Challenges and Chances in Future Data Transfer for in-Car and Car to X Communication

Daniel Kraus, Erich Leitgeb, Thomas Plank, Pirmin Pezzei
Institute of Microwave and Photonic Engineering,
Graz University of Technology

BMVIT 2016

BMVIT 2016:

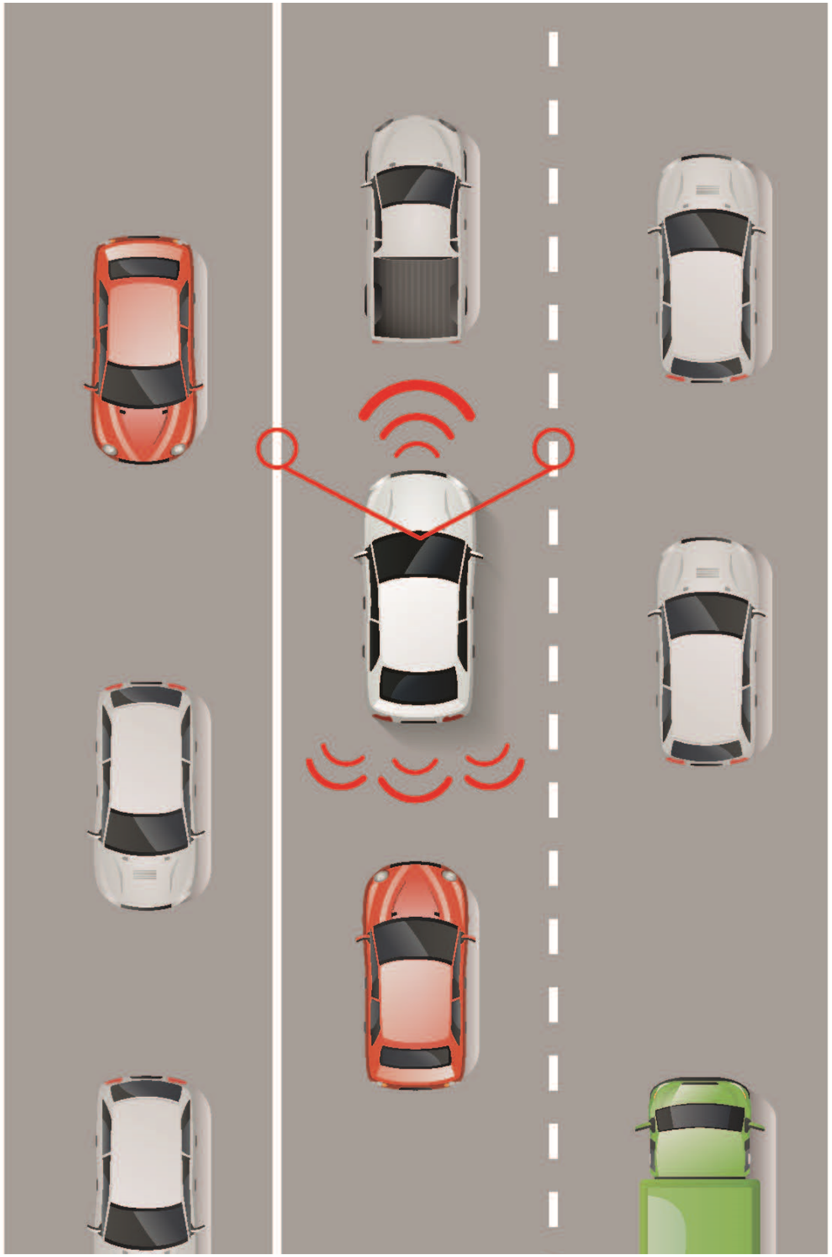
Austrian Research, Development & Innovation Roadmap for Automated Vehicles

!!!!!! in-Car and Car to X Communication !!!!!

The Austrian RDI Roadmap for Automated Vehicles serves several purposes:

in-Car and Car to X Communication

- **in-Car (Fixed or Wireless)**
  - Sensors and Electronics (incl. NFC and RFID)
- **Car to X Communication**
- **Main Aspects**
  - Costs / Power Consumption / Energy
  - Efficiency / Innovation
  - Reliability / Availability
  - Safety / Security



BMVIT 2016:

Austrian Research, Development & Innovation Roadmap for Automated Vehicles

!!!!!! Communication is an important factor in-Car and Car to X Communication !!!!!

in-Car and Car to X Communication

▪ Answers? Problems

- Real-Time Capability of the Systems
- Necessarity on Infrastructures for Implementation of Automated Driving
- Accuracy of Data (Sensors for Location the Vehicle) and Data-transfer and Communications to Assistant-Systems and Infrastructure
- Technologies (RF, Optic/Photonic) for Automated Driving
- Solutions in Future Wireless Mobile 5G (Big Data),

in-Car and Car to X Communication

- **Answers? Problems** (Regarding Vehicle to „X“ (X: other Vehicle, Base-Station, or Infrastructure)
  - Optical Links between Cars and to Fixed Transceivers,
  - Benefits and Disadvantages of Optics to RF (Radio Frequency), like Energy, Data-Rate
  - Spectrum of 5G and Usage of Optical Wireless
  - Interoperability and Convergence of the Systems
  - National and International Standards, also Relevant for Test-Infrastructure 5G and Optics

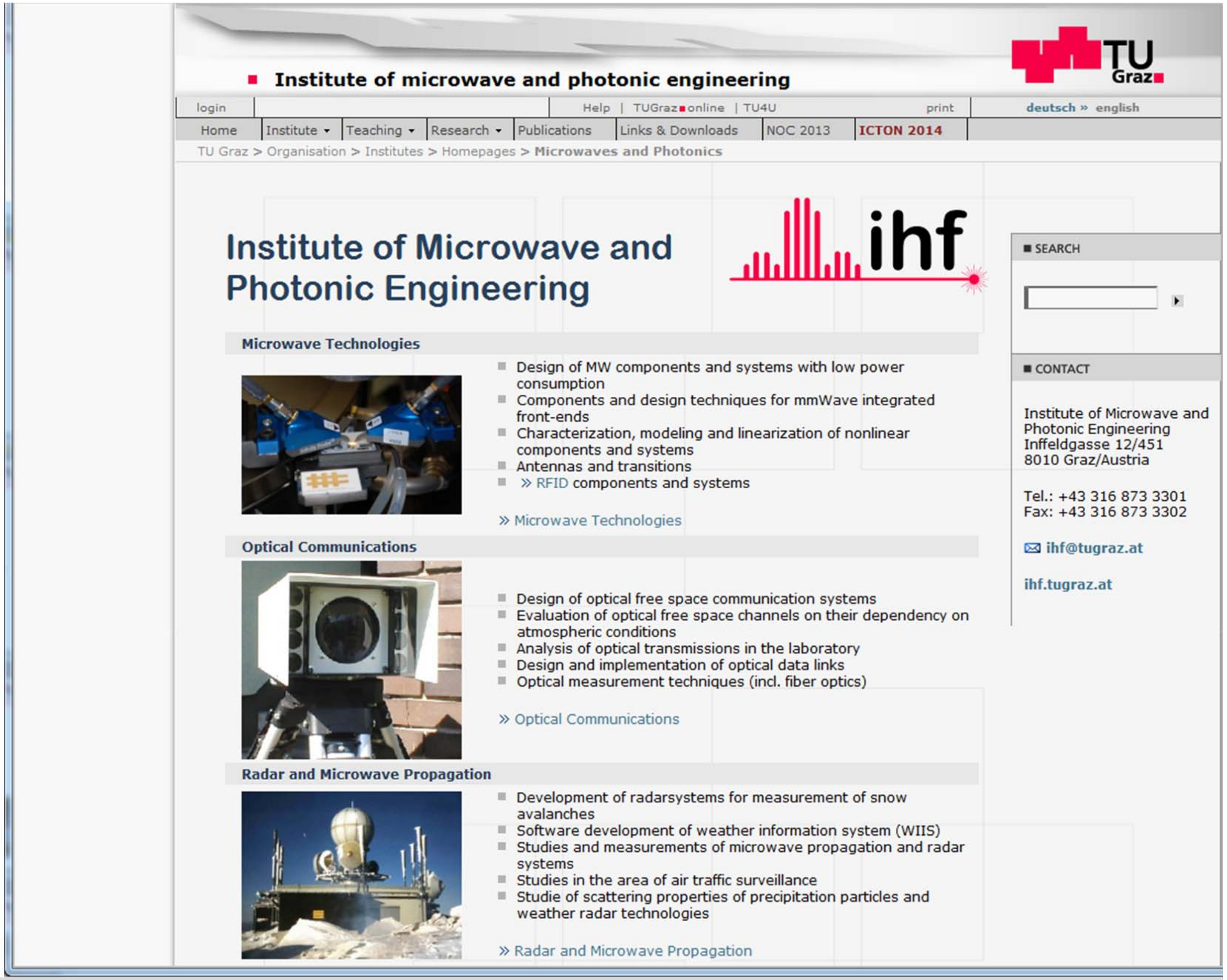
Institut für Hochfrequenztechnik - IHF

3 Main Areas

Topics

at

IHF


Institute of microwave and photonic engineering

login | Help | TUGraz online | TU4U | print | deutsch » english

Home | Institute | Teaching | Research | Publications | Links & Downloads | NOC 2013 | ICTON 2014

TU Graz > Organisation > Institutes > Homepages > Microwaves and Photonics

Institute of Microwave and Photonic Engineering

ihf

Microwave Technologies

- Design of MW components and systems with low power consumption
- Components and design techniques for mmWave integrated front-ends
- Characterization, modeling and linearization of nonlinear components and systems
- Antennas and transitions
- » RFID components and systems

» Microwave Technologies

Optical Communications

- Design of optical free space communication systems
- Evaluation of optical free space channels on their dependency on atmospheric conditions
- Analysis of optical transmissions in the laboratory
- Design and implementation of optical data links
- Optical measurement techniques (incl. fiber optics)

» Optical Communications

Radar and Microwave Propagation

- Development of radarsystems for measurement of snow avalanches
- Software development of weather information system (WIIS)
- Studies and measurements of microwave propagation and radar systems
- Studies in the area of air traffic surveillance
- Studie of scattering properties of precipitation particles and weather radar technologies

» Radar and Microwave Propagation

SEARCH

CONTACT

Institute of Microwave and Photonic Engineering
Inffeldgasse 12/451
8010 Graz/Austria

Tel.: +43 316 873 3301
Fax: +43 316 873 3302

ihf@tugraz.at

ihf.tugraz.at

- Future Broadband-Technologies for High Data Rates
- Next Generation Com. Applications for Smart Cities and Green Technology
- Optical Lab for Courses and Research
- Analysis on optical communication links in the Lab and verification
- Integration of optical components into Communication systems and networks
- Development and implementation of terre-strial Free Space Optics systems (demonstrator)
- Channel modeling, characterization & measure-ments of fiber and optical wireless systems
- Lab-Courses and Teaching

Replacement of the Controller Area Network (CAN) protocol for future automotive bus system solutions by substitution via Optical Networks

!!!! In-Car Communications and IHF contribution to ICTON 2016 in Trento

Replacement of the Controller Area Network (CAN) protocol for future automotive bus system solutions by substitution via Optical Networks

- Motivation for In-Car Optical Communications
- Specifications of CAN
  - Network Topology
  - Challenges
- Optical data communication
- Basic concept
  - Topology
  - Components
  - Network structure
- Conclusion

Motivation for In-Car Optical Communications

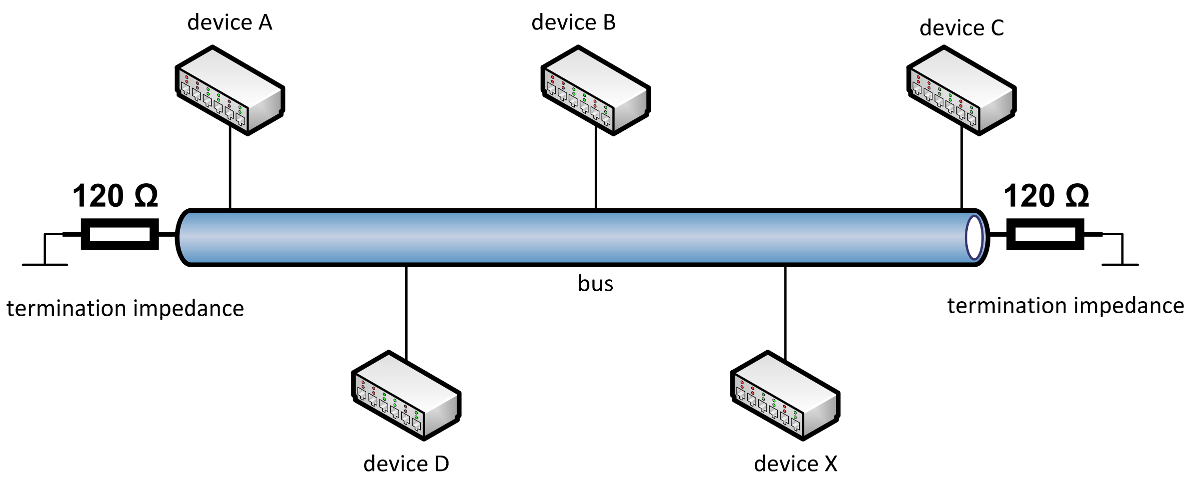
- Future automotive applications will be more sophisticated
  - Communication with environment
    - Buildings, road signs, pedestrians
  - Car-to-Car / Car-to-X
  - Automated & autonomous driving
- Current vehicle bus systems will not be able to handle the increasing network traffic / high data rates
- New approach required
  - Reduce complexity, weight, amount of wiring by using optical fibre

Motivation

- In state of the art vehicles, the weight of wires (mostly copper) add up to 100-150kg
  - Adding more advanced driver assistance systems and their components (sensors, cameras …) will increase the weight further
- Problems with electromagnetic interferences
  - Electromagnetic compliance (EMC)
- Material costs are steadily increasing

Network Topology

- Bus topology
  - Controller Area Network (CAN) still most commonly used topology in vehicles
    - Asynchronous serial bus (not synchronized)



Specifications of CAN

- Multi-Master-Bus
- Data rate between 10kBit/s up to 1Mbit/s (max. bus length of 1km)
  - Dependent on length of wire and speed of transceiver
- Low cost
- Easy protocol management
- Embedded features for error detection
  - Deterministic resolution of a conflict
  - Retransmission of messages

Specifications of CAN

- Data transmission event triggered
  - Every device/node can access the bus and check for events
  - Reactions in the range of a few milliseconds
- Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA) to avoid collisions
  - Number of collisions increase with amount of traffic
- Identifier (ID) to prioritize messages
  - Low ID, high priority

Challenges of CAN

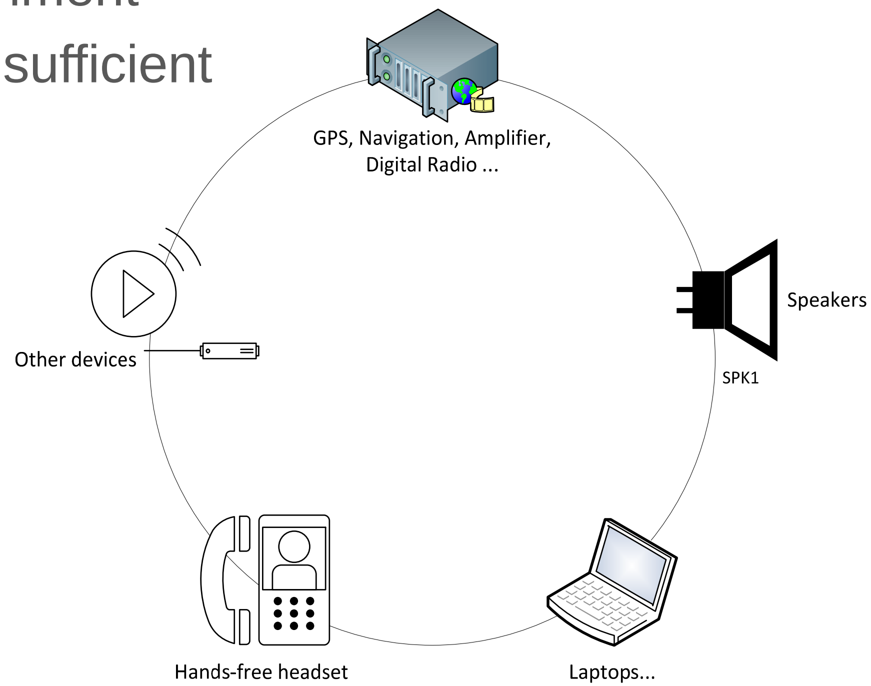
- Currently, existing bus systems are just expanded
  - Complex networks and cabling effort
  - Increased weight, material and fuel consumption
  - Higher assembly costs
  - Complexity of shielding increases
- CAN not able to handle high traffic on bus
  - Message length 130 bit
  - For longer messages → delay (not real time!)
    - Messages with high ID might not be transmitted
- CAN limited to certain amount of control units

Optical data communications

- Properties in automotive environment
  - Single fibre link sufficient to substitute a whole automotive wiring harness
    - But then multiplexing (wavelength) required
  - Electromagnetic compliance (EMC)
  - Attenuation
    - Short distances, cheap Polymer Optical Fibres (POFs) possible
    - Worst case 0.4 dB/m [-40° C to +85° C]
  - Prevent excessive bending of fibres
    - POFs robust to stretching and bending

Media Oriented Systems Transport (MOST)

- MOST Network with ring topology
  - Optimized for multimedia applications
    - Susceptibility to errors too high to be considered for other areas than Infotainment
    - Failure safety not sufficient
    - Not secure

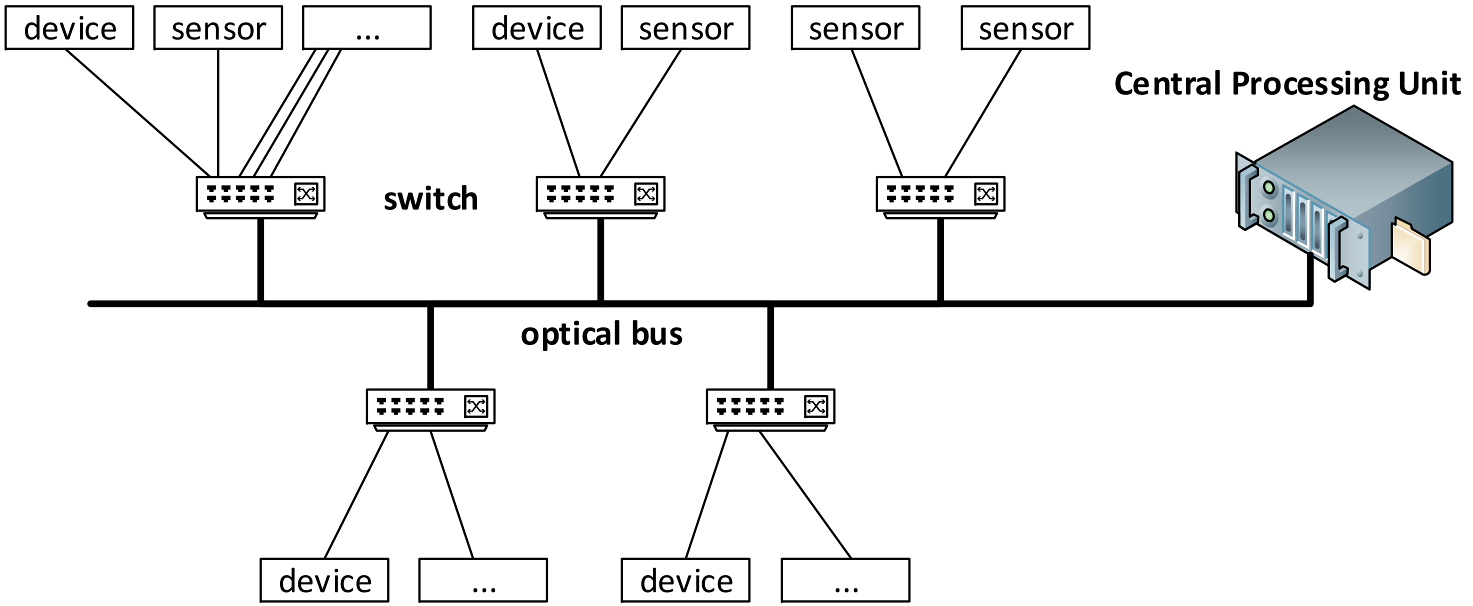


Basic Concept

- Solution for future automotive systems
  - Protection against EMC
  - Weight savings in the range of 50-80% when using optical fibre
    - E.g. optical fibre, 24 fibres, less than 10kg per km
  - POFs robust to stretching and bending
    - Distortion and attenuation sufficiently small for distances below 200 metres
  - Bandwidth up to 100 times higher than with CAN
  - Deliberate positioning of devices required to optimize network

Topology

- Topology: Hybrid of star and bus topology
  - Bus consists of several fibres for different areas of application (Instruments, Multimedia, Driving gear)
  - Optical Switches / Splitters



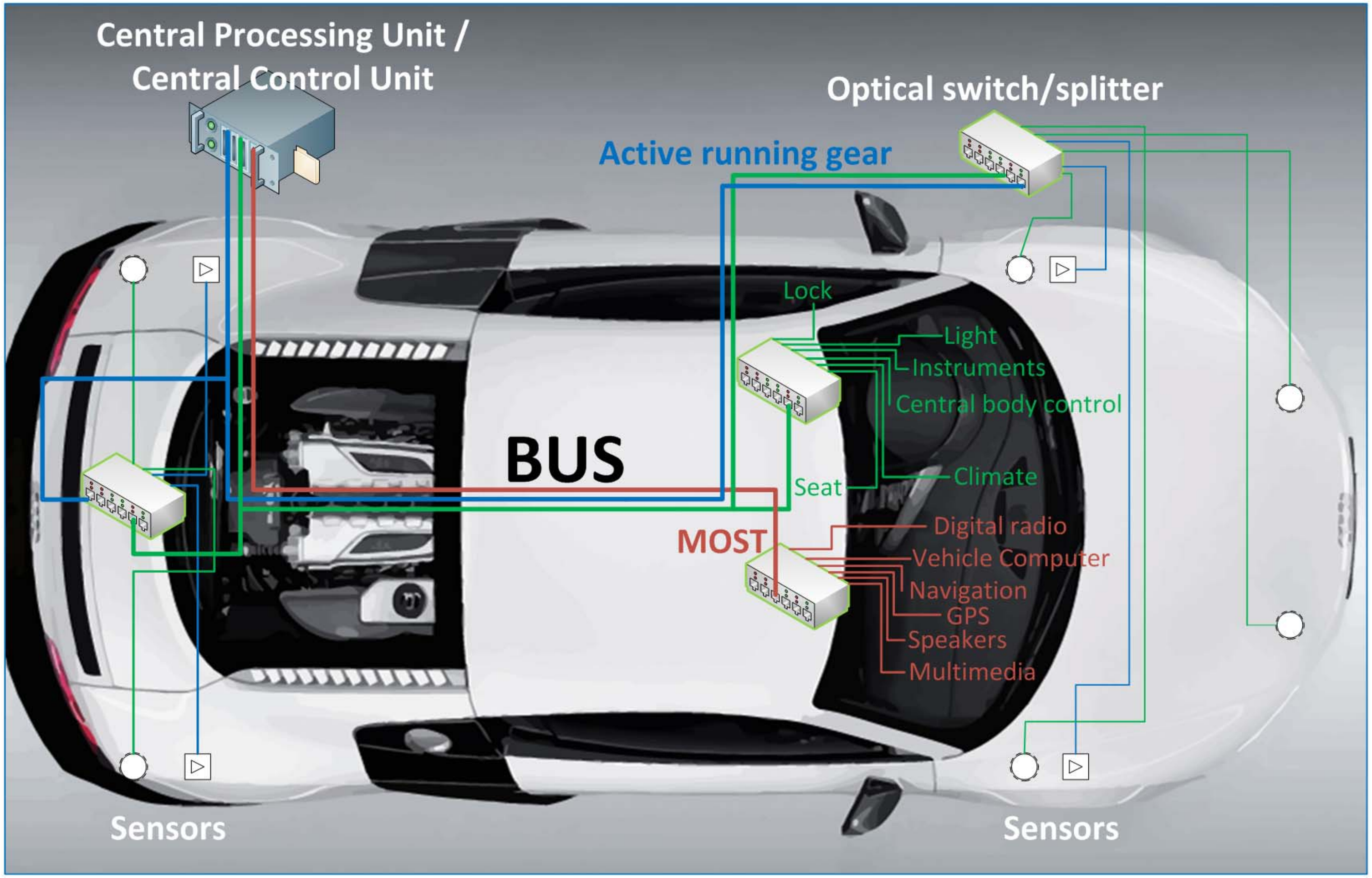
Components

- Topology: Hybrid of star and bus topology
  - To increase flexibility of the network
  - Central Processing / Control Unit (CPU/CCU)
    - Connected with data bus
  - ’Plug and Play’ by using optical switches/splitters
    - Positioning of these devices decisive to minimize wiring
    - Possibility to connect sensors and other devices to the switches with plug connectors
    - Max. 32 ports to limit attenuation (3dB per split)
    - Signal conversion currently within those switches / splitters
    - Optical interfaces of devices, sensors and cameras will make this approach very efficient

Network structure

- Separate fibres for different applications and functionalites
  - Improve organization of the whole structure
    - Limiting losses of excessive splitting
  - Improve reliability, safety and security
- CPU/CCU responsible for forwarding messages between the different fibres
  - All devices still connected with each other via CPU/CCU

Network structure



Vehicle shape ©FreeVector

Network structure

- Required to use a fitting network protocol for this novel design
- Proposed network protocol: **Stream Control Transmission Protocol (SCTP)**
  - Offers a combination of best properties of User Datagram Protocol (UDP) and Transmission Control Protocol (TCP)
  - Possible to prioritize messages with SCTP
    - Sequence number for each message
  - Redundant paths to increase reliability
  - Additional security features

Conclusion

- Improvements of data bus required for future automotive systems
  - Amount of data will increase exponentially
  - Counter possible security issues with convinient network structure and protocol
- Electromagnetic Compliance (EMC)
- Considerable weight, material, fuel and space savings by using optical solutions
  - 50-80% weight savings compared to copper wiring
  - Less complexity due to reduced amount of wiring
  - Retaining flexibility with ’plug and play’
  - Important also for ships, aeroplanes and trucks

Thanks!!!!!!!!!!!!

Electronic Control Unit (ECUs)

- Several ECUs with different tasks
  - Engine control unit
  - Speed control unit
  - …
- All of them are connected with a bus

Further bus systems

- TTCAN (time triggered)
  - Global system time
- CAN FD
  - 3 additional bit elements to make protocol more flexible and improve the data throughput
  - Payload increased from 8 byte to 64 byte
  - Data rates of 2 Mbit/s up to 4 Mbit/s
- FlexRay
  - Developed for active running gear
  - Up to 10 Mbit/s

Further bus systems

- Local Interconnect Network (LIN)
  - 20 kBit/s to minimize emissions in transmission lines
- Media Oriented Systems Transport (MOST)
  - Optical bus arranged in ring topology
  - Up to 150 Mbit/s
    - Video and Audio broadcast
- Ethernet and IP
  - Unshielded twisted pair with bandwidth of 100 Mbit/s (BroadR-Reach)
    - For camera based systems

Problems of TCP

- Specifications of SCTP [1]:
- *TCP provides both reliable data transfer and strict order-of-transmission delivery of data. Some applications need reliable transfer without sequence maintenance, while others would be satisfied with partial ordering of the data. In both of these cases the head-of-line blocking offered by TCP causes unnecessary delay.*
- *The stream-oriented nature of TCP is often an inconvenience. Applications must add their own record marking to delineate their messages, and must make explicit use of the push facility to ensure that a complete message is transferred in a reasonable time.*
- *The limited scope of TCP sockets complicates the task of providing highly-available data transfer capability using multi-homed hosts.*
- *TCP is relatively vulnerable to denial of service attacks, such as SYN attacks.*

Literature

[1] RFC 4960 - Stream Control Transmission Protocol, September 2007; https://tools.ietf.org/html/rfc2960