UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Case Study Analysis: Vehicular Networks

Vehicles in Perspective

- More and more technology on vehicles:
  - TV-DVD system
  - GPS/Navigators
  - Connectivity available on board:
    - 4G, 5G…
    - Development of IEEE 802.11p standard
      - 300-1000 m range; up to 54Mbps

- Vehicles are more and more endowed with technology for communication, safety, work, entertainment, etc.

Intelligent Transport Systems

- Intelligent transport system (ITS) is an umbrella term for a range of technologies including processing, control, communication and electronics, that are applied to a transportation system.
- Main motivations: (1) safety and (2) transport efficiency
  - In Europe around 40,000 people die and more than 1.5 millions are injured every year on the roads
  - Traffic jams generate a tremendous waste of time and of fuel
- Europe's Transport Sector
  - 10% of the GDP in the EU
  - 5% of total employment in the EU
  - 2 million jobs in the automotive sector + 10 million jobs in the transportation sector
  - €70 billion/year exports
  - €35 billion investment in R&D by industry

EU Targets 2020 – 2050

- By 2050 reduce emissions by 60%, and 20% by 2020 (2008 level): estimated to 25% of total emissions
- By 2050 move close to zero fatalities in road transport
- Halve the use of conventionally-fuelled cars in cities
- Achieve virtually CO2-free city logistics in major urban centres by 2030
- Reducing Congestion: estimated to 2% GDP

Applications

PUBLIC / SAFETY

- APPROACHING EMERGENCY VEHICLE ASSISTANT
- EMERGENCY VEHICLE SIGNAL PREEMPTION
- VEHICLE BASED PROBE DATA COLLECTION
- TRAFFIC INFORMATION
- CURVE SPEED ASSISTANCE
- STOP LIGHT ASSISTANT – INFRASTRUCTURE
- INTERSECTION COLLISION WARNING/AVOIDANCE
- COOPERATIVE COLLISION WARNING [V-V]
- OPTIMAL SPEED ADVISORY
- COOPERATIVE VEHICLE SYSTEM – PLATOON
- RAILROAD COLLISION AVOIDANCE
- INFRASTRUCTURE BASED TRAFFIC MANAGEMENT – VEHICLES AS PROBES
- WORK ZONE WARNING
- ROAD CONDITION WARNING
- ROLLOVER WARNING
- LOW BRIDGE WARNING
- LOCATION BASED PROBE DATA COLLECTION
- TRANSIT VEHICLE DATA TRANSFER (gate)
- TRANSIT VEHICLE SIGNAL PRIORITY
- EMERGENCY VEHICLE VIDEO RELAY
- MAINLINE SCREENING
- BORDER CLEARANCE
- ON-BOARD SAFETY DATA TRANSFER
- VEHICLE SAFETY INSPECTION
- DRIVER'S DAILY LOG

PRIVATE

- ACCESS CONTROL
- DRIVE-THRU PAYMENT
- PARKING LOT PAYMENT
- DATA TRANSFER / INFOFUELING
  - ATIS DATA
  - DIAGNOSTIC DATA
  - REPAIR-SERVICE RECORD
  - VEHICLE COMPUTER PROGRAM UPDATES
  - MAP and MUSIC DATA UPDATES
  - VIDEO UPLOADS
- DATA TRANSFER / CVO / TRUCK STOP
- ENHANCED ROUTE PLANNING and GUIDANCE
- RENTAL CAR PROCESSING
- UNIQUE CVO FLEET MANAGEMENT
- DATA TRANSFER / TRANSIT VEHICLE (yard)
- TRANSIT VEHICLE REFUELING MANAGEMENT
- LOCOMOTIVE FUEL MONITORING
- DATA TRANSFER / LOCOMOTIVE

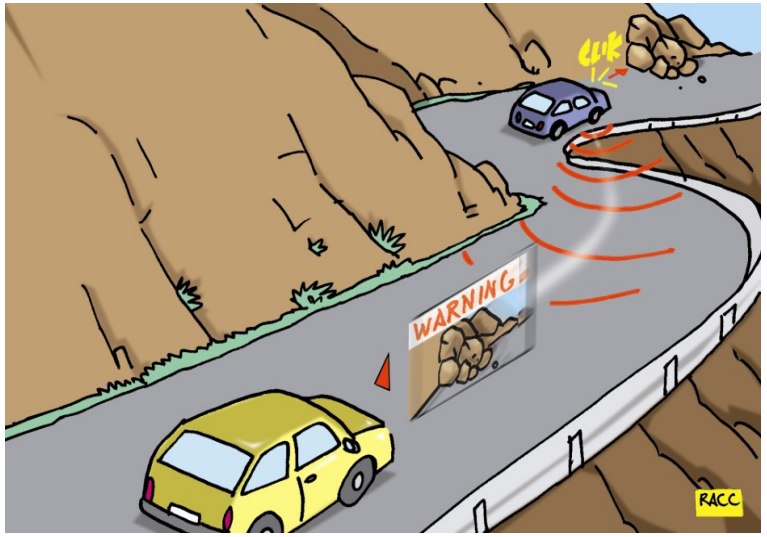
Internet Applications!

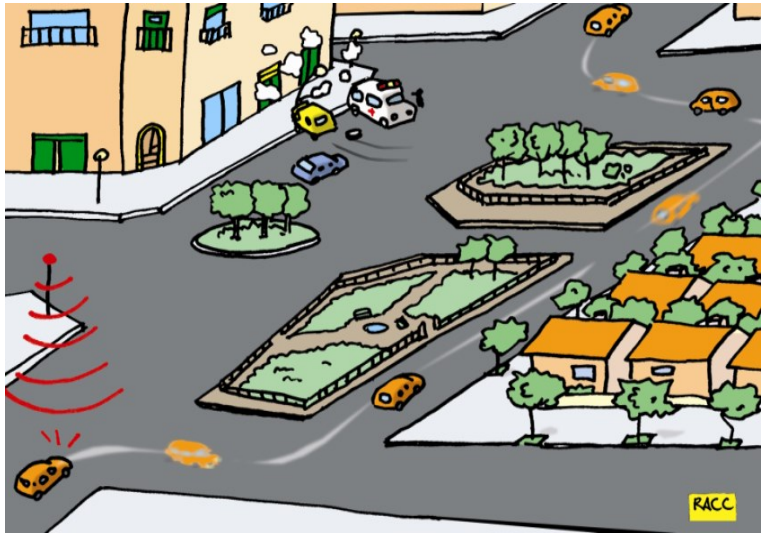
ATIS - Advanced Traveler Information Systems
CVO - Commercial Vehicle Operations

RED – Long Range Applications (up to 1000 meters)
BLUE – Medium/Long Range Applications (90-300 m)
BLACK – Medium Range Application (Up to 90 meters)

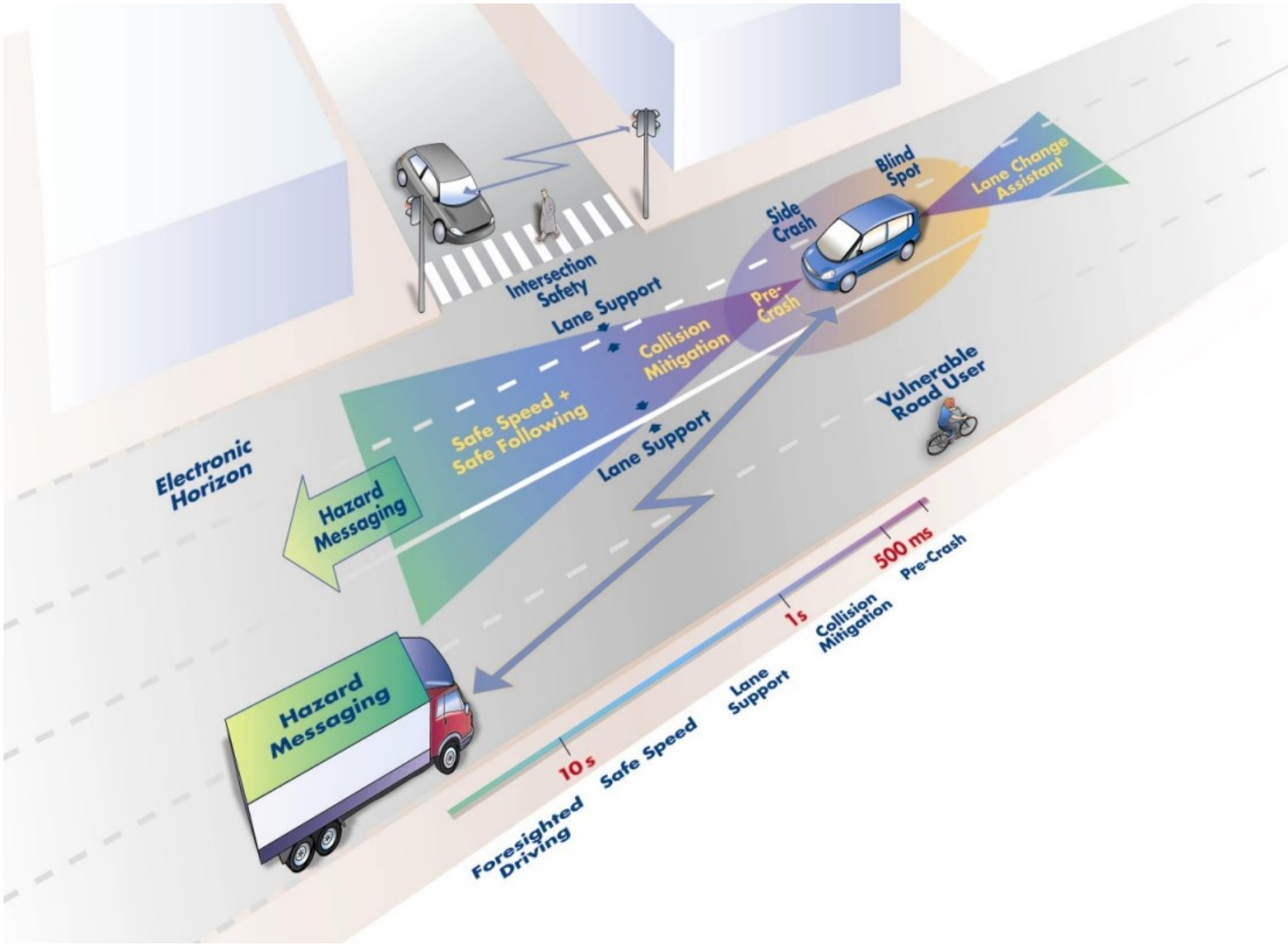
Safety & Driver Assistance Systems

- Active and Preventive Safety & Advanced Driver Assistance Systems (ADAS) will become connected and see a larger penetration in Europe over the next 20 years
  - Move towards a zero accident society
- Human-Machine Interface (HMI) will become more restrictive to avoid negative effects
- All services will be location based (**LBS**)

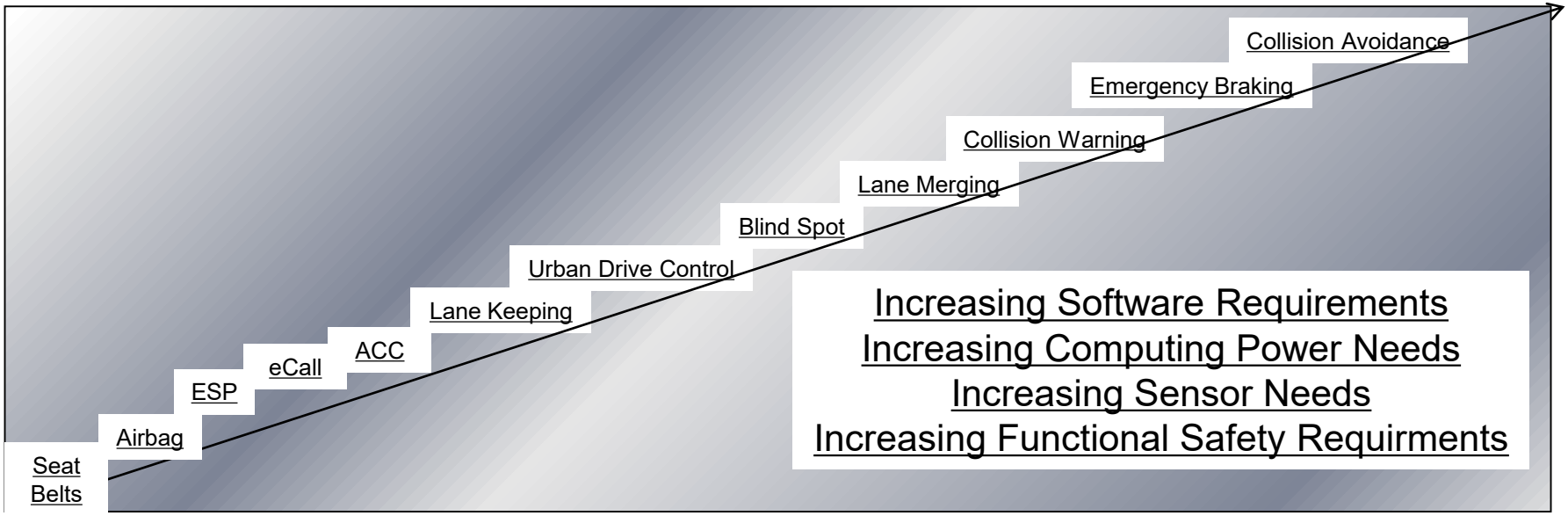


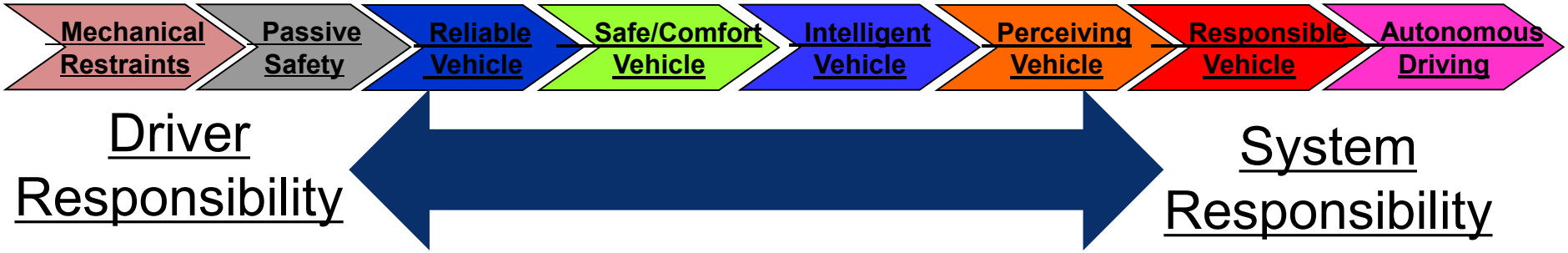


Safety scenario



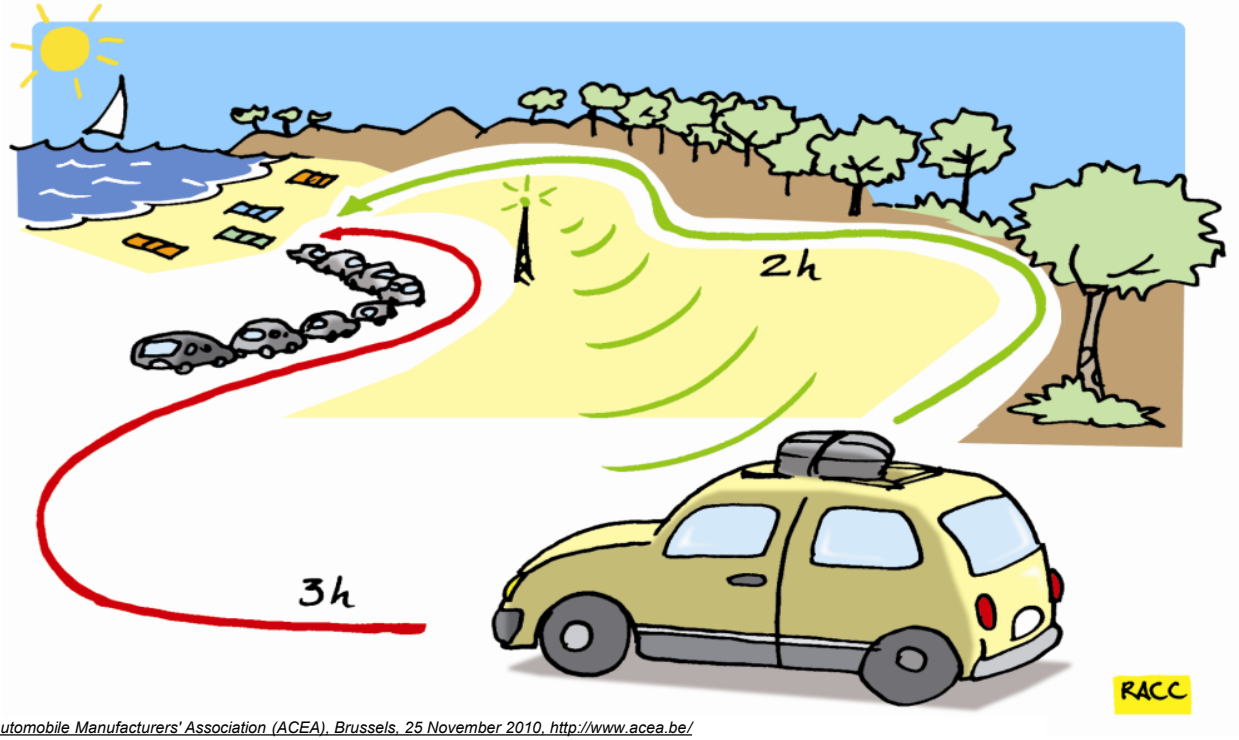
Driver To System Responsibility





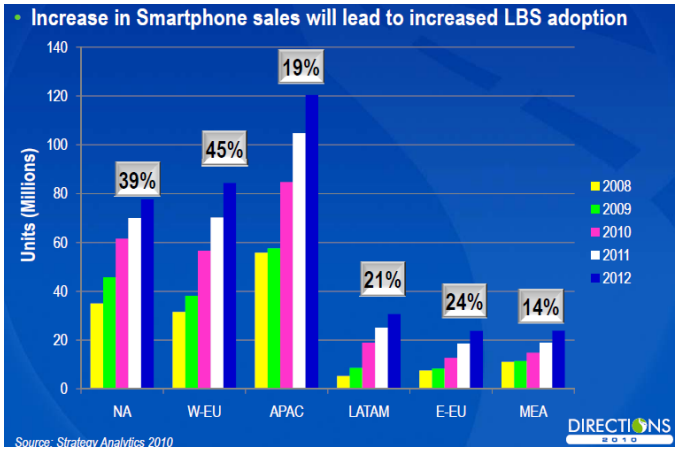
Eco-Driving Assistance

- Eco-Driving represents the largest potential for energy-efficiency but requires permanent feedback after training
  - Increasing fuel prices will push (slow) behaviour change
  - Eco-navigation and eco-routing become more important
  - Pressure to reach 25% energy saving potential by 2025



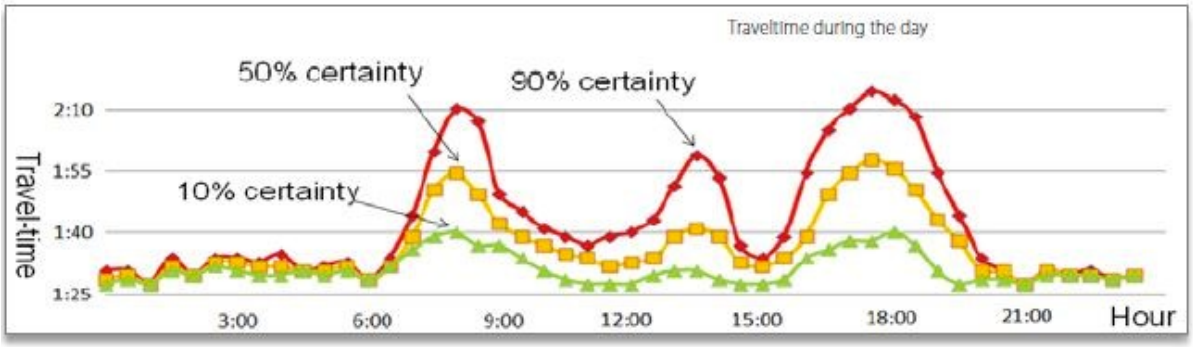
Dr. Wolfgang Reinhardt, European Automobile Manufacturers' Association (ACEA), Brussels, 25 November 2010, http://www.acea.be/

Real time Traffic/Travel information



Extended Floating Car Data (XFCD), traffic info platform

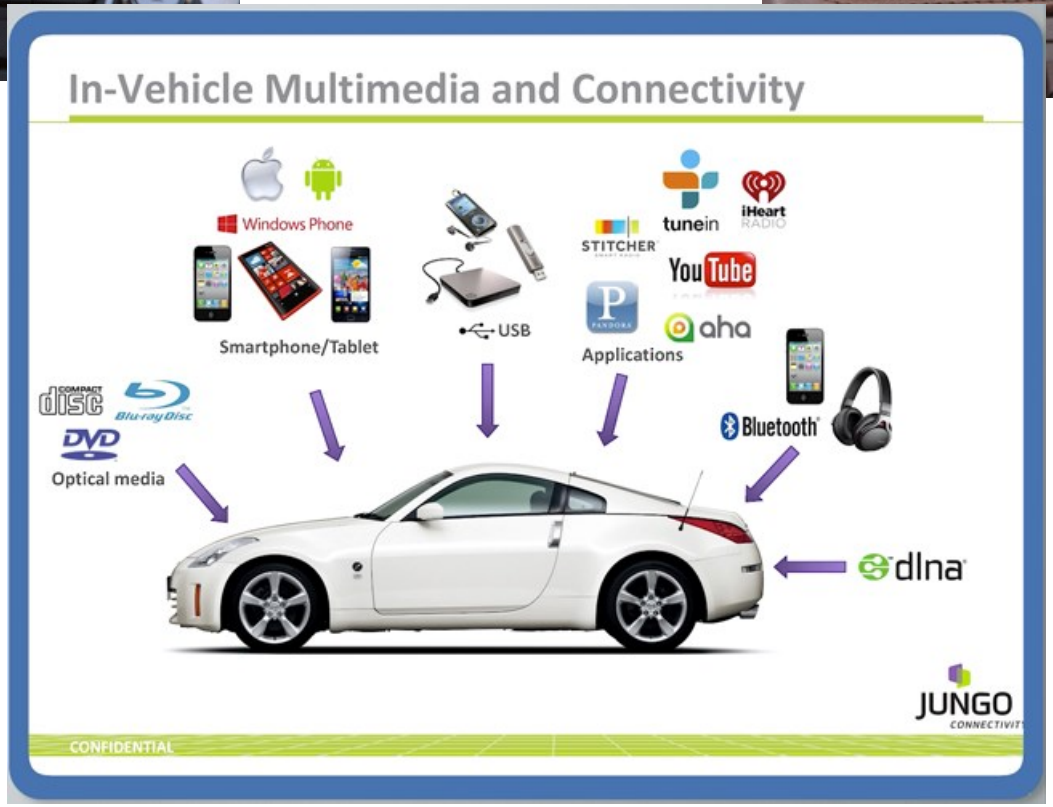
- Vehicles with systems (mobile or embedded) to access standardized Real Time Traffic Information (RTTI)



Multi-Modality

- Multi-Modality will develop over the next 20 years first in cities to combine private and public traffic and then extended to more traffic modes and regions

Infotainment



Smart connected electromobility

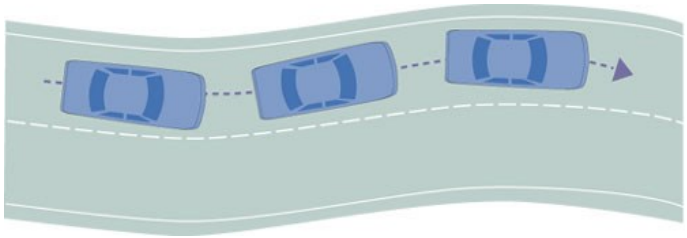
- Accelerate market penetration of electrical vehicles (incl. hybrids) by 2020 around 7 million vehicles and increasing
  - Vehicle park in Europe around 250 million units
- Electric Vehicles can play an important role in offering efficient, clean, zero-emission urban mobility
- Today first generation of Fully Electric Vehicles on the European market
  - Hybrids and plug-ins in the transition

Automated driving

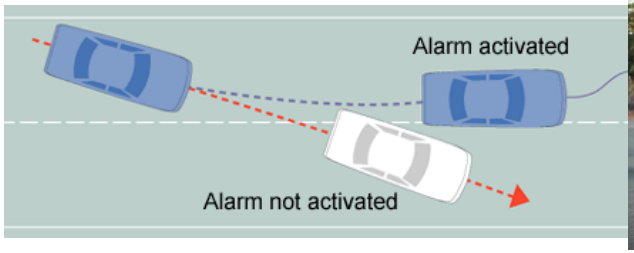
- A system present in a vehicle that allows it to drive itself from one point to another without assistance from a driver
- The driver needs assistance in increasingly complex traffic situations
  - The highly automated vehicle could take care of some driving tasks to make his/her task easier
  - **Majority of accidents (> 90%) is caused by human error.** The human is not always making optimal driving choices for (energy) efficiency either.
- Increasingly seen as the only long-term option

Credit: Junior, a robotic Volkswagen Passat parked at Stanford University

Credit: Mercedes-Benz



Lane keeping assistance



Lane deviation systems

Google car

Example of Application: Safe Driving

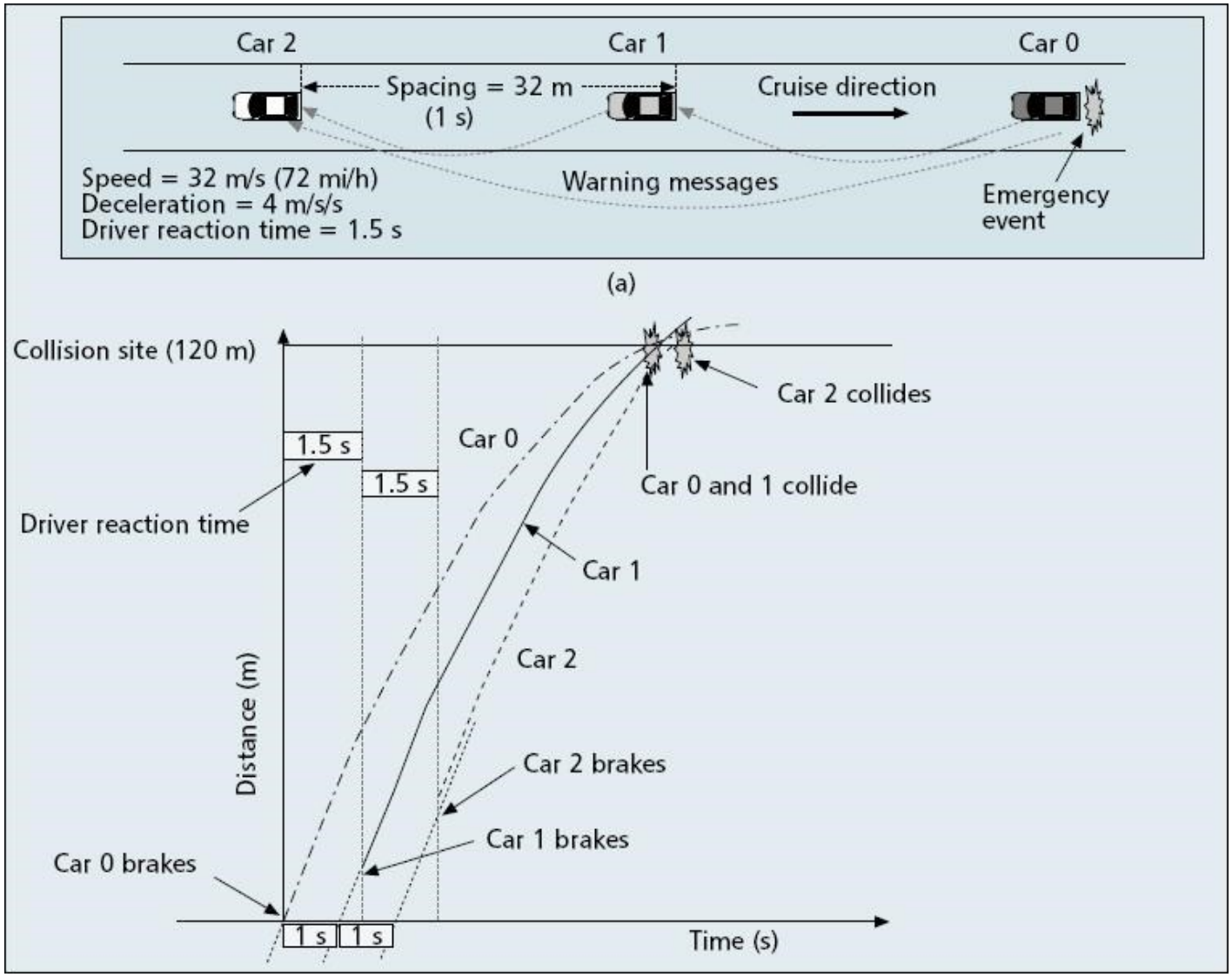
- Humans have limited sight and reaction time.

- Vehicle safety applications employs *Alert Messages* to overcome human's limitations
  - *Avoid multiple accidents*

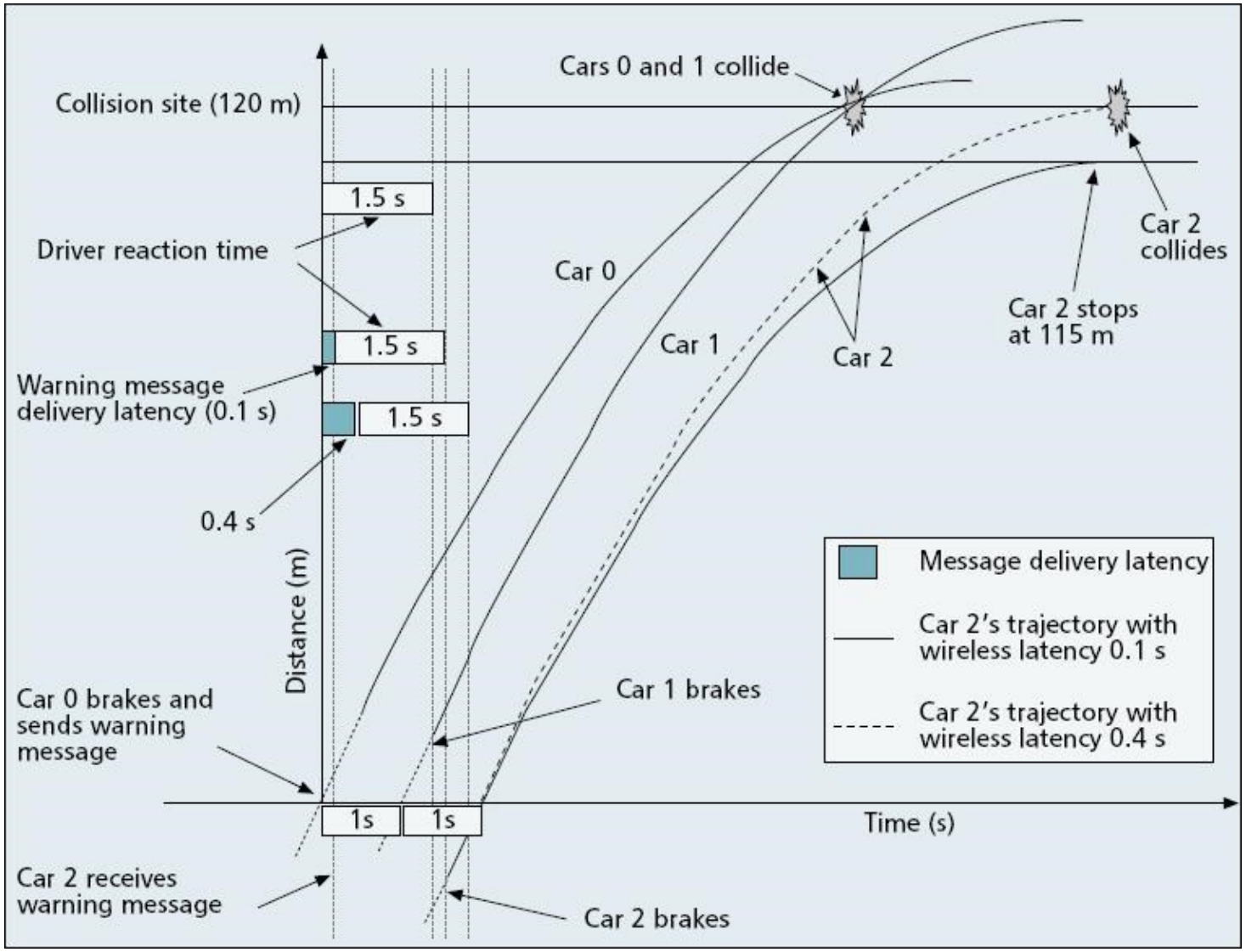
- In case of accident or abnormal behavior of a vehicle, alert messages are broadcast from the *Abnormal Vehicle (AV)* to following ones

https://www.youtube.com/watch?v=3z09fCqmILU
https://www.youtube.com/watch?v=Q8Cn47L8FRQ

Human Reaction: Multiple Crash



Employing Alert Messages



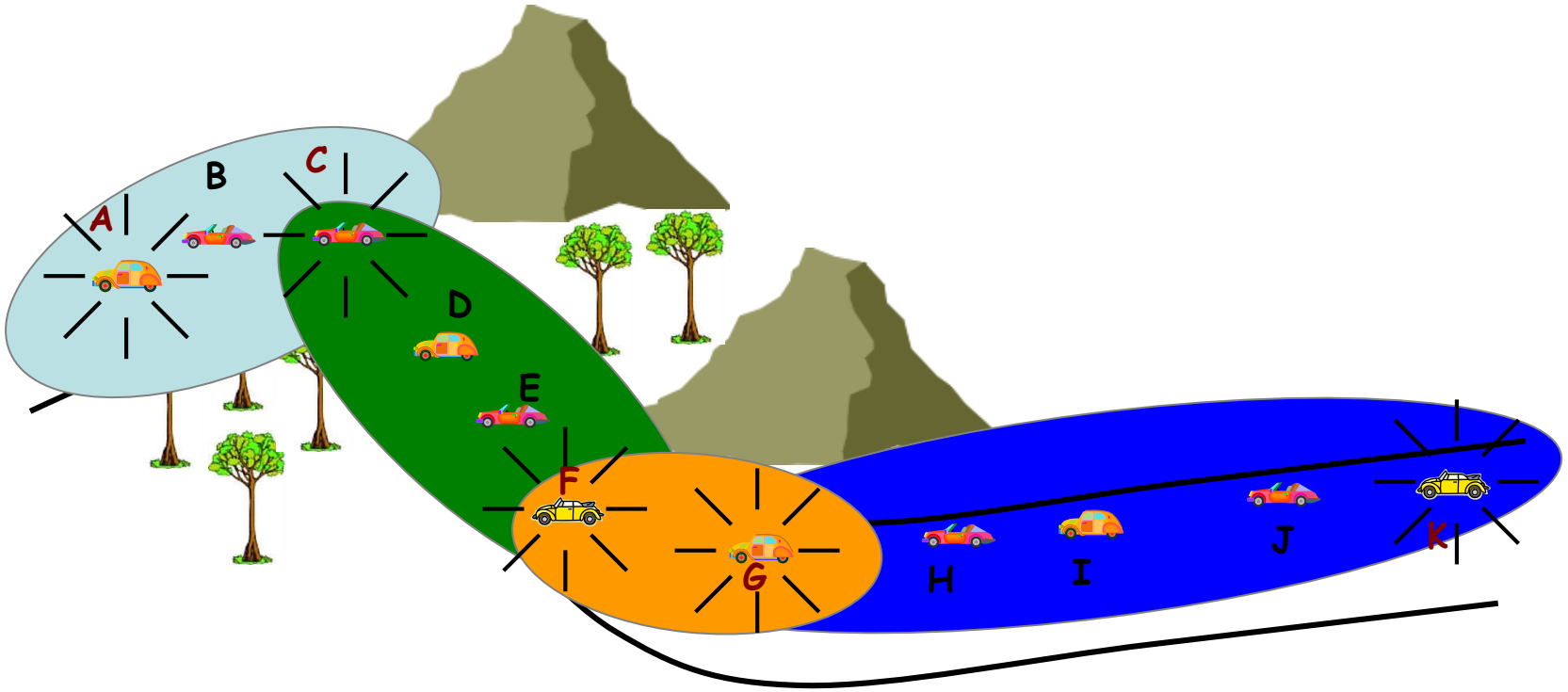
Safe Driving: Problem Statement

- Alert Messages has to be delivered very quickly to all cars following the Abnormal Vehicle (AV)

- Problems arise from multiple transmissions in case of accidents
  - multiple AVs
  - chain reactions

- Various proposals to reduce multiple (and redundant) transmissions
  - Use only specific nodes (e.g., the farthest ones from the sender?) to propagate the alert message

Simple Example



- Who has to forward the Alert Message?
  - Optimal solution: A, C, F, G, and F broadcast the *Alert Message* (one message and 4 hops)

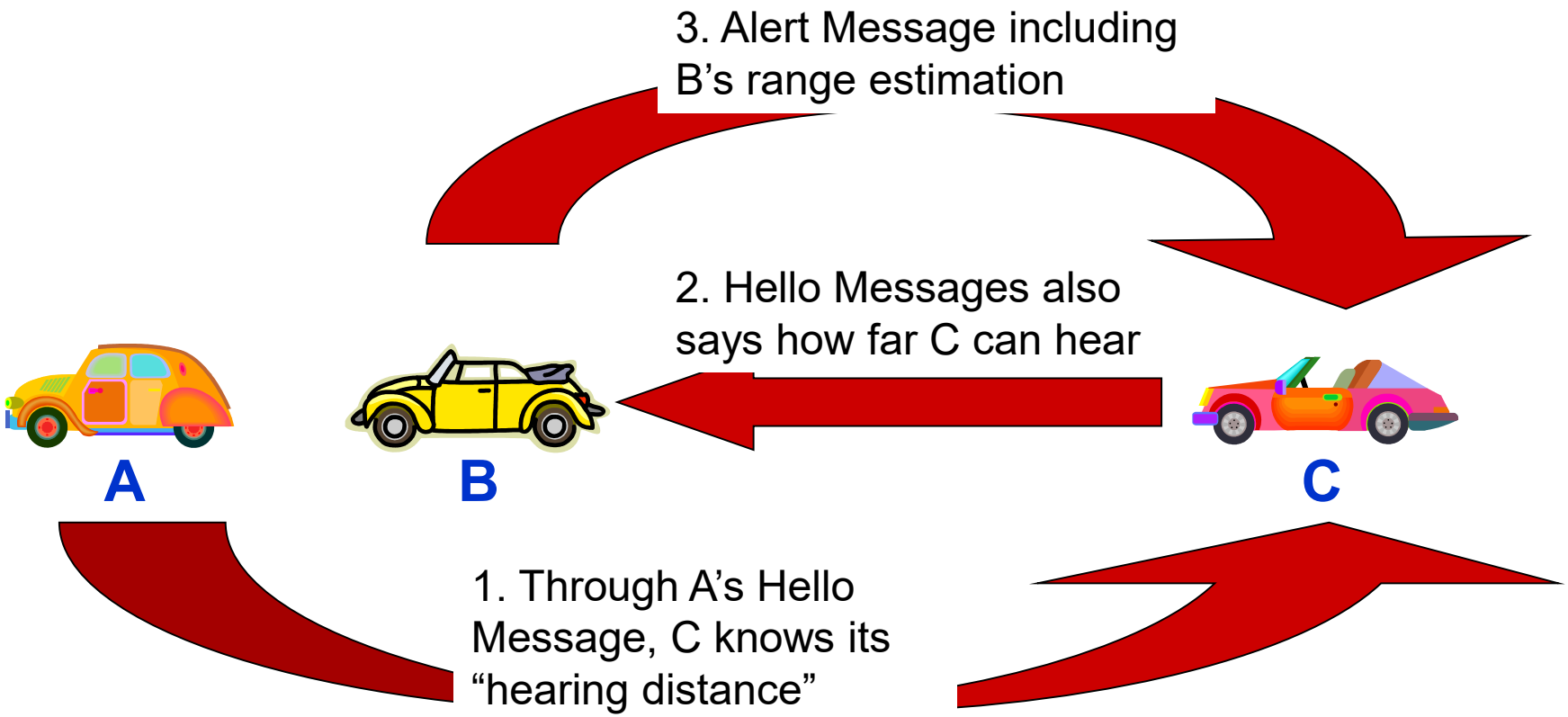
Fast Broadcast: Basics

- We need *Alert Messages* covering the area-of-interest in as less time as possible (as few hops as possible)

- Tipically: two phases
  - *estimation phase*: vehicles exchange few *hello messages* to collect information in order to **estimate their own tx range**.
  - *broadcasting phase*: the tx range estimation is put to good use to reduce the number of hops that an *Alert Message* will experience in its trip to destination.

Fast Broadcast: Two Kinds of Messages

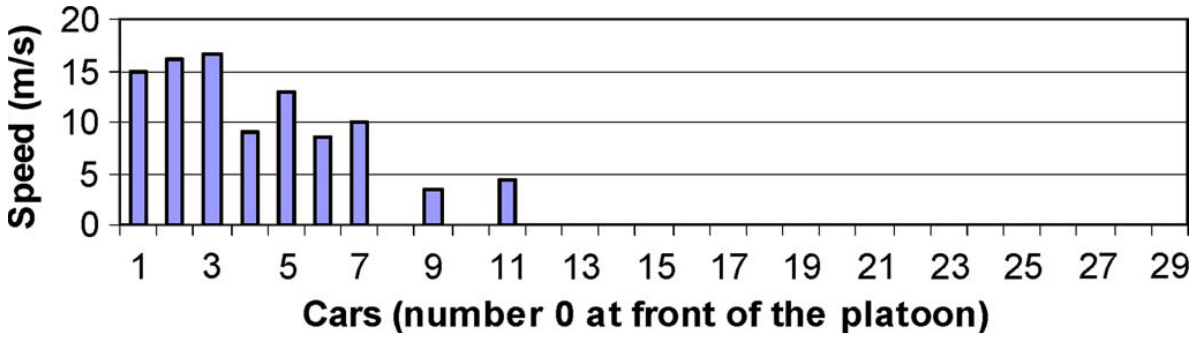
- In *Hello Messages:* information to estimate tx range
- In *Alert Messages:* sender's transmission range



Avoiding crash accidents

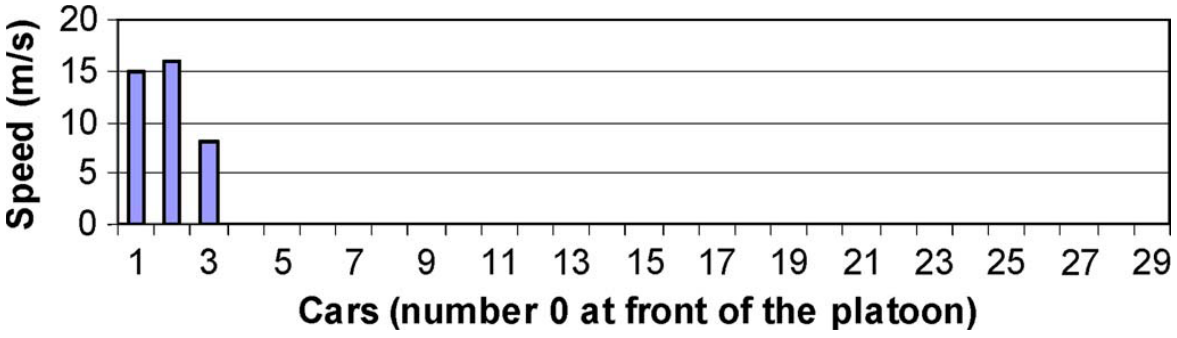
Speed after stop

If speed > 0 then accident at that speed

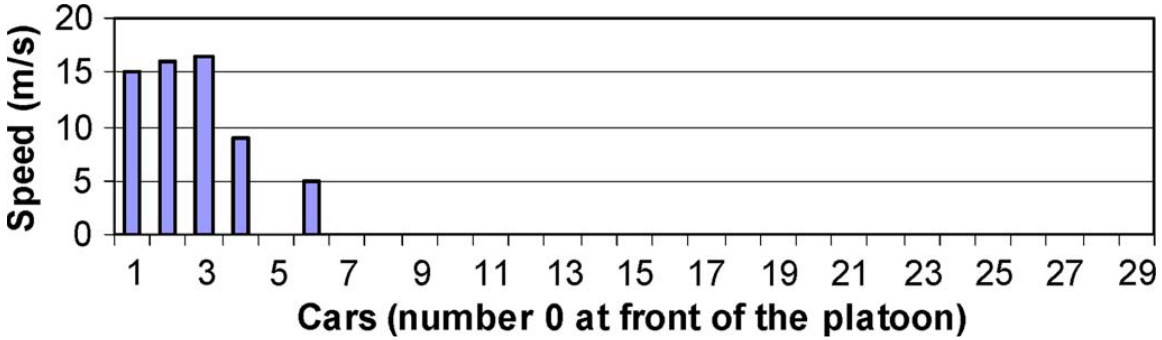


ALERT

none



all



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Autonomous Vehicles: Got Hackers?

https://www.youtube.com/watch?v=MK0SrxBC1xs

Autonomous Vehicles: Law Dilemma

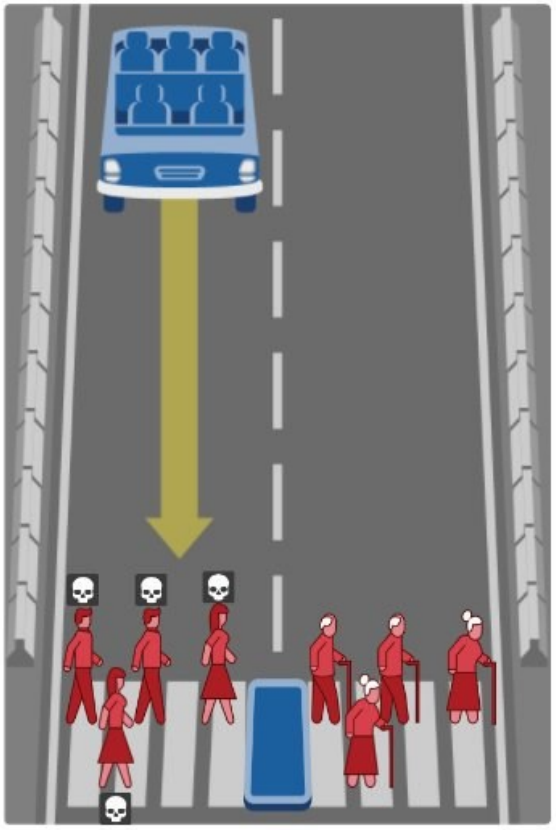
- Who is responsible in case of accident?
  - The “driver”
  - The car’s owner
  - The car’s manufacturer
  - The software developer
  - …

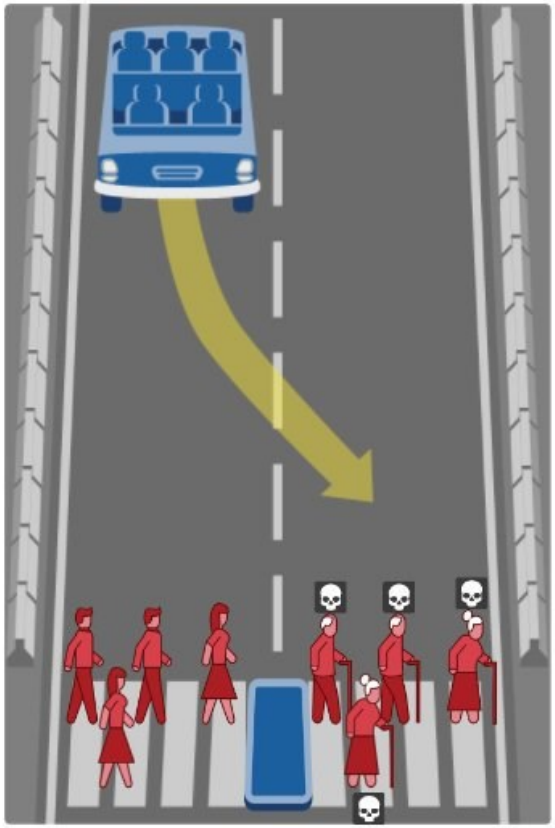
Autonomous Vehicles: Moral Dilemma

What should the self-driving car do?

In this case, the self-driving car with sudden brake failure will continue ahead and drive through a pedestrian crossing ahead. This will result in ...
Dead:

- 2 men
- 2 women





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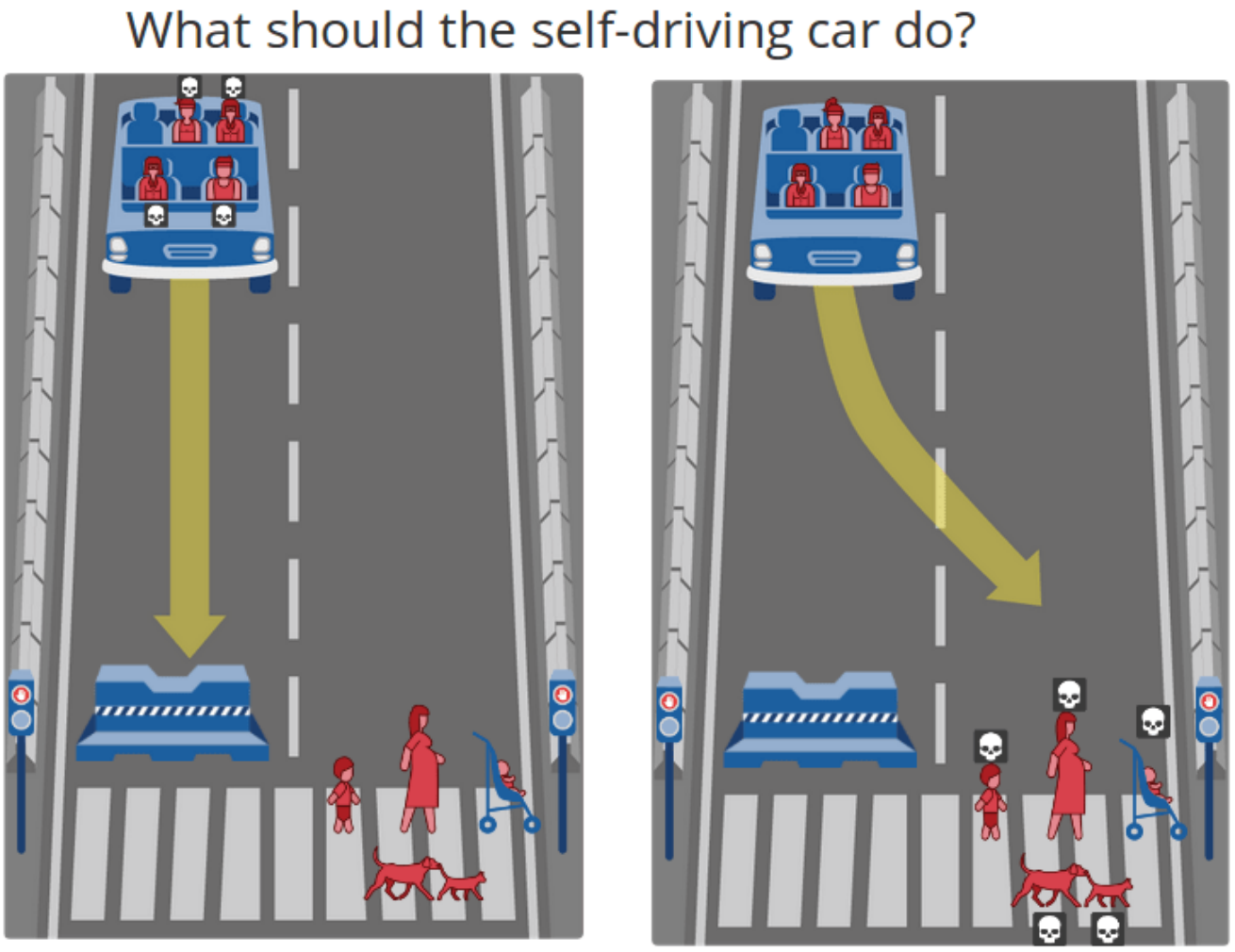
In this case, the self-driving car with sudden brake failure will swerve and drive through a pedestrian crossing in the other lane. This will result in ...
Dead:

- 2 elderly men
- 2 elderly women

Autonomous Vehicles: Moral Dilemma



http://moralmachine.mit.edu/