Technische Universität Braunschweig

ERIKA

IDA INSTITUTE OF COMPUTER AND NETWORK ENGINEERING

Towards OFDMA-based Ethernet for future in-vehicle communication

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Project Overview

Domain: **automotive communication systems**

- Alternative high-speed bus-based system
- Compatible with Ethernet standards
- Compatible with legacy components

Electromobility with **R**edundant **I**ntelligent **C**ommunication **A**rchitecture

Project details:

- Starts in 2019 for 3 years
- Founded by German national authorities

IKT FÜR ELEKTROMOBILITÄT

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

DLR Projektträger

Consortium Technical Objectives

New technology for the signal modulation in bus

Focus on Physical and Data Link layers
from the OSI model

Including automotive requirements:

- **Functional safety -** ISO26262 standard
- **Low energy**
- **Cost reductions** – easy integration of components off-the-shelf
- **Flexibility, Scalability** – reduce number of cables, weight
- **Legacy support** – e.g. tunneling of LIN, CAN, FleyRay traffic

Project Partners:

BMW GROUP

PORSCHE

technica engineering

NXP

HHI

Technische Universität Braunschweig

Continental

TECHNISCHE UNIVERSITÄT CHEMNITZ

FKFS RESEARCH IN MOTION.

Talk 1: Overview

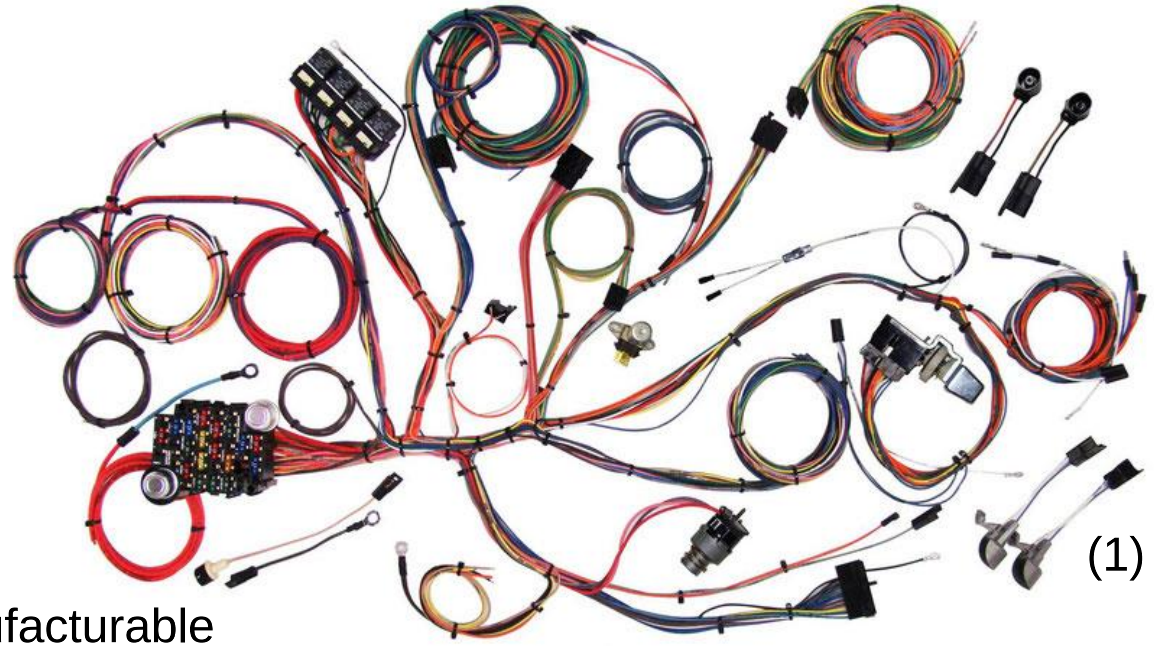
- **Motivation**
- **Future communication system for automotive**
- **OFDMA-based Ethernet**
- **Conclusion**

Motivation

Trends towards **autonomous driving** increasing demands
on top of existing in vehicle communication systems

- New sensors (e.g. Lidar, Camera)
  require high bandwidth
- Standard systems (e.g. LIN, CAN, FR, MOST)
  can not fulfill demands

State of the art: Adding more buses but this increase the wire harness complexity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Result: the wire harness is to complex and in future not manufacturable

How to simplify the cable harness?

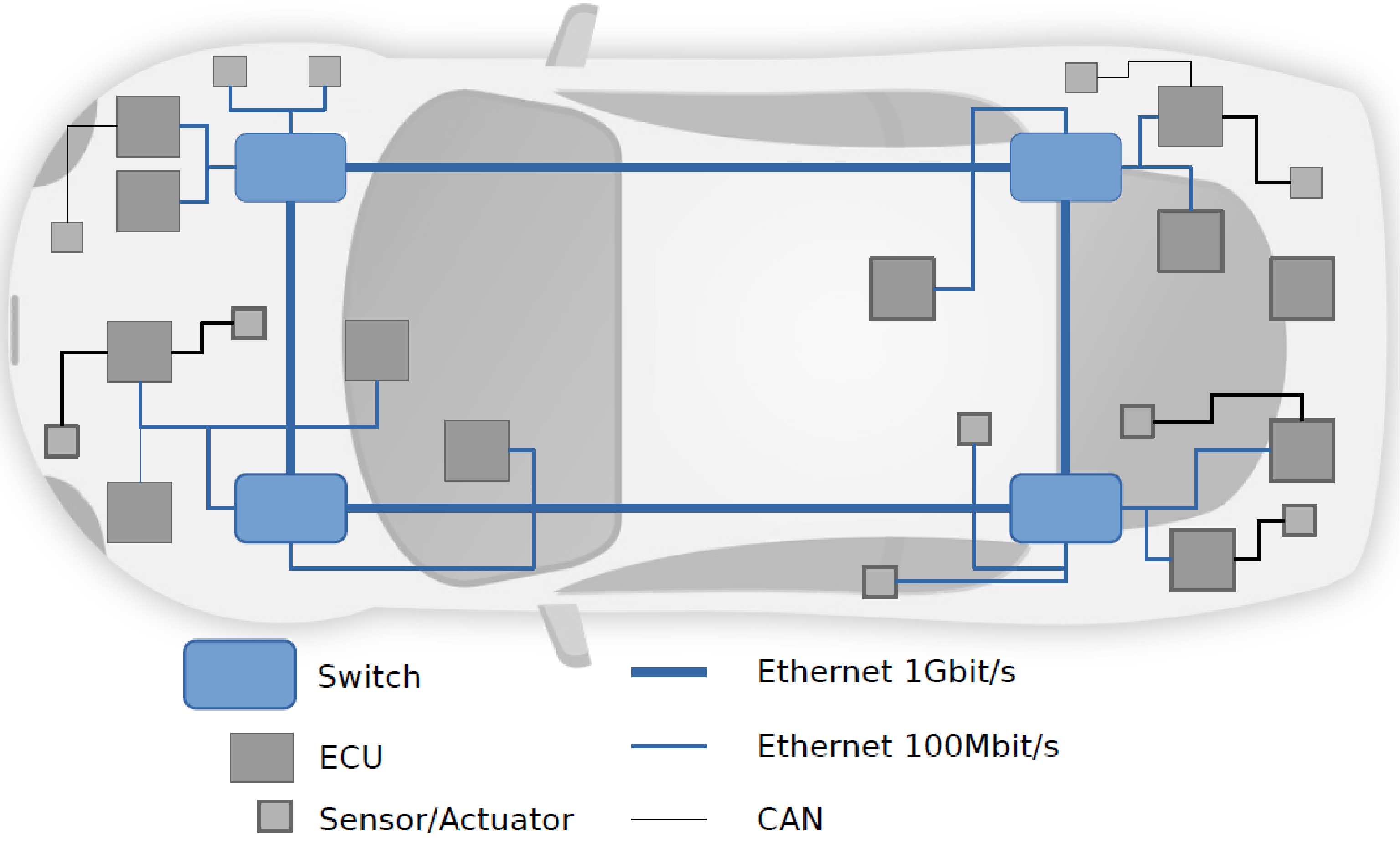
Zonal Architecture

Main features:

- Split wire harness into pieces
- Spatial distribution of ECU
- Smaller pieces are better producible
- Zones are connected via backbone

Challenges:

- Required performant physical layer for **backbone**
- Support for high bandwidth and low latency traffic
- Tunneling of legacy traffic
- Support for functional safety i.e. ISO26262
- Scalability e.g. wire harness



Automotive Interconnects – Physical Layer

Bus based technologies CAN, CAN-FD, LIN, FlexRay

- Decentralized arbitration or fixed time schedule → low scalability
- Low bandwidth 1 Mbit/s – 10 Mbit/s

In Ethernet defined by IEEE 802.3

- Major variants 10BASE5, 10BASE2, 10BASE-T, 100BASE-TX, 1000BASE-T, 10GBASE-T
- Point-to-point transmissions
- All transmissions serialized on the same link
- Complex interference scenarios

Scalability is the main challenge!

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Orthogonal Frequency Division Multiple Access (OFDMA)

OFDMA is a well-known technology

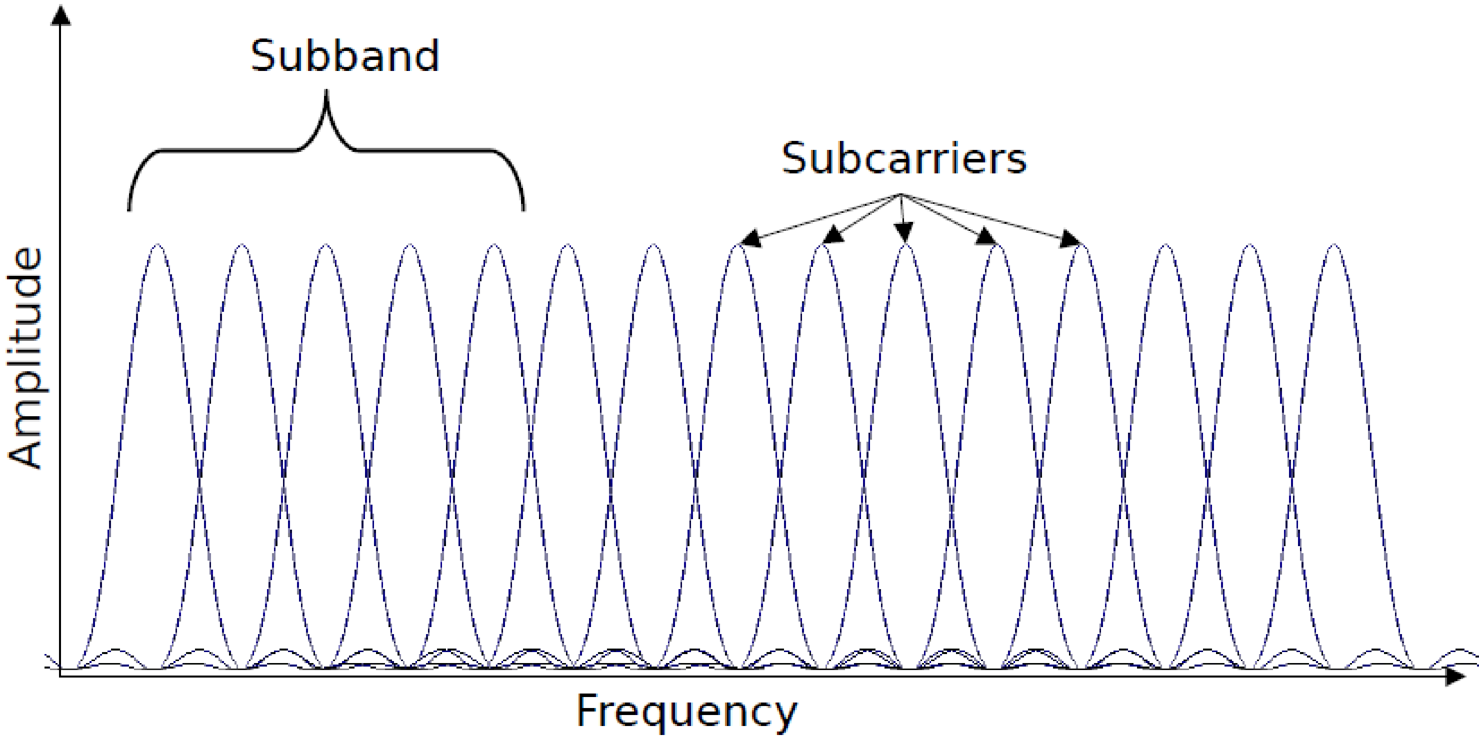
applied in **mobile** communications

- WLAN, UMTS, LTE, 5G

As we as **cable** based communications

- DOCSIS
- Powerline Communications (ITU G.hn)

Allows parallel transmissions over the same medium on different frequencies



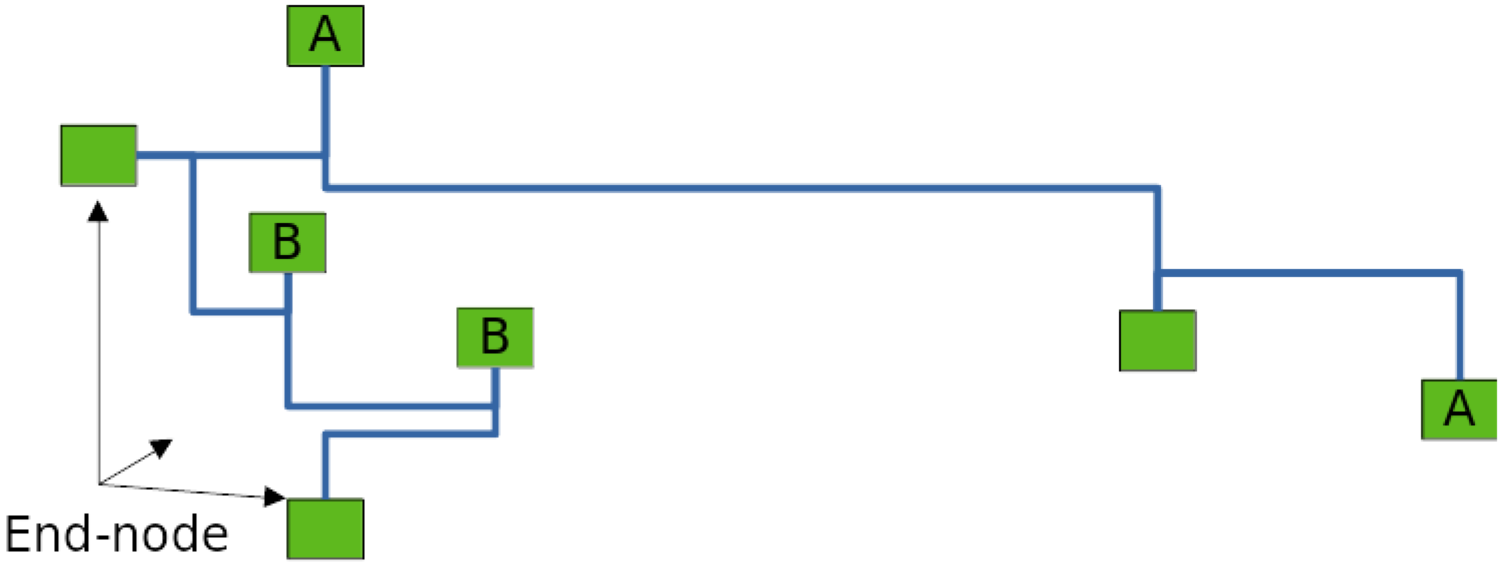
Main trade off - scalability

- i.e. dependency between number of subcarriers in a subband and latency

OFDMA-based Solution Developed in ERIKA Project

Bus based on OFDMA technology:

- Unshielded Twisted Pair (UTP)
- Daisy-Chain Topology
- Scalable and flexible



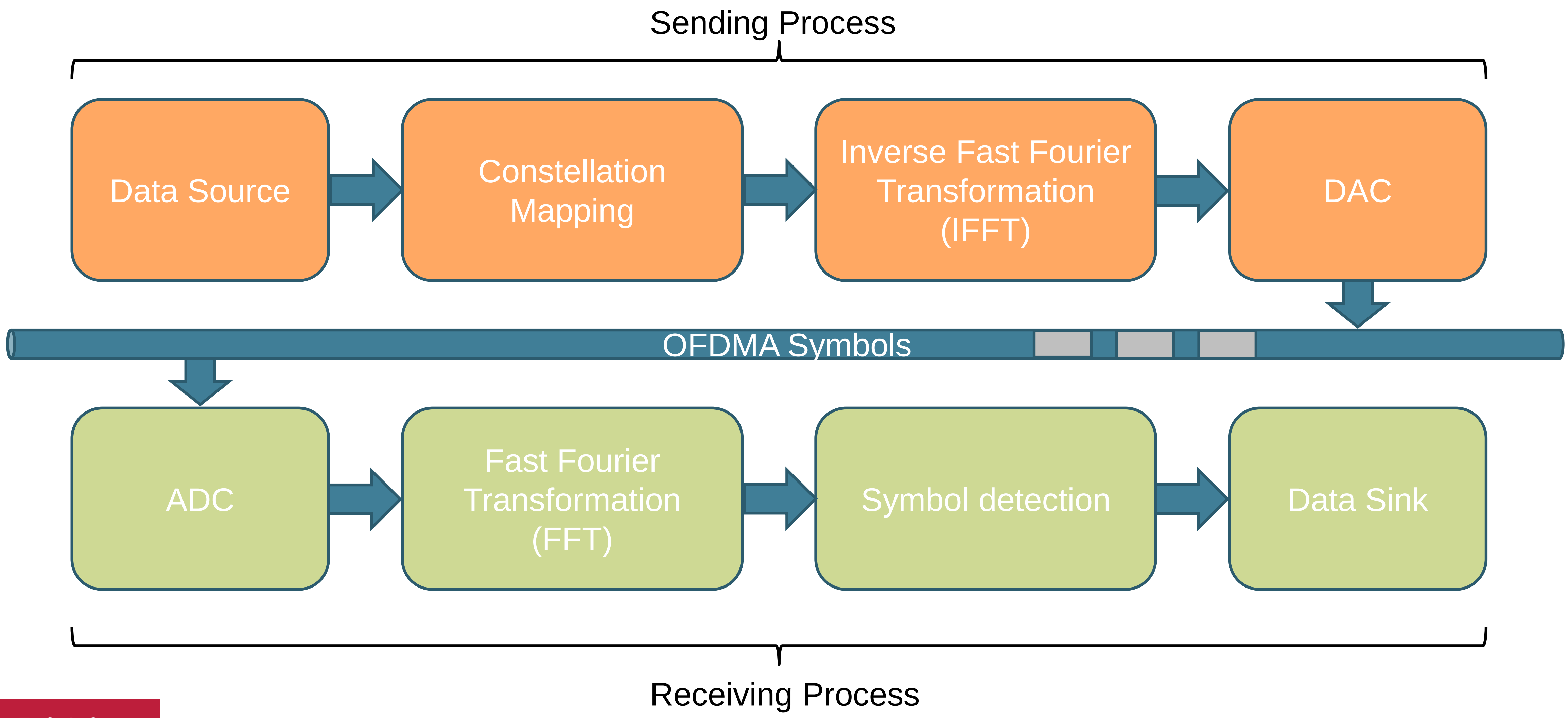
Main focus on OSI ISO Layer 1 (Physical Layer)

- Transmission and reception of a bit streams over a physical medium

and OSI ISO Layer 2 (Data Link)

- Reliable transmission of data frames between two nodes connected by a physical layer

OFDMA Modulation Process



OFDMA-based Ethernet – Resource Blocks

Frequency division (FDMA)

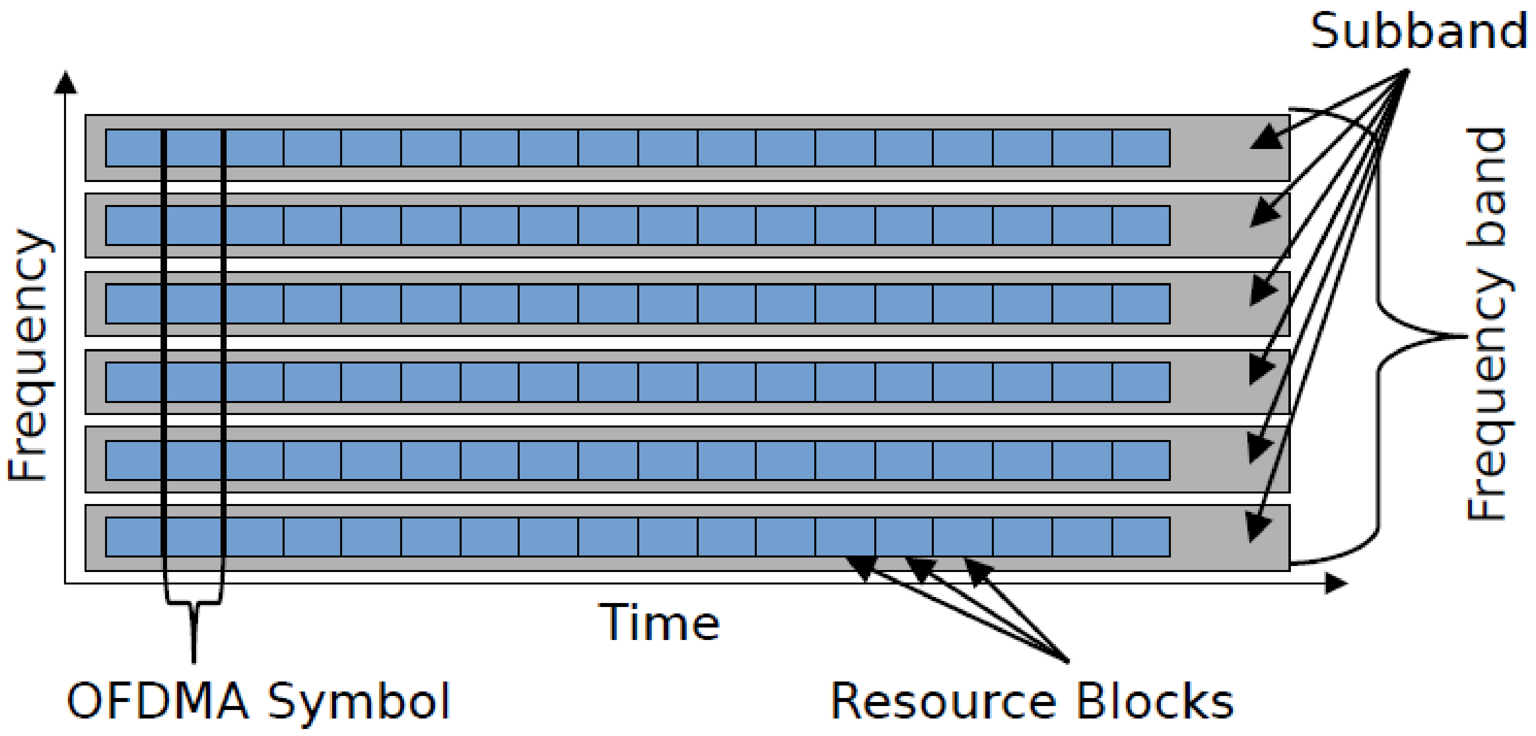
- Subbands

Time division (TDMA)

- OFDMA Symbols

Combination Resource Block

- Smallest schedulable unit



Safety Challenge

Vehicle is a **mixed criticality** system

- Design and operation governed by functional safety standard ISO26262
  - Classifies functions in criticalities ASIL D to ASIL A and QM
  - All computing and communication involved in an ASIL A to D function must adhere to a highly structured and constrained design process

Safety concern whenever traffic classes interfere e.g. links, buffers

Safety standards require:

- Strict physical and/or temporal isolation of different criticalities
- Assuring "**sufficient isolation**" through selected mechanisms cf. ISO26262
- Allowing interference but enforcing a safe upper-bound on the interference

Future communication system Requirements – Communication Use Cases

Traffic Classes	Communication Use Case	Data rate	Timing requirements	Addition Comments
A	SerDes	3-13 Gbit/s		continuous data stream hard timing requirements
B	Ethernet	100 Mbit/s to 1 Gbit/s	non deterministic; max 20ms	best effort traffic no hard timing requirements
C	Ethernet with AVB	50 Mbit/s	<50µs deterministic max 2ms	low latency
D	CAN, LIN	19.2 Kbit/s to 10 Mbit/s	non deterministic	short message frames no hard timing requirements
E	FlexRay CAN/FD	1 Mbit/s to 10 Mbit/s	<10µs deterministic max 100µs	low latency e.g. chassis control or airbag

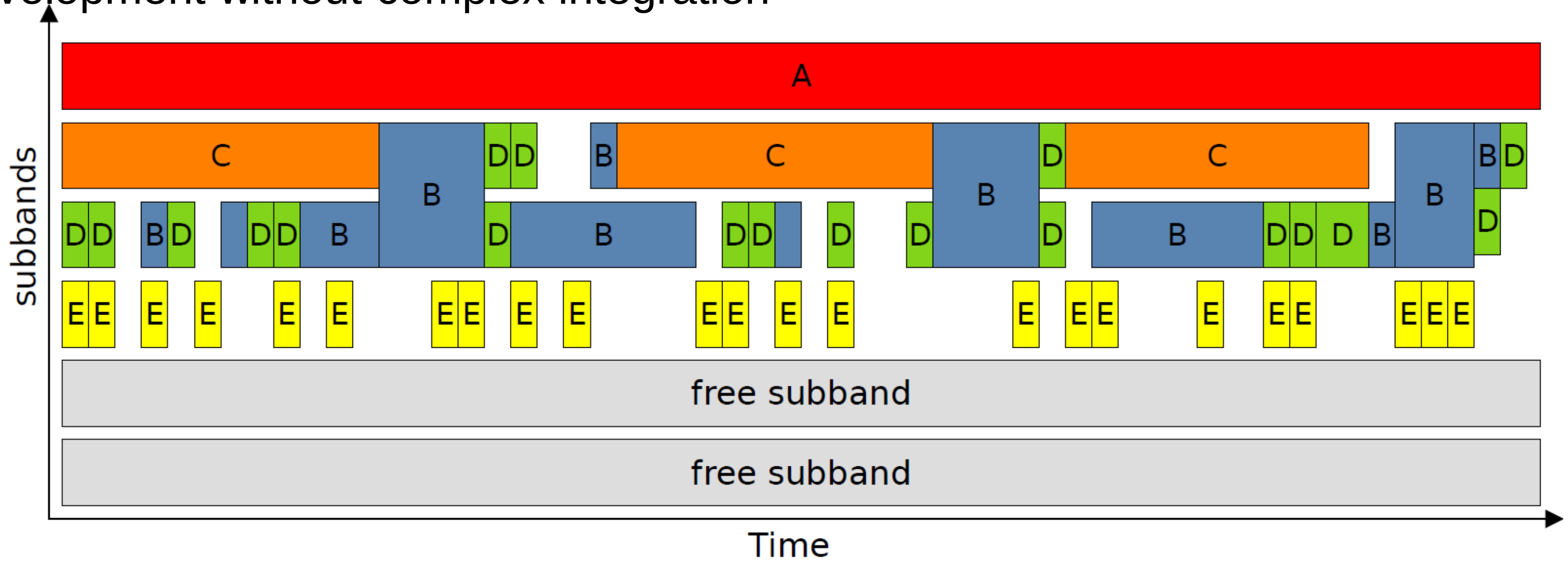
OFDMA-based Ethernet – Isolation

Subbands enable:

- **Isolation** between Traffic Classes (A to E)
- **Parallel** data transmissions
- Tunneling legacy traffic

More subbands than Ethernet Traffic Classes – allows more flexible integration

- e.g. allocating subbands to separate streams/applications
- Agile feature development without complex integration



OFDMA-based Ethernet – Timing Example

Example: QAM512 as modulation

- *256 Subcarriers * 9 Bit/Subcarrier = 4608 Bit / Resource Block*
- Ethernet frame needs 3 Resource Blocks

Assumption:

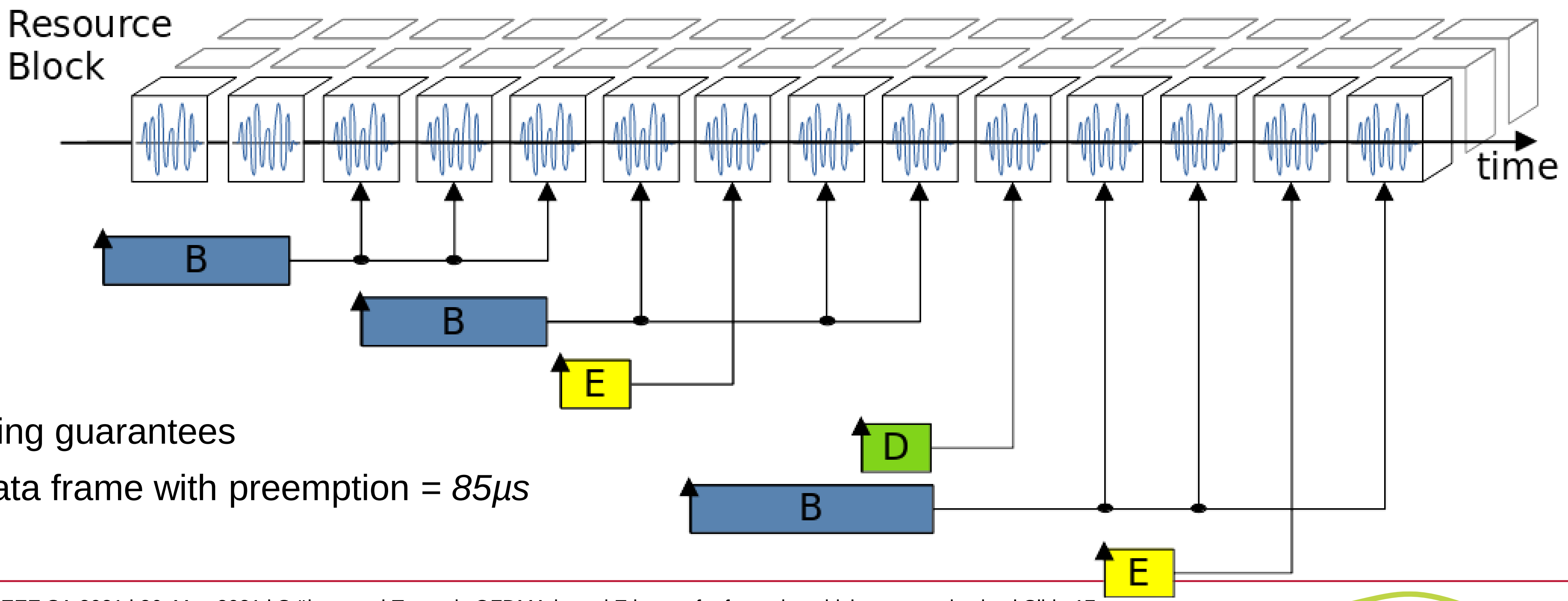
- Preparation time, transmission time and post processing time are equal to 17µs
- Resulting *Transport time = 51µs*

Fits requirement of class E

OFDMA-based Ethernet – Preemption Example

Preemption within a subband

- Resource Blocks are independent what allows preemptions
- Support for mixed criticality
  - otherwise high criticality traffic must wait until low priority transmission will finish



- Provide timing guarantees
  - class B data frame with preemption = *85µs*

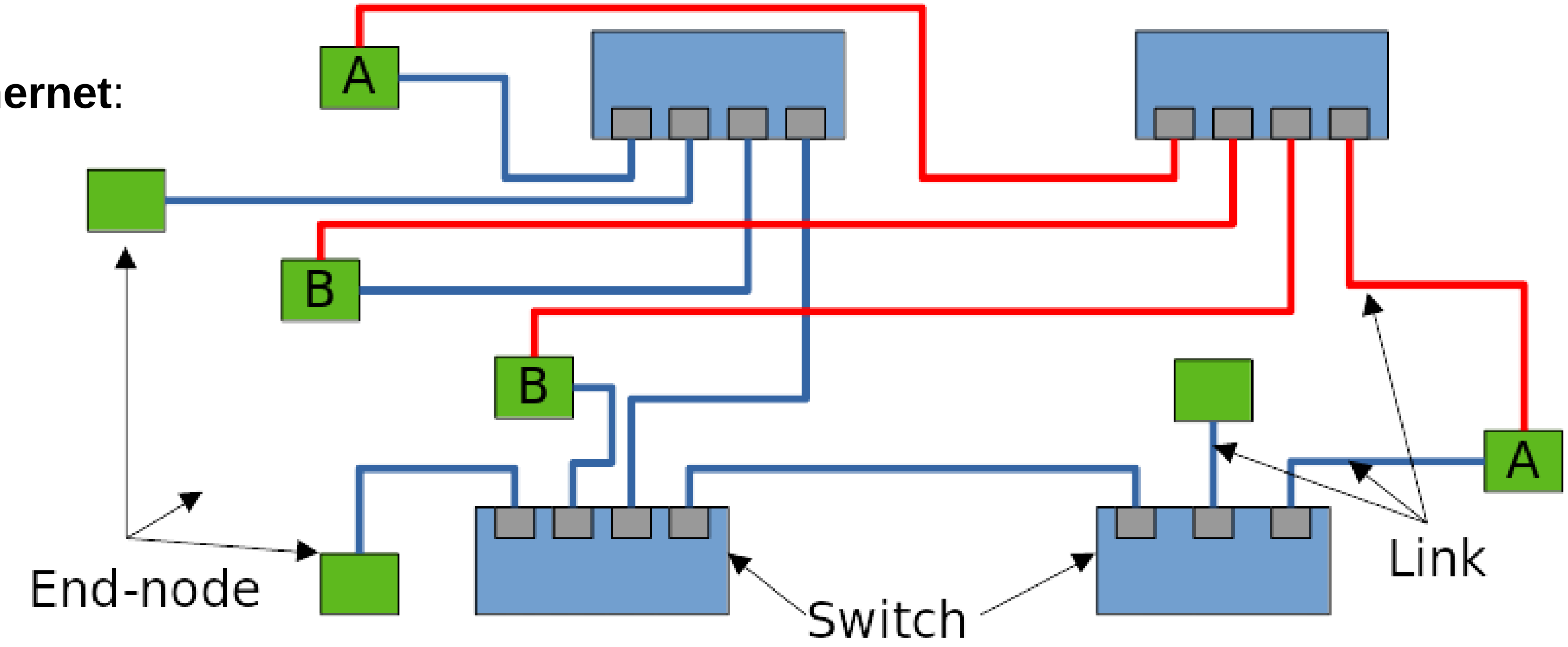
Ethernet – Redundancy

Redundancy is required by **safety standards for dealing with permanent failures**

- Permanent failures are sporadic but must be considered
- For example functions A and B are safety critical
  - Therefore they require redundant links and switches
  - Assuming that only one component may fail at a time

High overhead in traditional Ethernet:

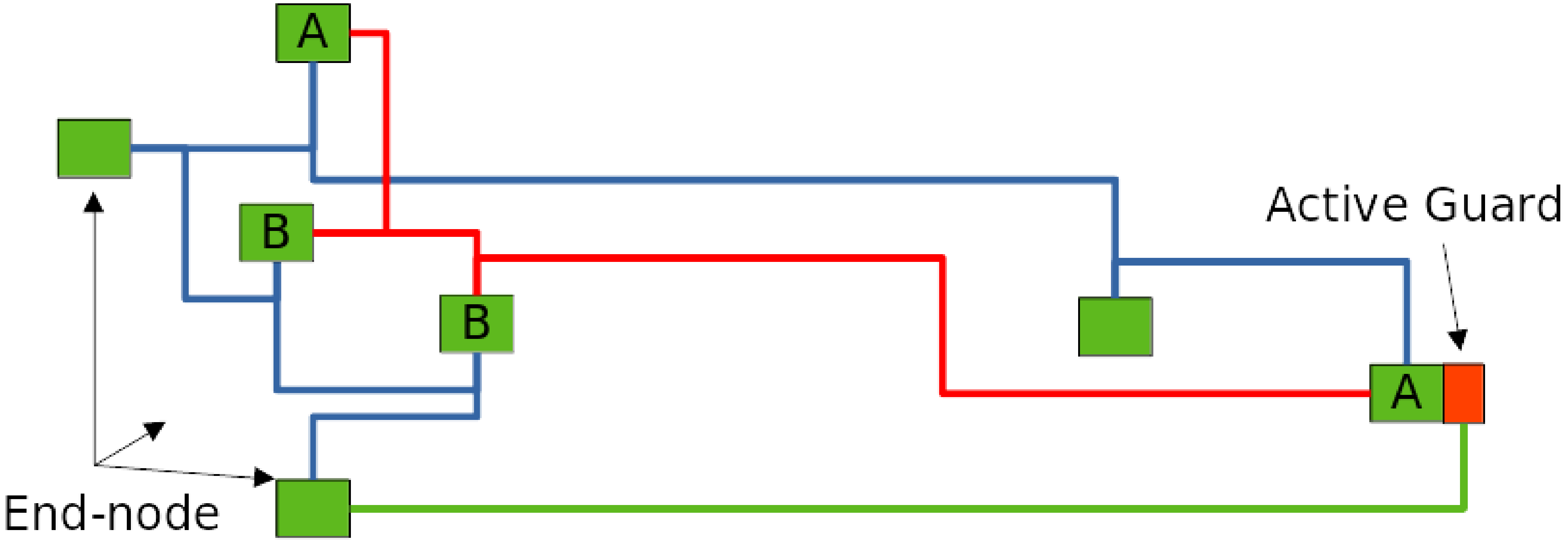
- require addition infrastructure (1 switch and 4 links)
- redundant transmissions on different links decrease available bandwidth (e.g. IEEE 802.1CB FRER mechanism)



OFDMA-based Ethernet – Redundancy

OFDMA-based Ethernet:

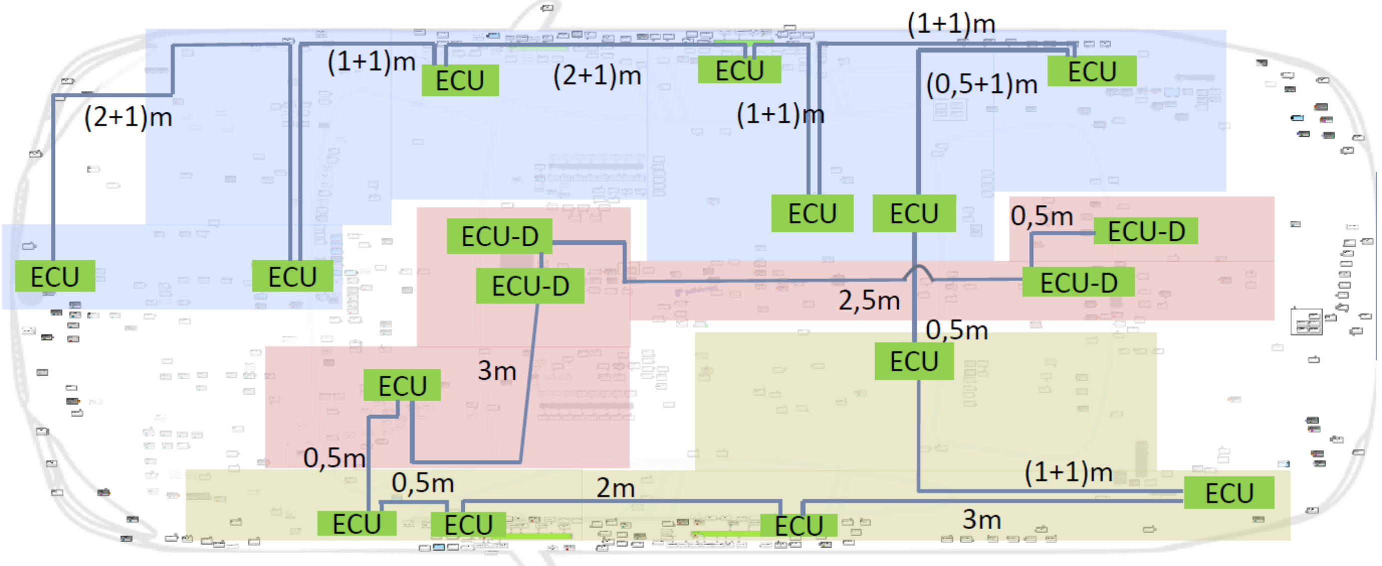
- Either by adding a **second cable** (red cable)
- Or by closing the line topology to a ring with **Active Guard** (green cable)



Wire Harness

Ethernet	OFDMA-based Ethernet
17 ECU	17 ECU
3 Switches	1 cable, no switches
52 m cable	28 m cable

- In Project example up to 50% cable reduction (details in the paper)
- Saving increase along with the number of integrated ECUs



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Conclusion

Promising technology for future in-vehicle network

- Harness reduction up to 50%
- Safety with Isolation based on subbands and redundancy
- Tunneling with parallel transmissions and preemption

Future work:

- Deeper transmission details presented in second Talk
- Resource allocation in a shared medium in third Talk

Thank you for your attention.