooth
RFID

WIFI
Bluetooth
RFID

WIFI
Bluetooth
RFID

Divisions

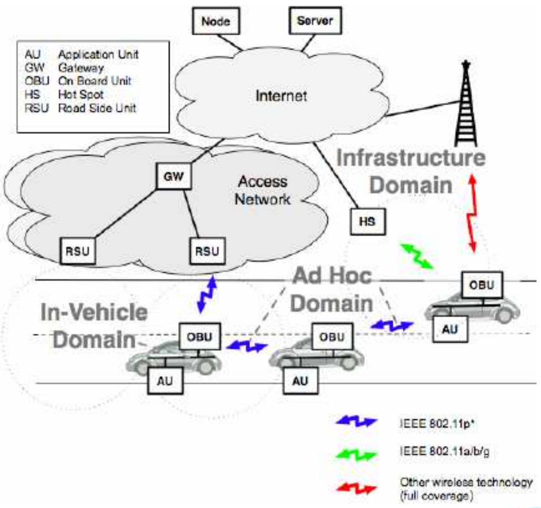
Requirements

Applications

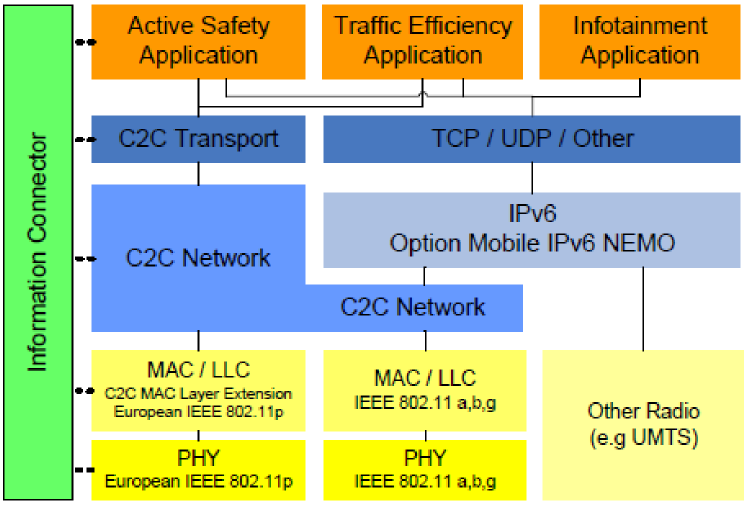
Action Mode

Bus Systems

Car 2 Car and Car 2 Infrastructure Communication (i) - Architecture



Car 2 Car and Car 2 Infrastructure Communication (ii) - Protocols



Information Connector

Active Safety Application

Traffic Efficiency Application

Infotainment Application

C2C Transport

TCP / UDP / Other

C2C Network

IPv6
Option Mobile IPv6 NEMO

C2C Network

MAC / LLC
C2C MAC Layer Extension
European IEEE 802.11p

MAC / LLC
IEEE 802.11 a,b,g

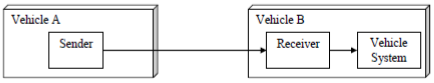
Other Radio
(e.g UMTS)

PHY
European IEEE 802.11p

PHY
IEEE 802.11 a,b,g

Car 2 Car and Car 2 Infrastructure Communication (iii) – Applications (i)

- C2C Cooperative Awareness
  - Information is broadcasted, other cars can access it
  - Ranges from 300m to 1000m



- C2C Unicast Exchange
  - Direct communication between two cars
- C2C Decentralized Environmental Notification
  - Car receives Information about e.g. traffic jam and repeats it to increase the range

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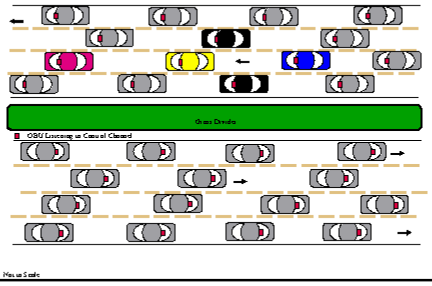
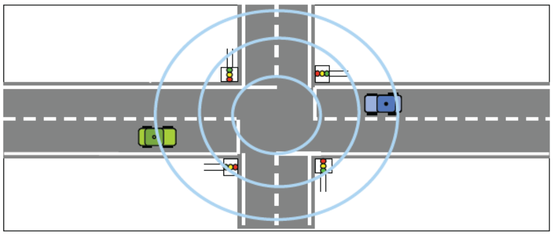
Car 2 Car and Car 2 Infrastructure Communication (iv) – Applications (ii)

- Cooperative Forward Collision Warning
  - To avoid crashes caused by the instant braking of a driver in front
  - During normal driving, the vehicles equipped with the system anonymously exchange useful information such as position, speed and control options
  - To predict an impending collision from behind, each vehicle monitors the actions of their own driver and the position and behavior of all other vehicles nearby



Car 2 Car and Car 2 Infrastructure Communication (v) – Applications (iii)

- Green Light Optimal Speed Advisory
  - The Green Light Optimal Speed Advisory provides information to the driver in an effort to make your driving smoother and avoid stopping
  - When a vehicle approaches a signalized intersection, the vehicle receives information on the location of the intersection and signal timing (number of seconds to change from green to red light)
  - With this information, the vehicle speed is calculated using the ideal distance from the vehicle to the intersection and the time for the signal to turn green



Car 2 Car and Car 2 Infrastructure Communication (vi) – Drawbacks

- Short time to establish communication
- Short time to transmit data
- Very different influences on transmission channel (rain, fog, trees)

Summary

- Bus communication has many advantages compared to single wires and wire harnesses
- Very different requirements need very different communication protocols
- Bus systems have to be able to communicate with each other
  - Gateways have an important role
- Many possible applications for C2C and C2I networks
  - Via Wireless Networks
- Trends to include more electronics and further applications will hold on for years!

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