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Topic

Car-2-Car Communication from the perspective of a global OEM

- Vision: Safe and Intelligent Mobility
- Ford Research Test Environment
- Test Results
- Summary and Outlook

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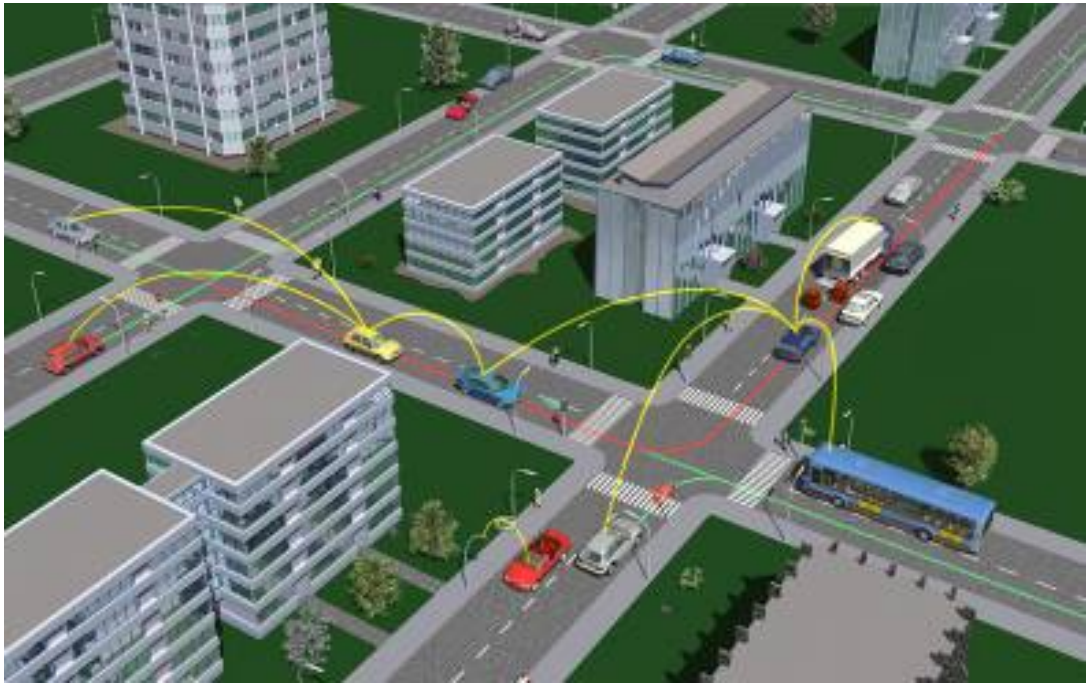
Safe and Intelligent Mobility

The vision can be reached by directly connecting vehicles, driver assistance systems, and the road infrastructure.

Car-2-Car-Communication (C2C)



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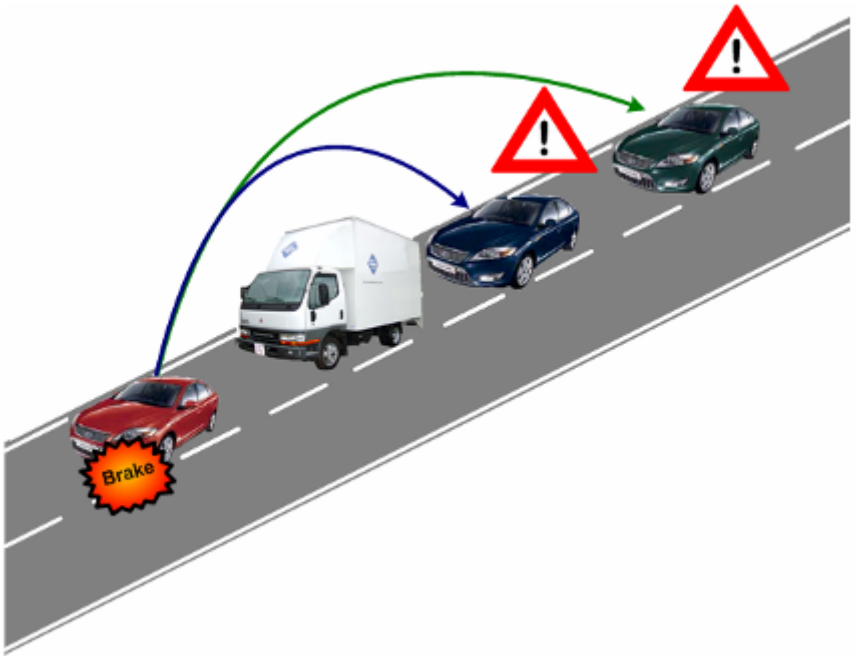
Example Application: Electronic Emergency Brake Lights (EEBL)

Purpose

Warn about sudden braking vehicles ahead

Concept

- Periodic broadcast of local information (Beacon)
- Receivers compare message with own data
- Receiver decides, if an alert or system preparation is necessary



Challenge

Beacon must immediately reach all followers

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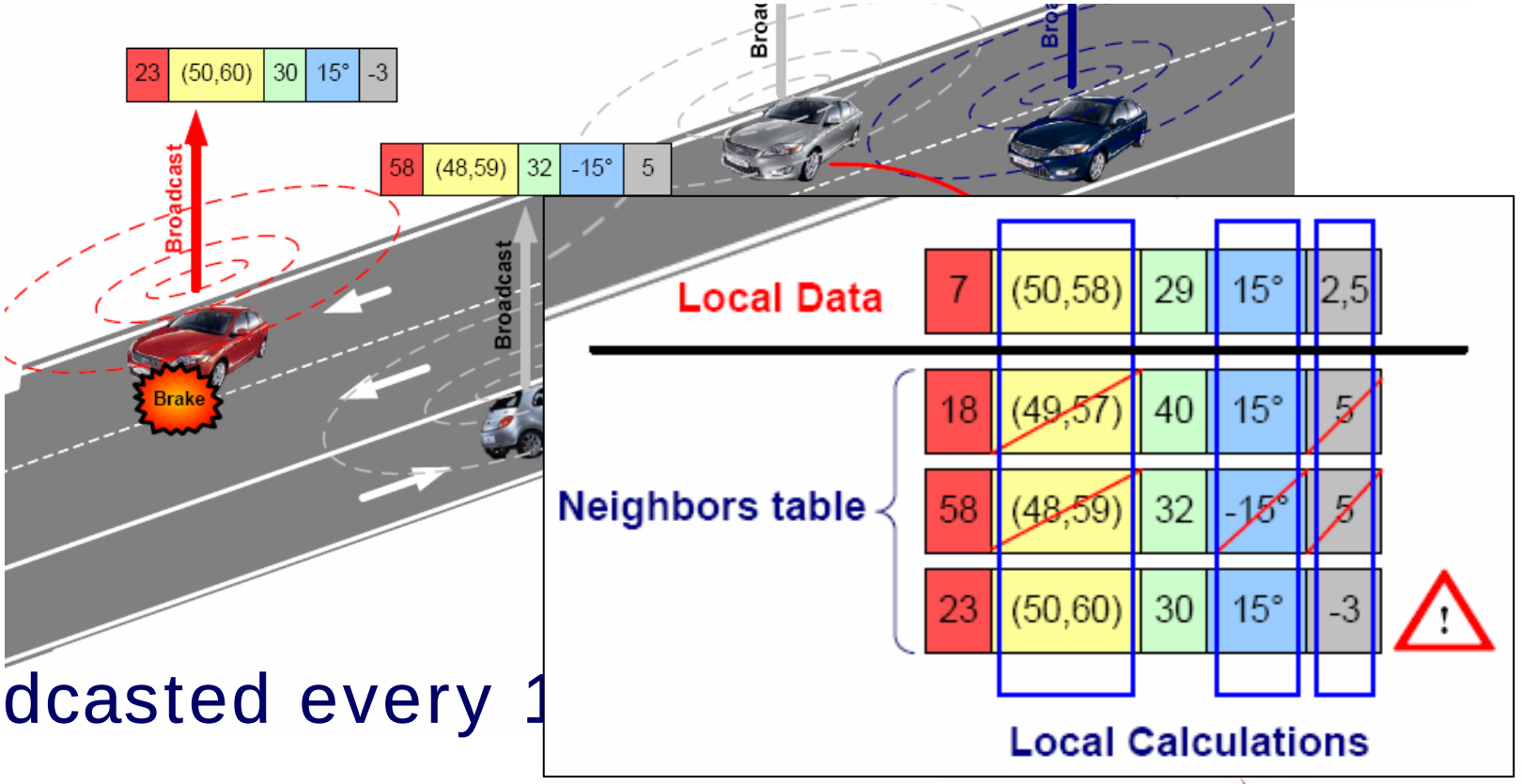
Network Beacon

ID	Position (longitude,latitude)	Speed (m/s)	Heading (grads)	Acceleration (m/s^2)



broadcasted every 1

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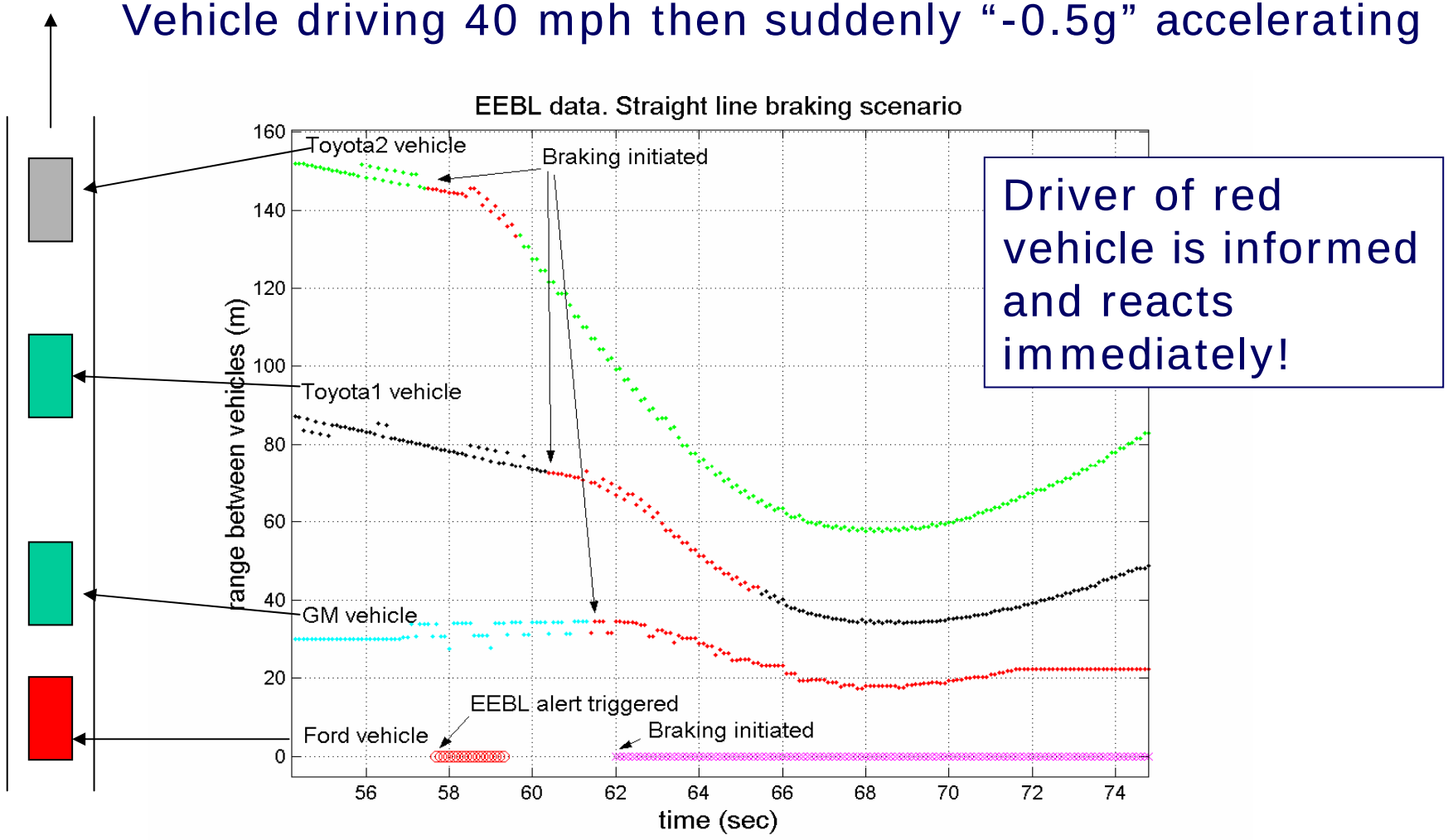
EEBL – Impact of Alert

Vehicle driving 40 mph then suddenly "-0.5g" accelerating



Driver of red vehicle is informed and reacts immediately!

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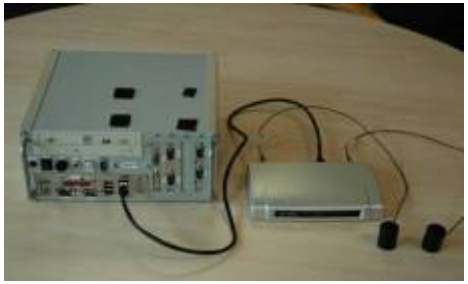
Wireless Communication Set-up

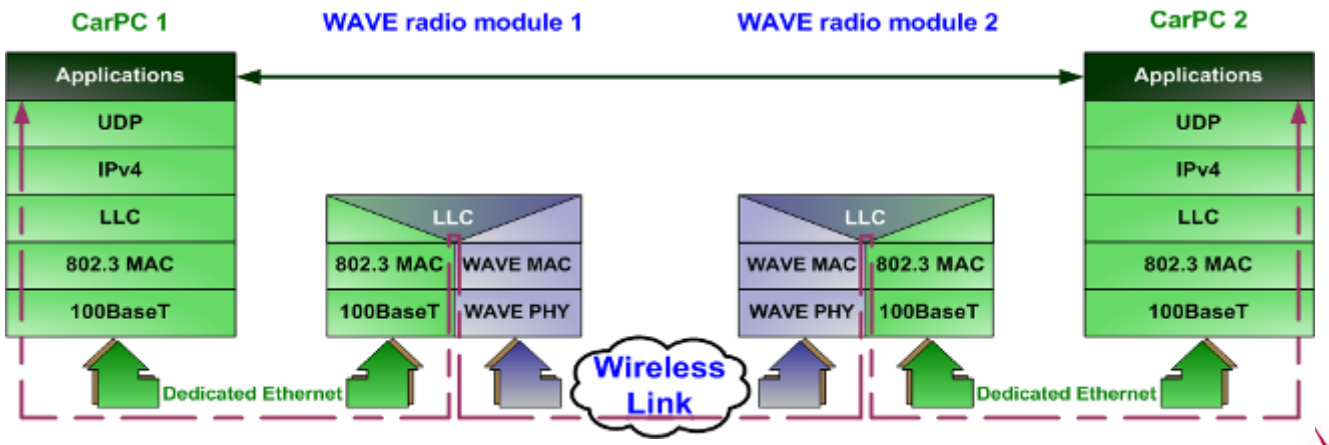
DENSO radio modules:

- Prototypes of IEEE 802.11p
- 10 MHz channels
- Up to 33 dBm

Communication:

- Compliant with WAVE standard





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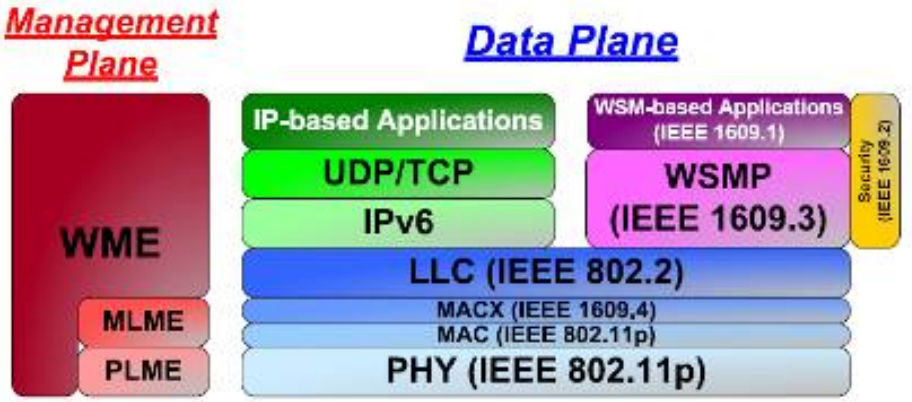
WAVE - a Global Standard?



- WAVE defines communication protocols for vehicle networks
- However compatibility does not exist, neither between Europe and USA (e.g. frequency) nor within Europe
- Each new project creates proprietary communication modules
- *Challenge:* Protocol layers are not finally defined and agreed

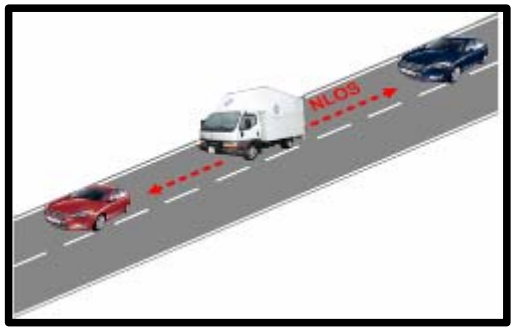
Test and Validation

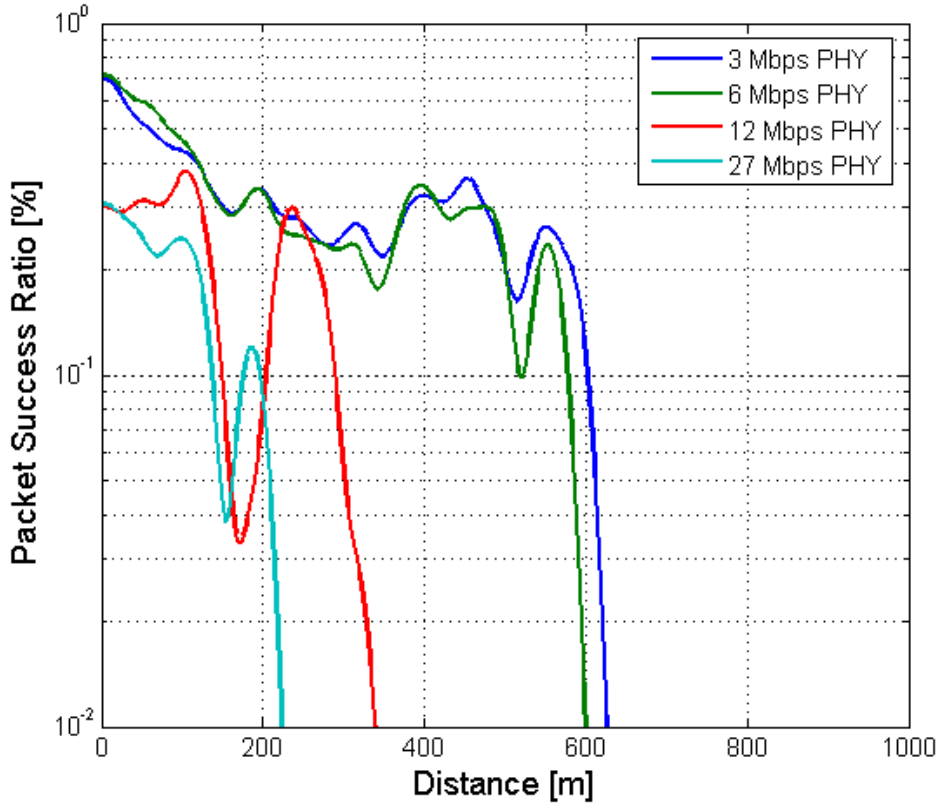
Results from real-world test drives in the area of Aachen, Germany

- 2 to 3 vehicles in test scenario
- Measurement of
  - Communication Range
  - Time delay
  - Channel overload
- Multi-hop communication

Communication Range

Scenario: Non-line-of-sight on highways at 120 Km/h



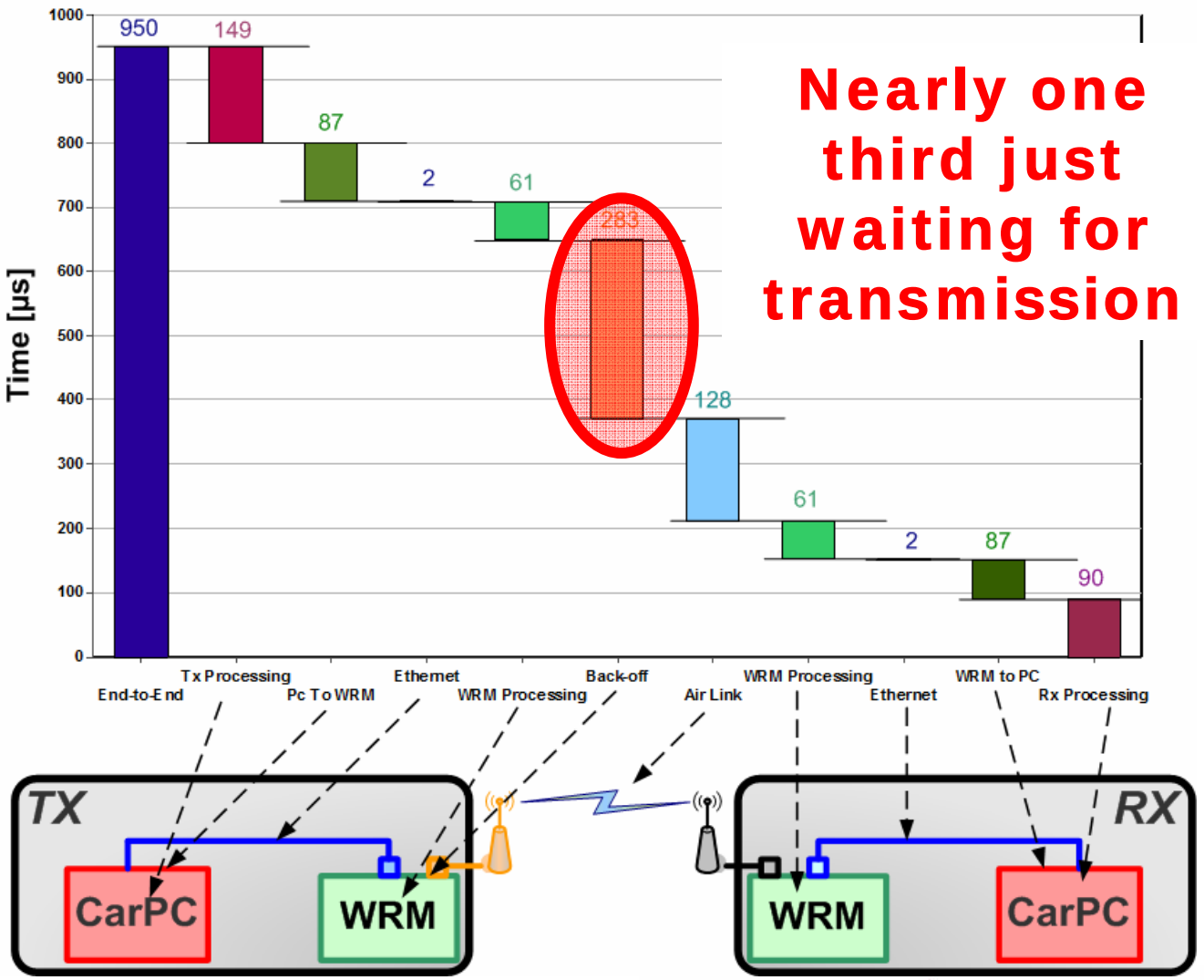


End-to-end Delay Analysis

Messages

- Length: 61 Bytes
- Date rate: 6 Mbps

(Average delay)



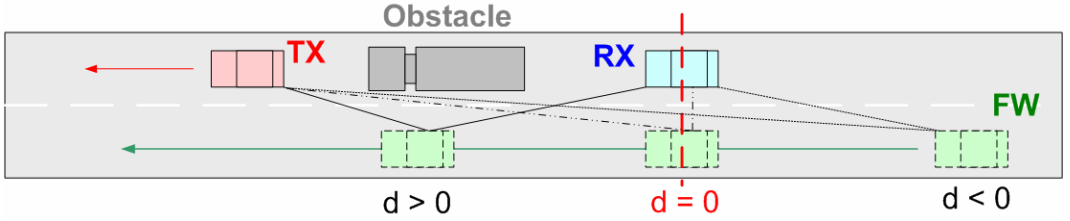
Nearly one third just waiting for transmission

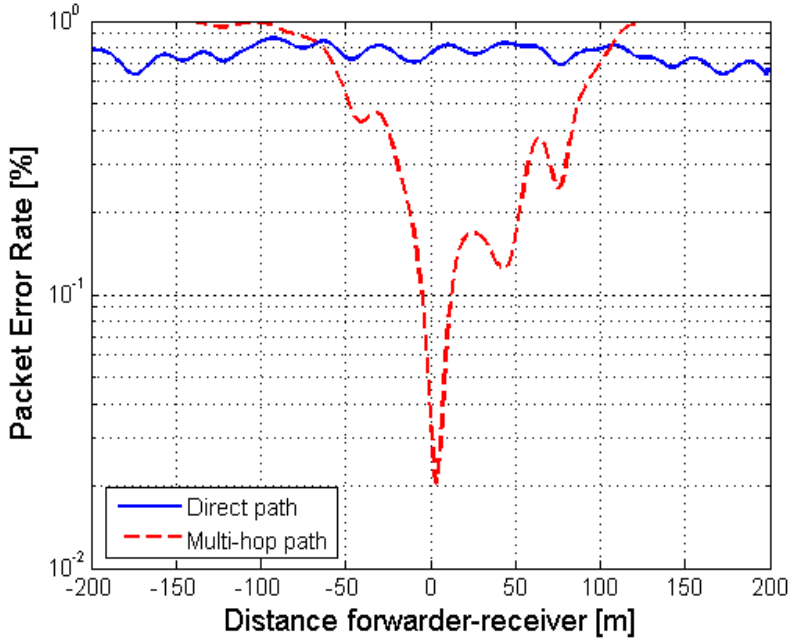
Channel Overload?

- Our analysis shows an upper limit of 50 transmitting units per channel
- Mechanisms to avoid channel overload are needed - but not yet finalized
- Approaches to reduce transmissions:
  - Congestion control (on different layers)
  - Dynamic control of transmission power
  - Geocast, i.e. broadcast to all nodes in a geographical area

Multi-hop Communication

Third vehicle with DENSO radio module as forwarder to bypass non-line-of-sight communication

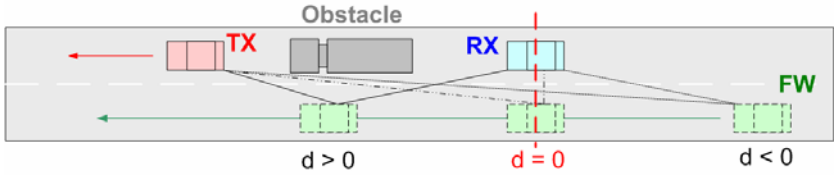


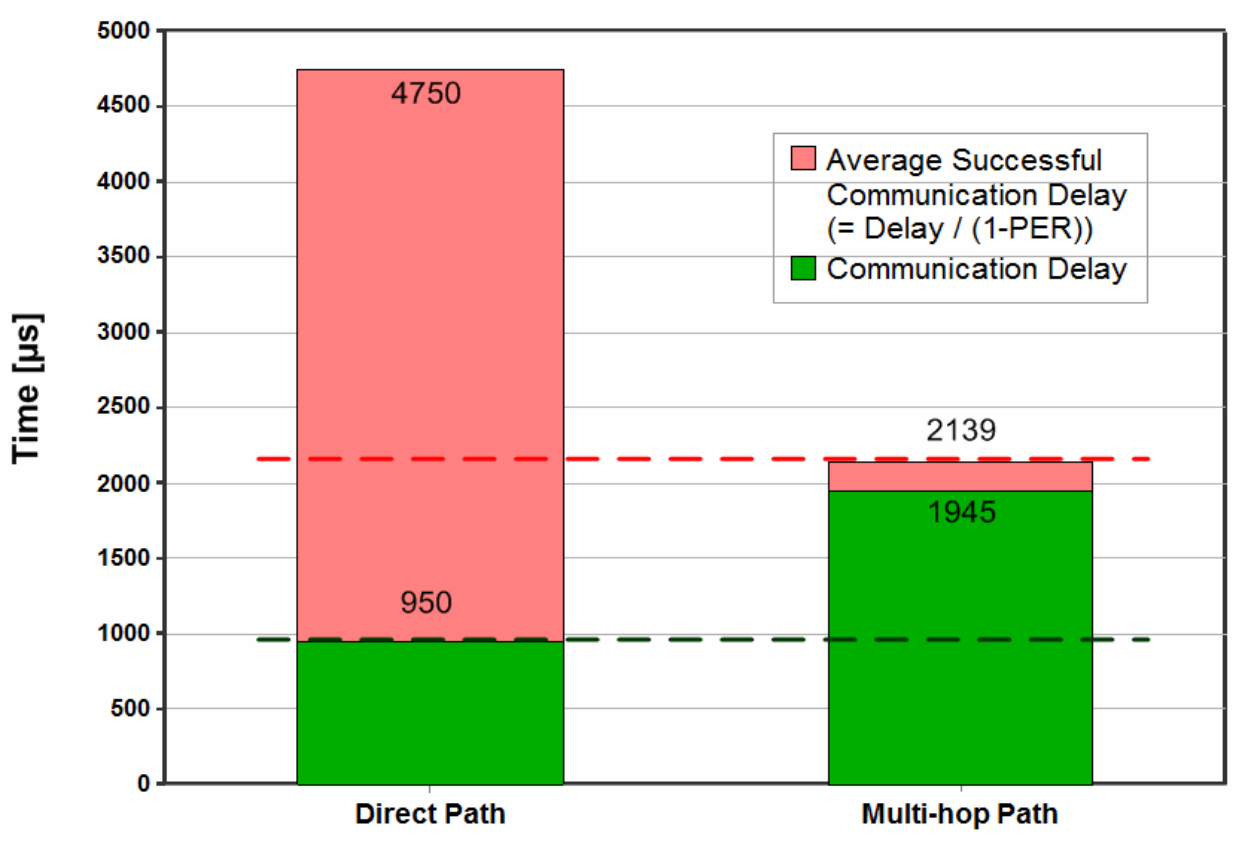


Improved performance

Multi-hop Delay

Lower average delay for successful communication





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Summary and Outlook

- C2C-Communication provides a great benefit for road safety (e.g. EEBL)
- C2C-C is reliable for more than 500 meters
- Compatibility is an issue as long as network layers are still being developed
- Technology is quite mature but still requires refinement and testing in a large scale environment (Field Operational Test)

Contact

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Thank you for you attention!