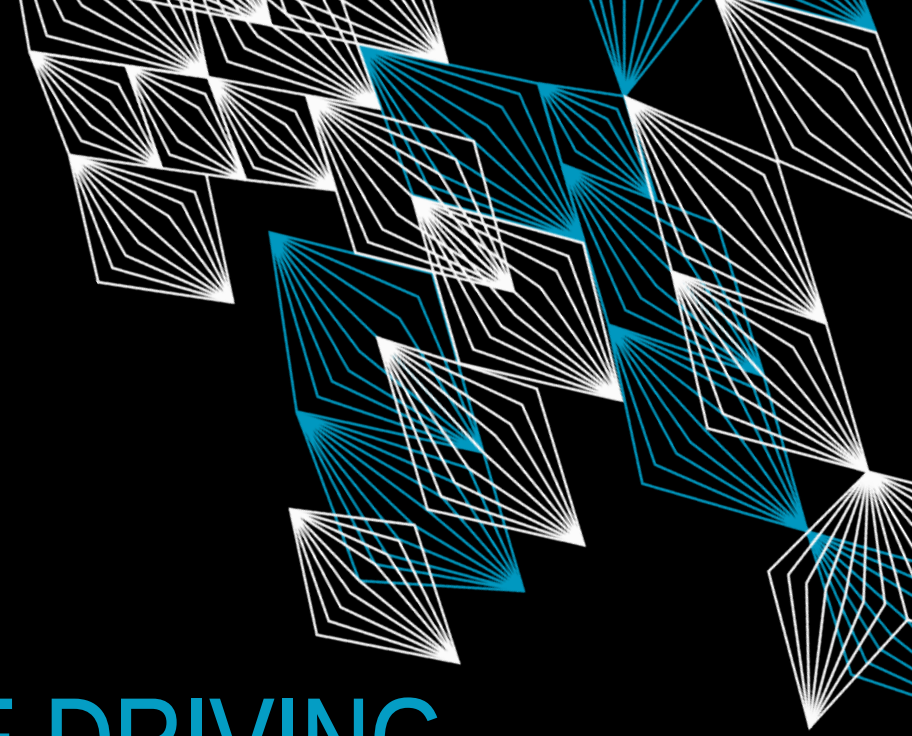


TOWARDS COOPERATIVE DRIVING

VEHICULAR NETWORKING AS AN ESSENTIAL INGREDIENT FOR INTELLIGENT TRANSPORTATION SYSTEMS

GEERT HEIJENK – UNIVERSITY OF TWENTE

CWTE RESEARCH RETREAT, 9 OCTOBER 2019

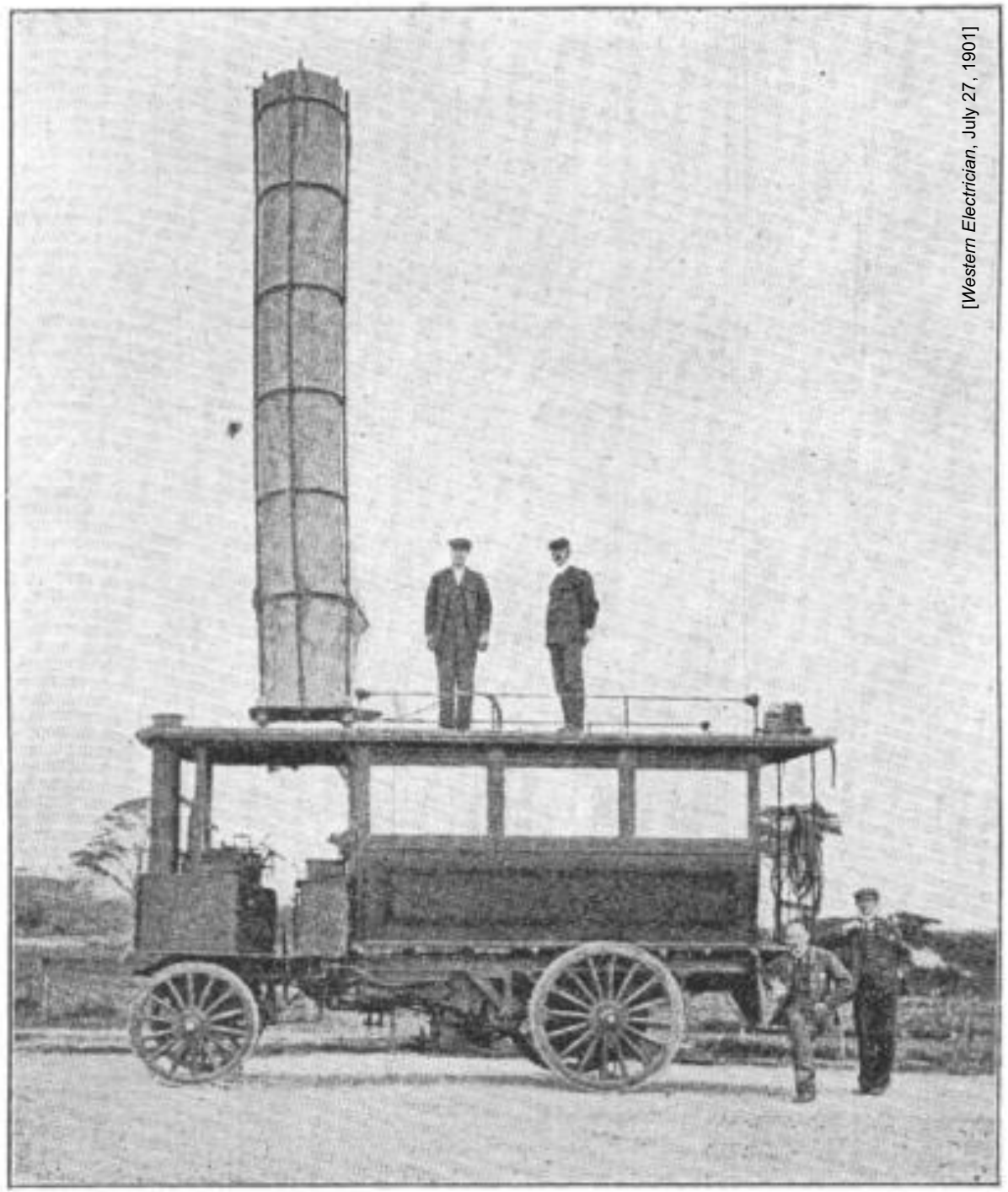
UNIVERSITY OF TWENTE.

VEHICULAR NETWORKING: HISTORICAL PERSPECTIVE

Guglielmo Marconi, 1902:

"… The system is a handy thing for automobiles in general. I had a breakdown in England and was able to send a wireless message to my base asking that dinner be kept hot. …"

[The Cosmopolitan, May 1902]

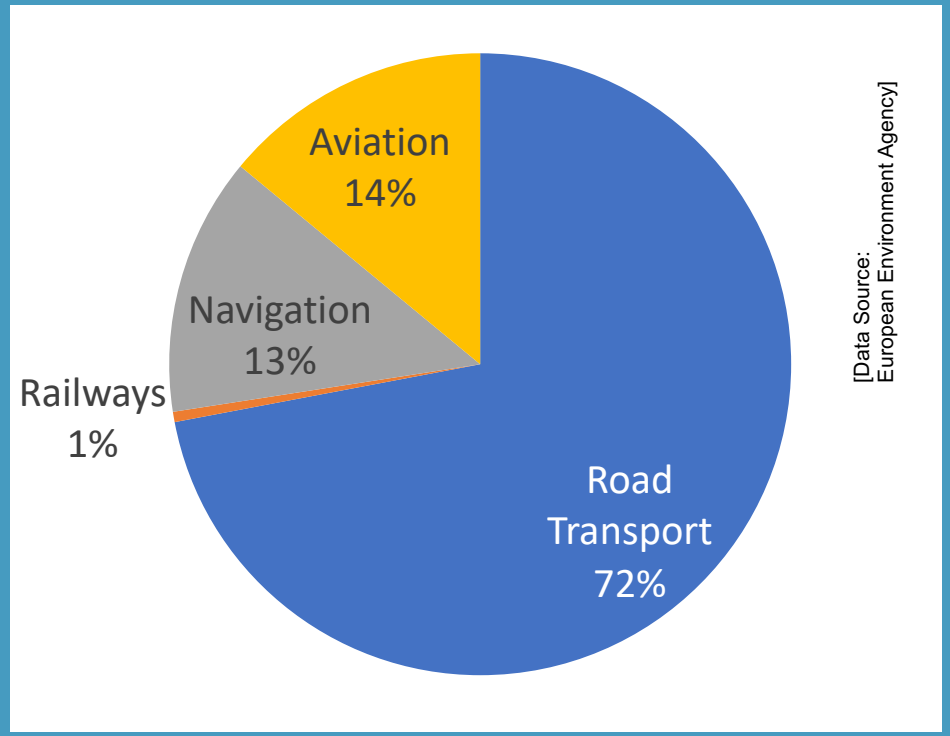


[*Western Electrician*, July 27, 1901]

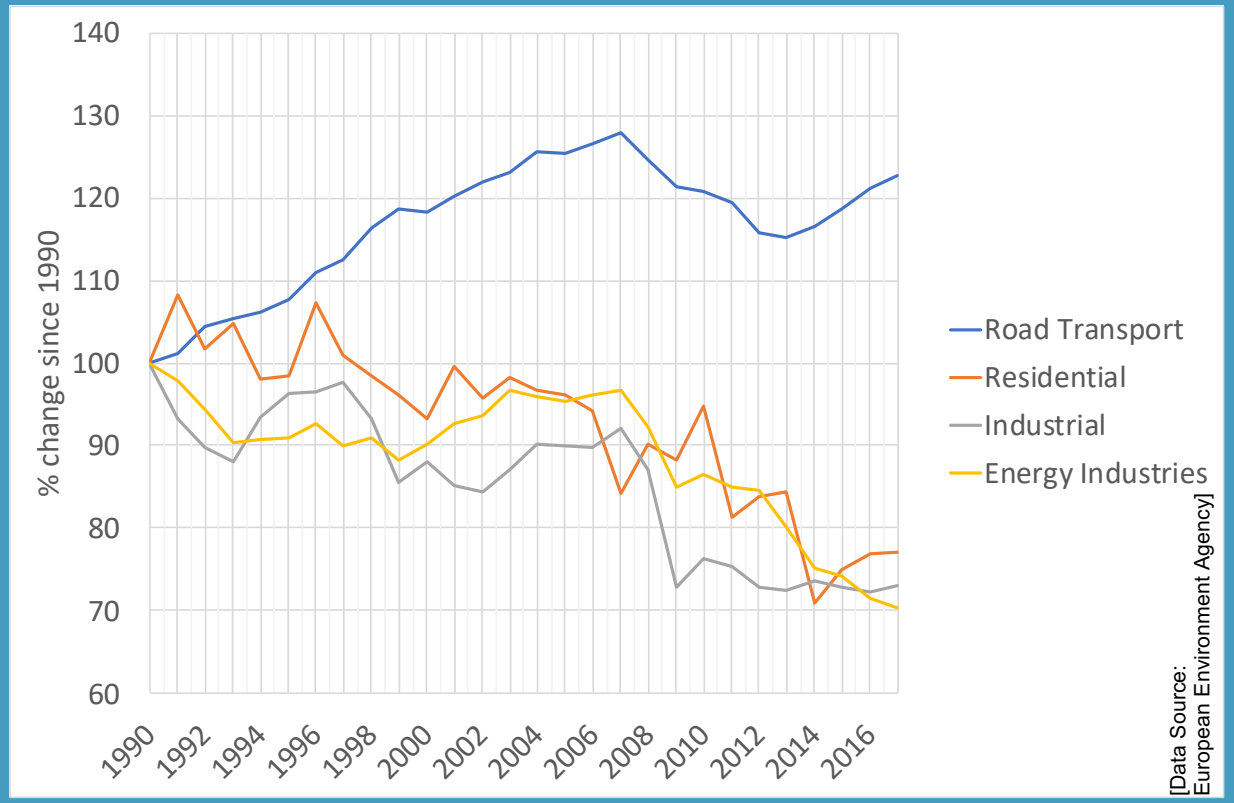
OUTLINE

- Why vehicular networking?
- How and what to communicate?
- Technological and scientific challenges for vehicular networking

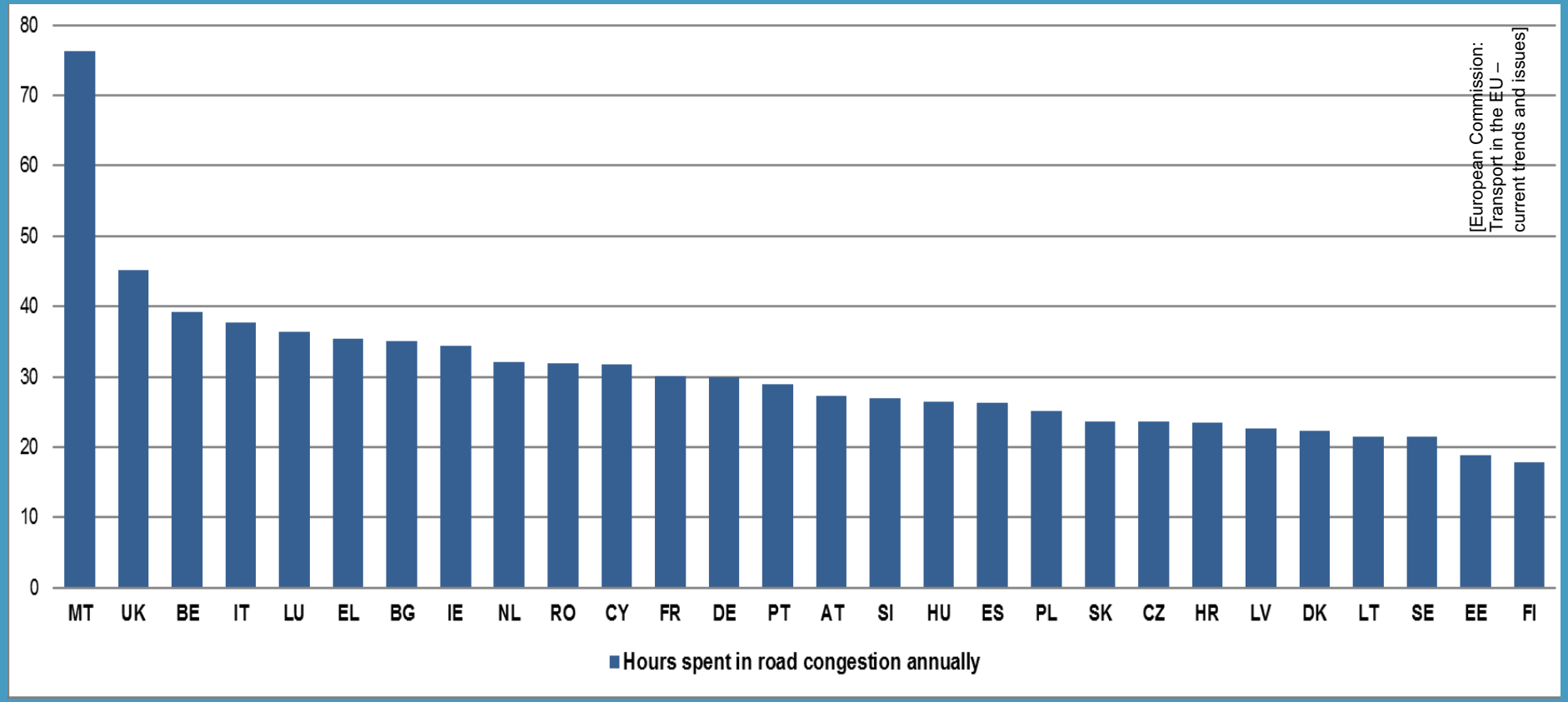
2017 GREENHOUSE GAS EMISSIONS EU TRANSPORT (25% OF TOTAL)



EU GREENHOUSE GAS EMISSIONS

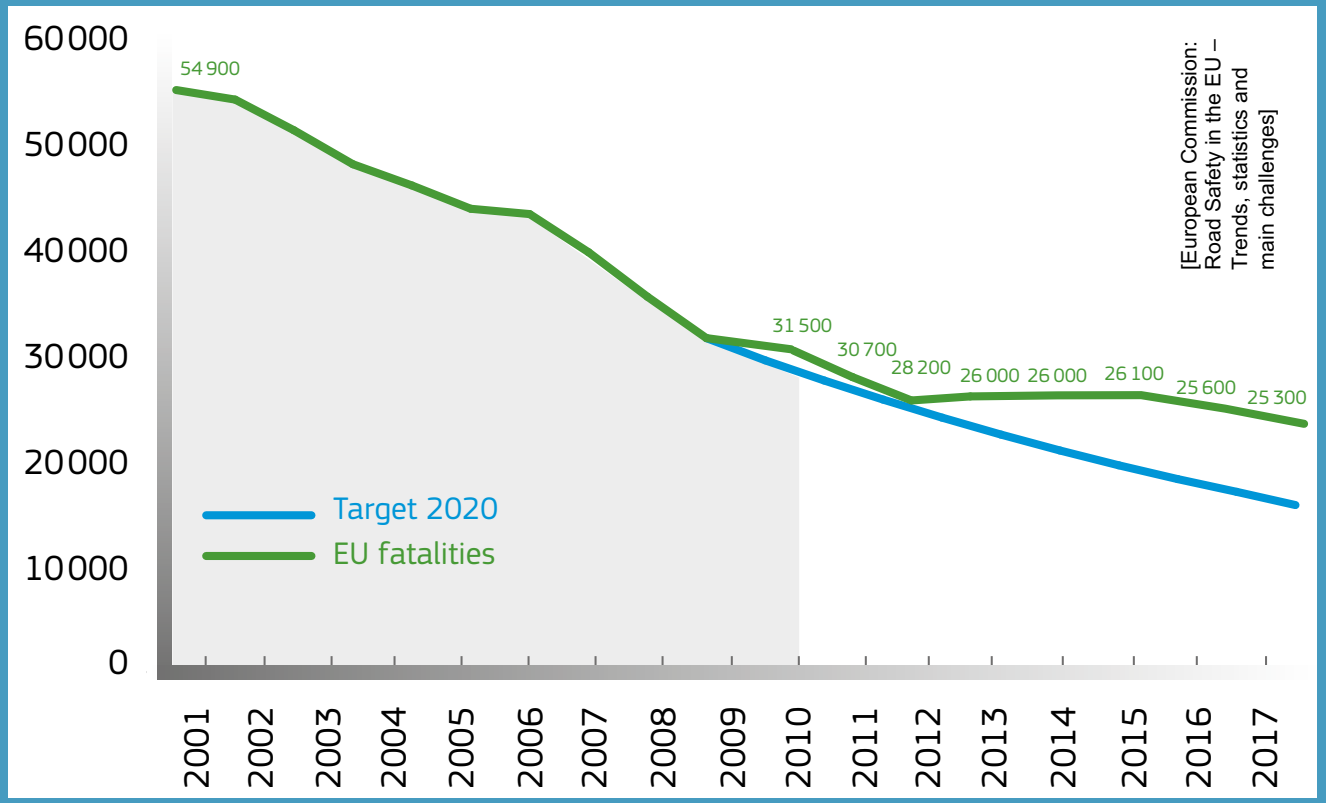


AVERAGE ANNUAL HOURS SPENT IN CONGESTION PER VEHICLE (2018)



Data source: European Commission, Joint Research Centre, based on TomTom data. Data for Cyprus include Nicosia agglomeration on both sides of the demarcation line. For methodological reasons, the data for Malta are of limited comparability with the ones for the other countries studied.

FATALITIES IN EU ROAD TRAFFIC



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Volvo says it will make 'death-proof' cars by 2020

By Ryan Whitwam on January 20, 2016 at 4:15 pm | 20 Comments

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Swedish automaker Volvo has long kept track of how many people are seriously in
killed while driving its vehicles. It uses this data to see how much safer it can make
vehicles in the event of a crash. Now, the company has made a bold promise — by
there will be no serious injuries or fatalities in a Volvo car or SUV.

Cars are getting smarter with the addition of autonomous technologies, and this is
Volvo hopes to reach its goal of zero deaths in its cars. This does not, of course, pr

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TRANSPORTATION UBER RIDE-SHARING

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Uber halts self-driving tests after pedestrian killed in Arizona

A woman was killed Sunday night in Tempe

By Andrew J. Hawkins | @andyjayhawk | Mar 19, 2018, 12:55pm EDT

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The New York Times

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Fatal Tesla Crash Raises New Questions About Autopilot System

Tesla's semi-autonomous driving system, shown here in 2015, is coming under new scrutiny after a fatal crash on March 23 in California occurred while the Autopilot feature was engaged. Beck Diefenbach/Reuters

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Tesla Autopilot design 'led to' crash

5 September 2019 Share

The design of Tesla's Autopilot system and "driver inattention" led to a crash in 2018, according to a US National Transportation Safety Board report.

THE POTENTIAL OF AUTONOMOUS DRIVING

VEHICULAR NETWORKING: INCREASING ROAD SAFETY

[Photo: Continental AG]

VEHICULAR NETWORKING: INCREASING ROAD EFFICIENCY

[Photo: Bart Klaassen]

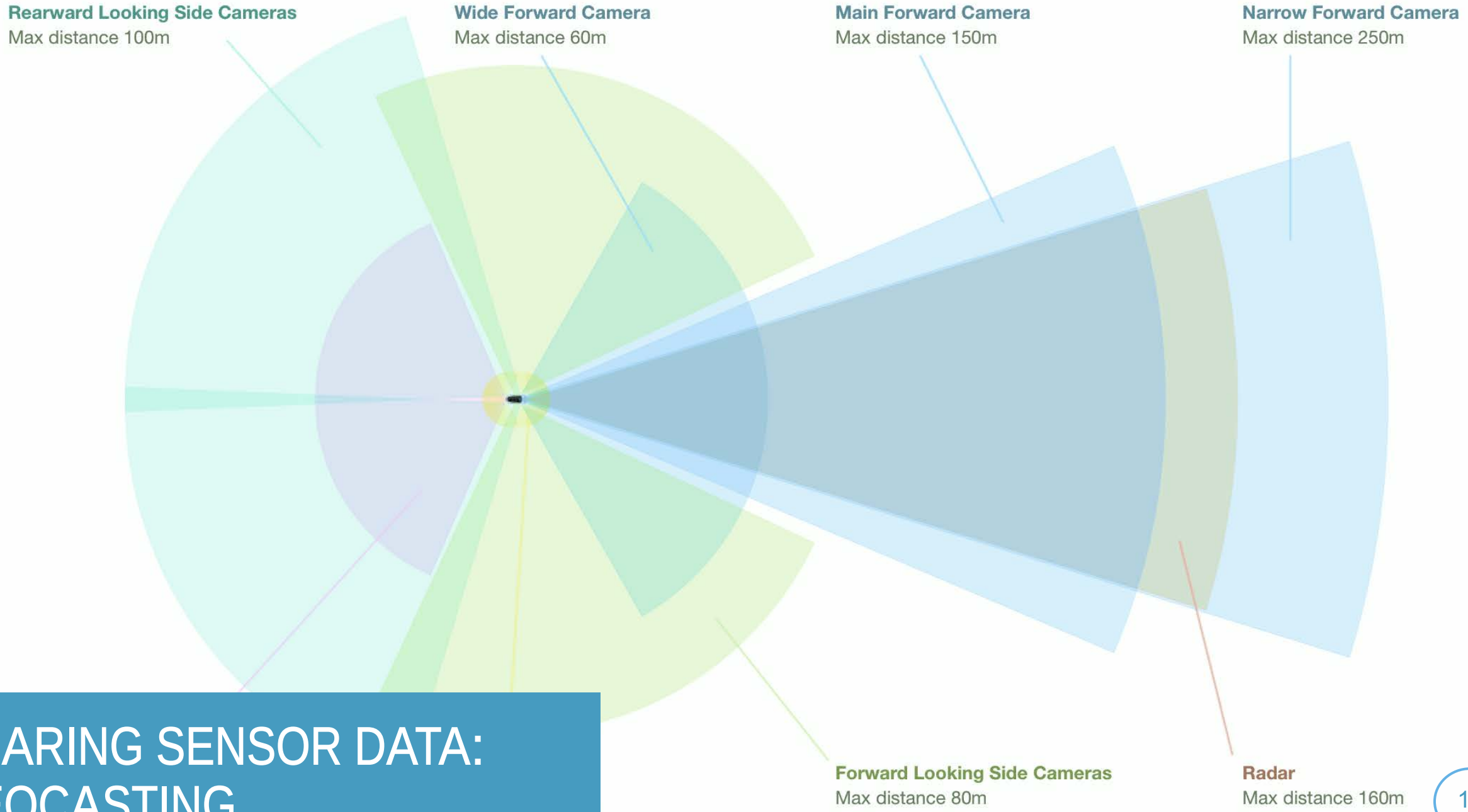
VEHICULAR NETWORKING: REDUCING EMISSION

[Photo: Volvo Group]

OUTLINE

- Why vehicular networking?
- How and what to communicate?
- Technological and scientific challenges for vehicular networking

CREATING AWARENESS: BEACONING



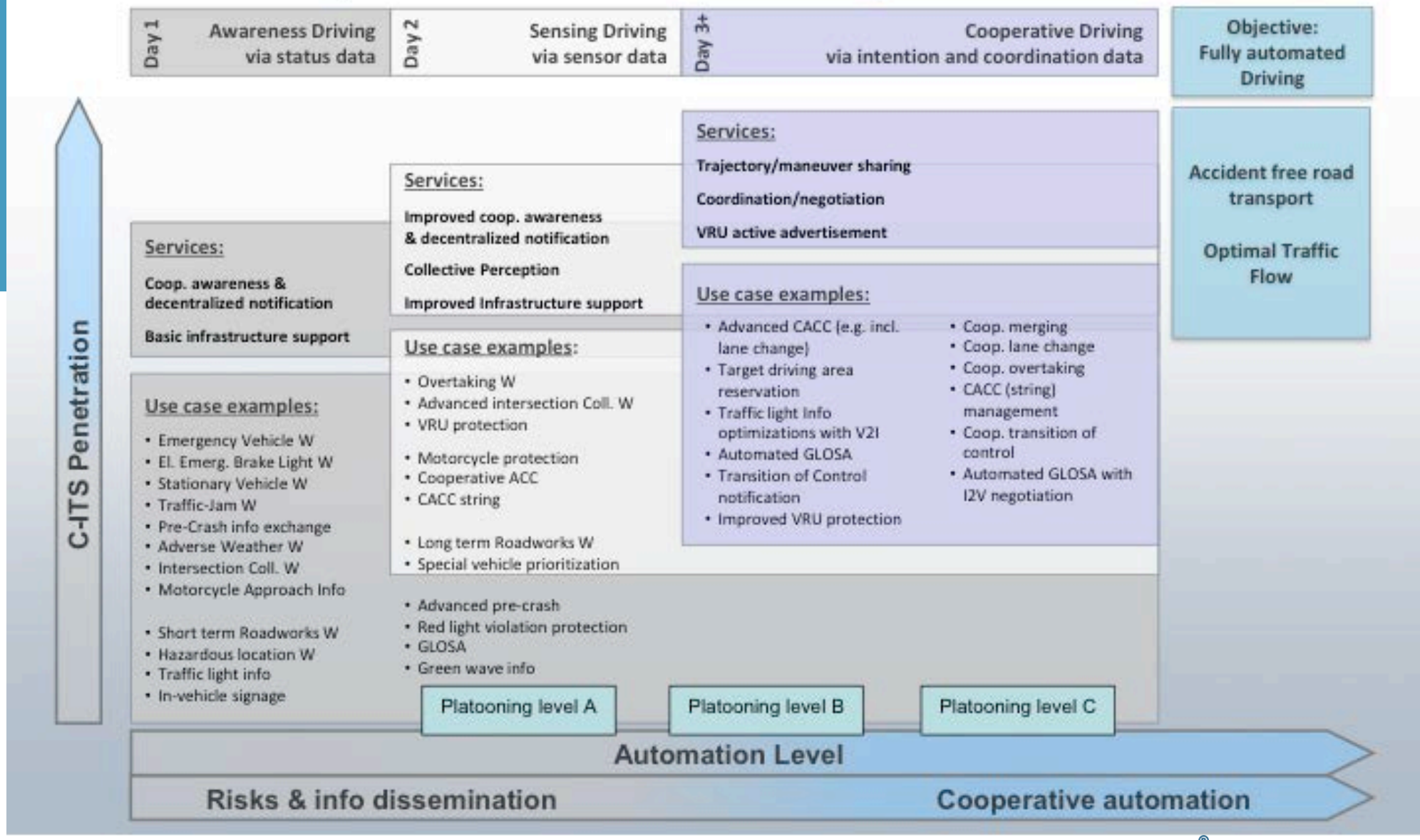
SHARING SENSOR DATA: GEOCASTING

[Picture: Tesla]

COOPERATION: SHARING INTENTION AND COORDINATION MESSAGES

[Photo: (CC) Kipp Jones]

TOWARDS COOPERATIVE AUTOMATED DRIVING



CAR 2 CAR COMMUNICATION CONSORTIUM

OUTLINE

- Why vehicular networking?
- How and what to communicate?
- Technological and scientific challenges for vehicular networking

TECHNOLOGY: 5G vs G5

- 3GPP C-V2X
  (Cellular Vehicle-to-everything)
- based on LTE / 5G
- Infrastructure-based,
  direct V2V possible via
  sidelink (PC5),
  w/w.o. eNodeB control

→ 5G-V2X

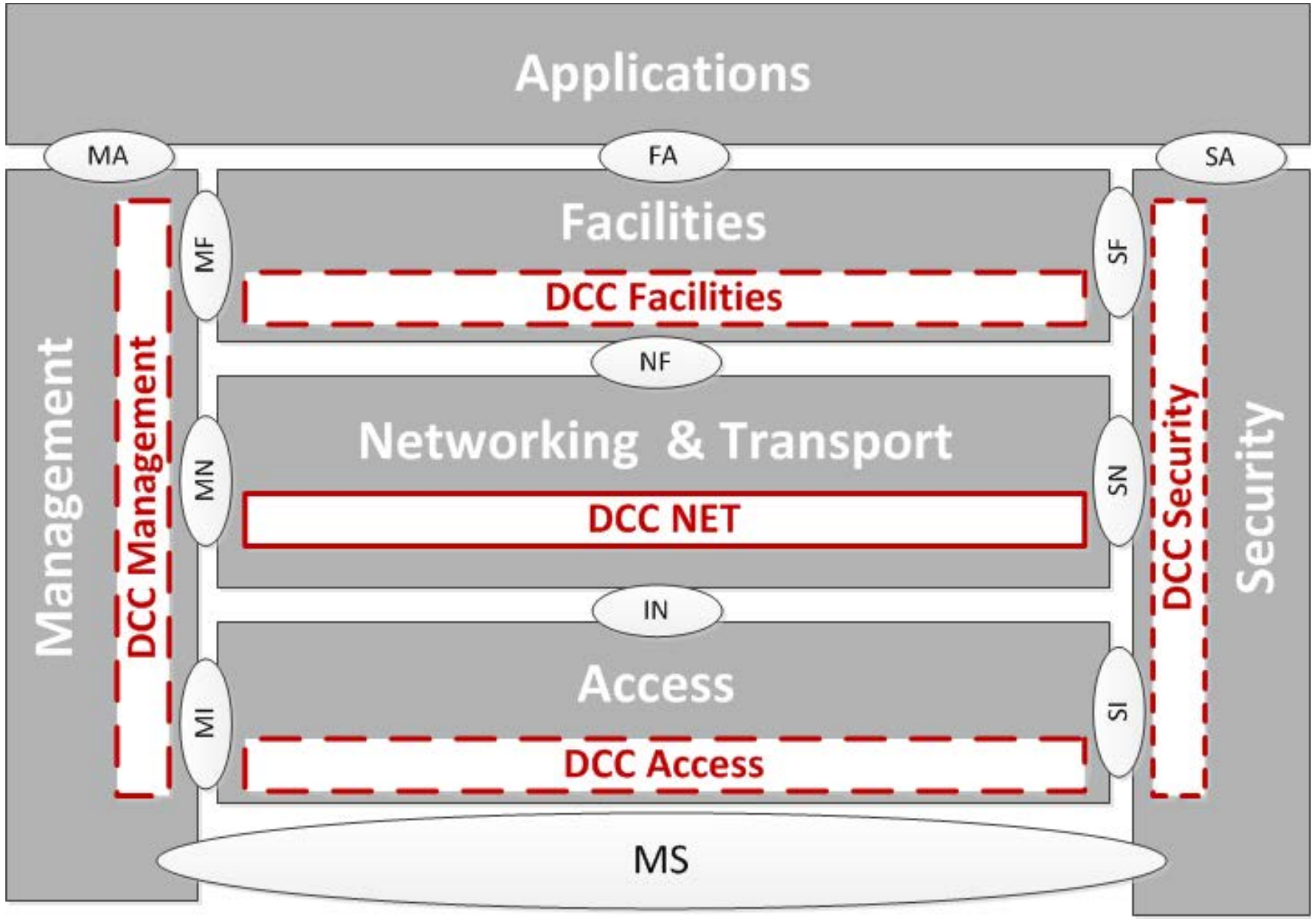
- ETSI ITS G5
  (Intelligent Transport Systems)
- based on IEEE 802.11p
- Fully distributed V2V,
  V2I via road-side units
  possible

→ 802.11bd

VEHICULAR NETWORKING RESEARCH CHALLENGES

- Providing extreme reliability
- (Distributed) resource management for a wide range of critical applications

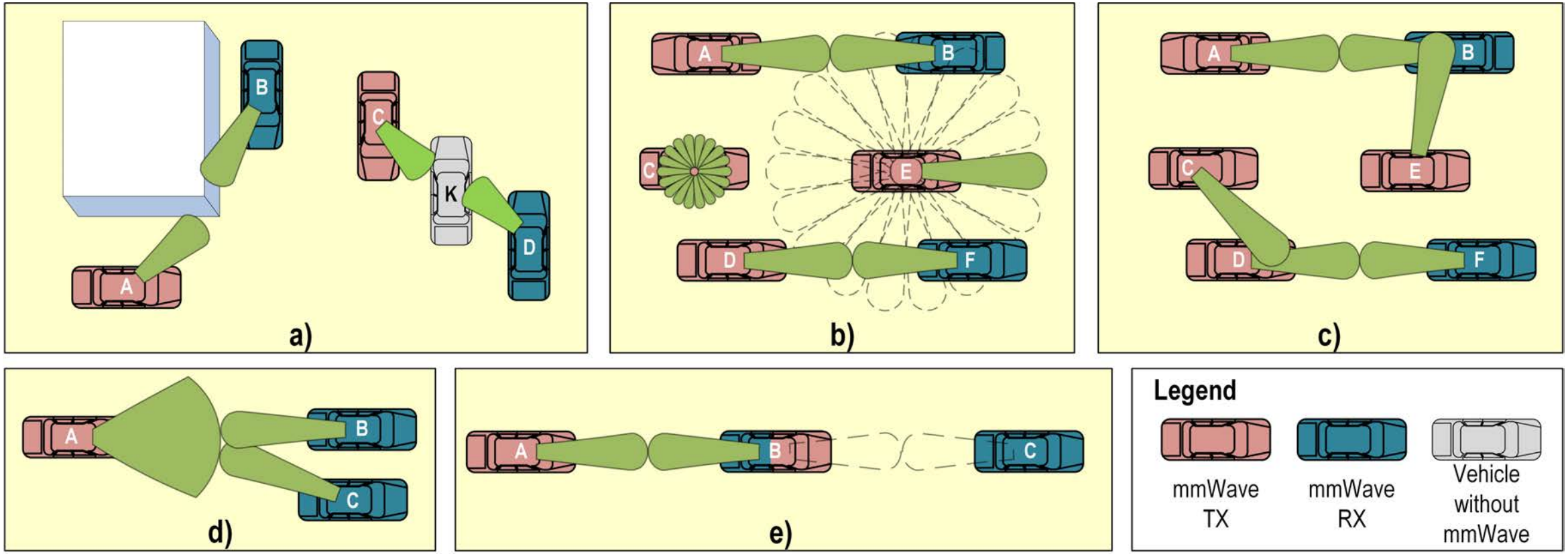
RESOURCE MANAGEMENT



[From: Jérôme Härri, C2C Communications Consortium, 2017.]

VEHICULAR NETWORKING RESEARCH CHALLENGES

- Providing extreme reliability
- (Distributed) resource management for a wide range of critical applications
- mmWave beam control



[From: B. Coll-Perales, J. Gozalvez, M. Gruteser, "Sub-6GHz Assisted MAC for Millimeter Wave Vehicular Communications", IEEE Communications Magazine, March 2019.]

MMWAVE BEAM CONTROL

VEHICULAR NETWORKING RESEARCH CHALLENGES

- Providing extreme reliability
- (Distributed) resource management for a wide range of critical applications
- mmWave beam control
- Joint modelling of wireless network and coordinated control
- Dealing with and exploiting extreme amounts of data

SUMMARY:

- Towards **Cooperative** Automated Driving
- Vehicular Networking:
  an essential ingredient for Intelligent Transportation Systems
- Many interesting research challenges

THANK YOU

geert.heijenk@utwente.nl

[Photo: Kasjan Farbisz]