Smart Mobility Lab - Cooperative transportation solutions

Jonas Mårtensson, KTH
ACCESS Linnaeus Center

ACCESS Linnaeus Center

ACCESS was established from VR grant 2006

Developed into **a leading European university research center** in networked systems

- 36 faculty, 30 postdocs, >100 PhD students

Graduate school with **>50 graduated PhD’s**

Faculty renewal and mobility programs

Research program on the fundamental principles
for the design of the future **interconnected society**

Application projects on

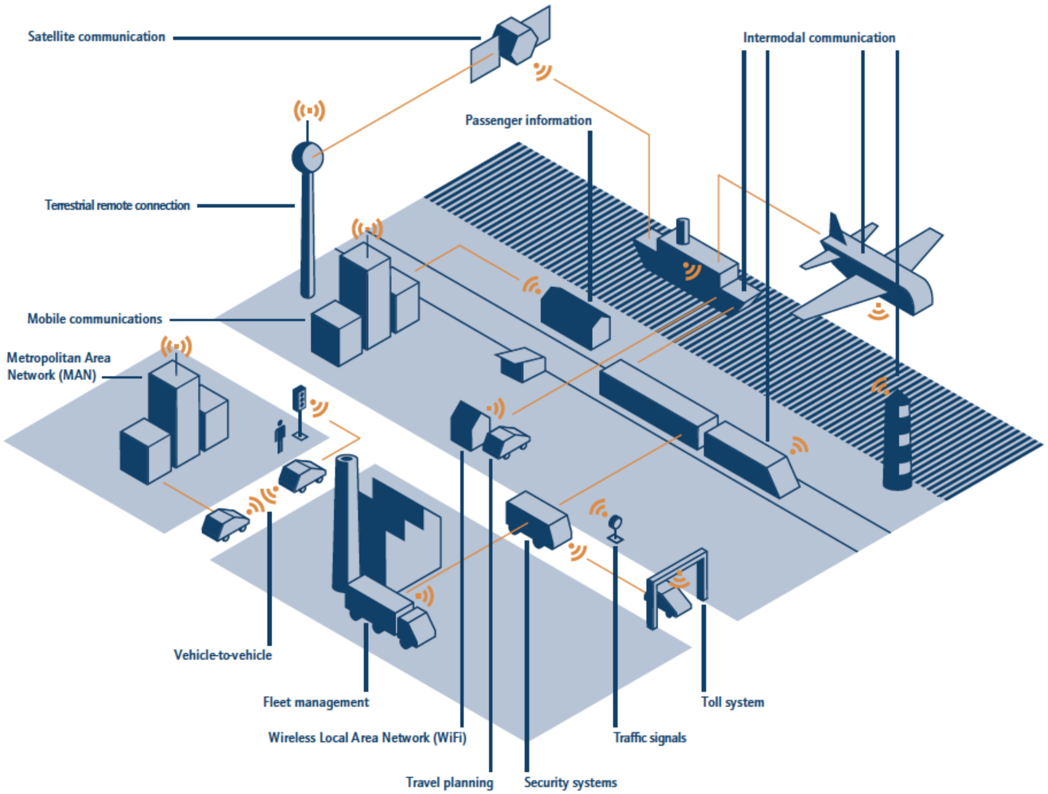
- Smart mobility
- Smart energy grid
- Multimedia communications

© Jonas Mårtensson, KTH

> *“[ACCESS] is the largest and leading research center in its field in Europe, being able to generate world-class research and being highly attractive for international recruitments and exchanges.”*
>
> MID-TERM EVALUATION REPORT 2012

Cyber-physical transportation system

- The transportation system is a cyber-physical system
- Mainly without global control and optimization
- New information technology has dramatic potentials



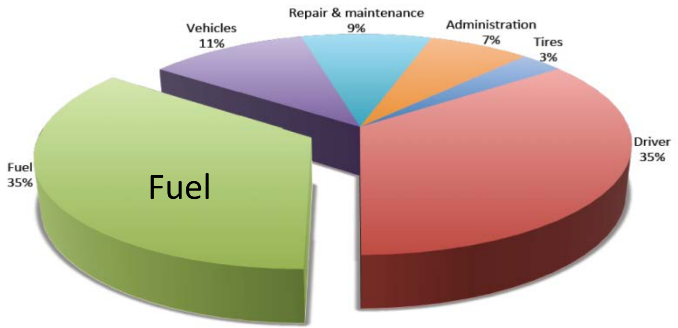
Cyber-Physical Systems Roadmap, German National Academy of Science and Engineering, 2011

Demands from Goods Road Transportation

- Transport sector consumes 1/3 of EU energy
- 45% of all freight transport is on roads
- Road transport accounts for 20% of CO_2 emissions
- Emissions increased by 21% for 1990-2009

Eurostat (2011), EU Transport (2013)

Life cycle cost for European heavy-duty vehicle



Total fuel cost 80 k€/year/vehicle

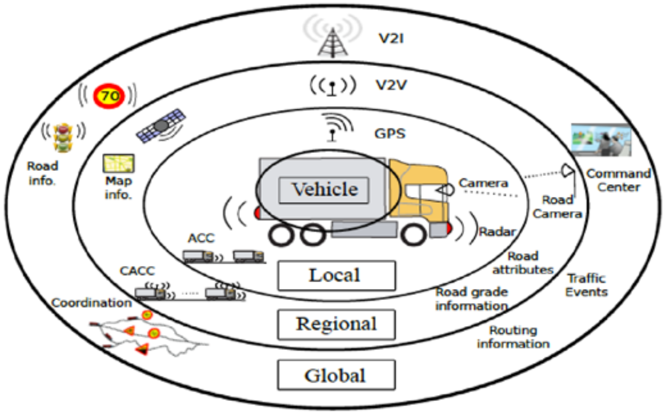
Schittler, 2003; Scania, 2012

- 24% of long haulage trucks run empty
- 57% average load capacity

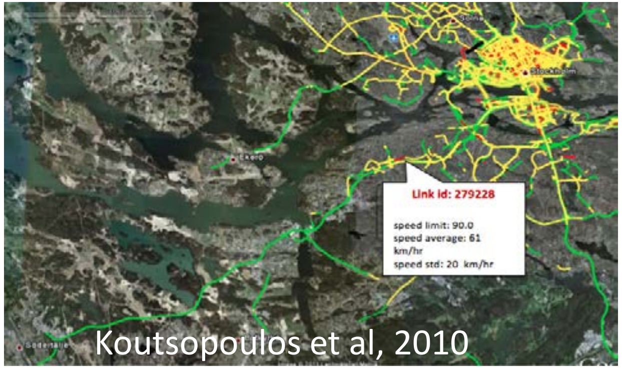
Dr. H. Ludanek, CTO, Scania

Technology push

Sensor and commununication technology



Real-time traffic information



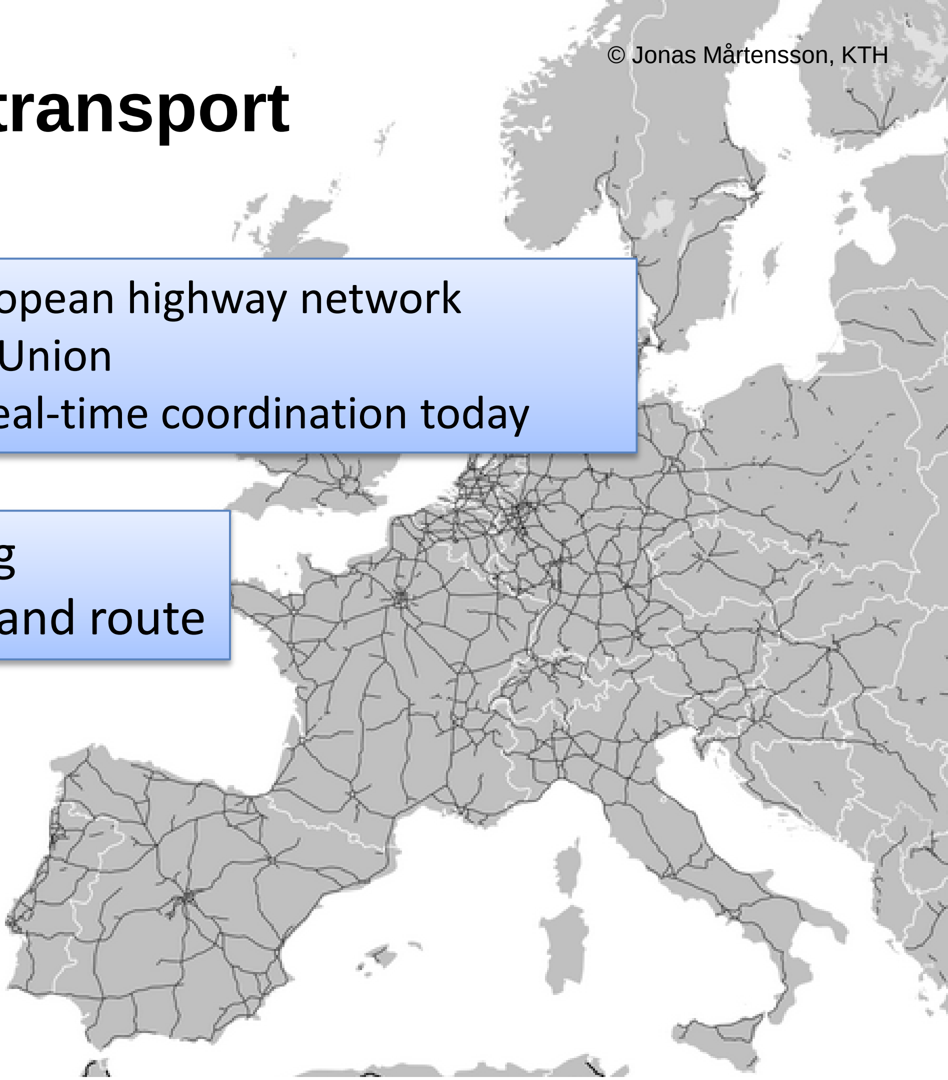
Koutsopoulos et al, 2010

Vehicle platooning and semi-autonomous driving

Fuel optimized goods transport

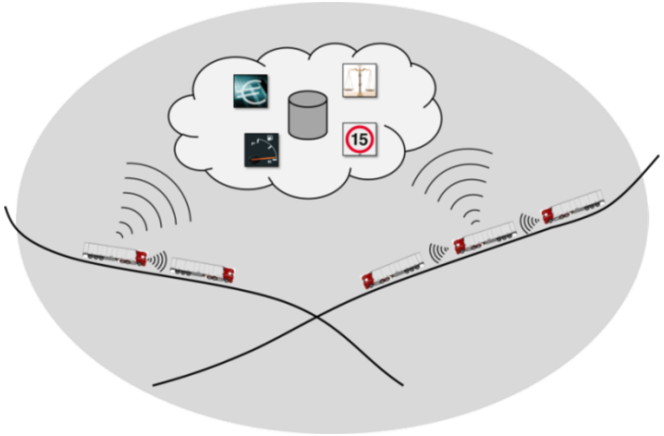
- Goods transported between cities over European highway network
- 2 000 000 long haulage trucks in European Union
- Large distributed control systems with no real-time coordination today

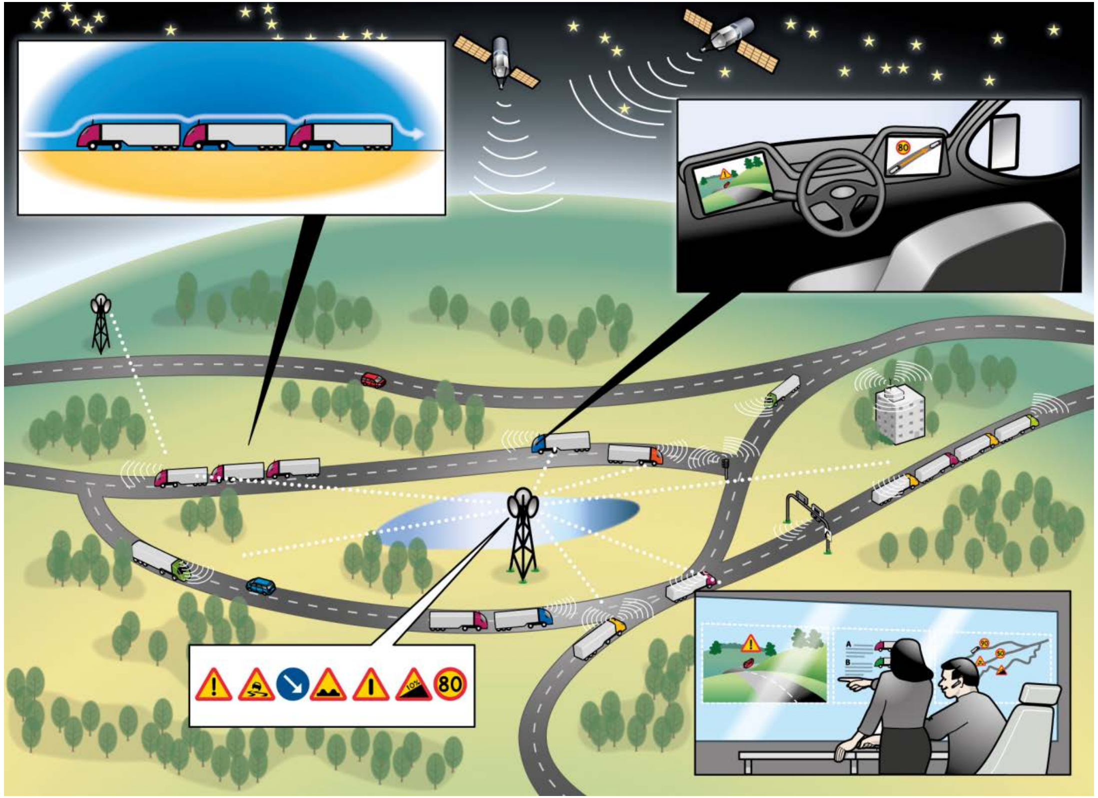
Goal: Maximize total amount of platooning
with limited intervention in vehicle speed and route



Real-time coordination of transports

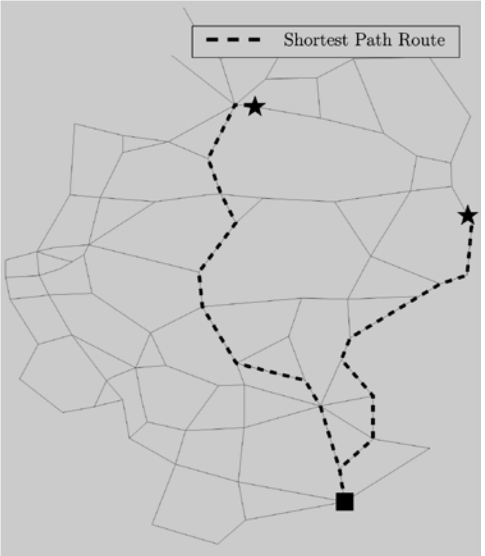
- ICT infrastructure
- V2x communication
- GPS
- Sensor technologies
- On- and offboard computing

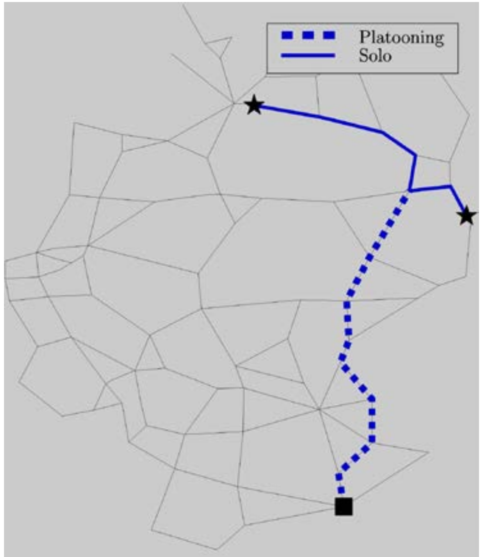


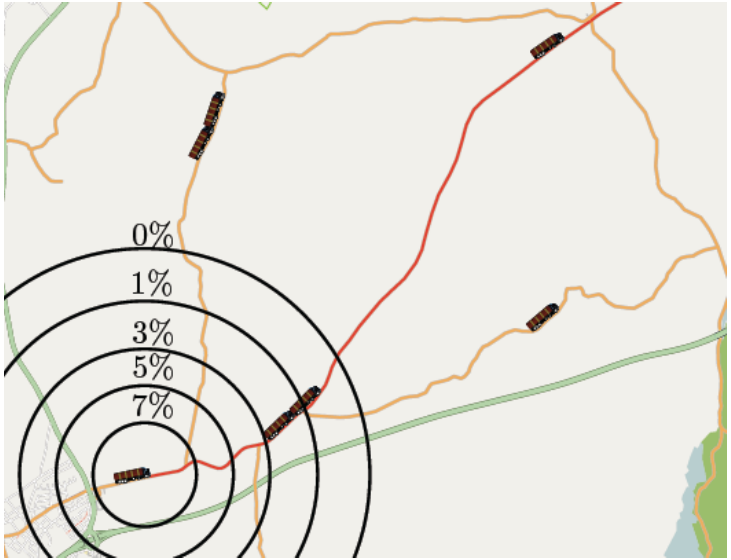


Real-time platoon formation

- Fuel optimal paths with platooning
- Adjusting speed or route
- On-time deliveries
- Requires fuel prediction models

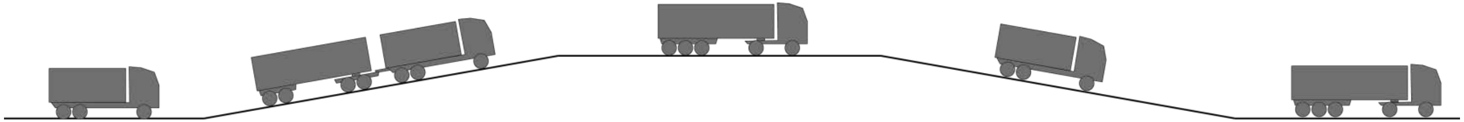






Platooning in hills

- Heterogeneous vehicles in a platoon is a problem in uphills and downhills, especially for heavy vehicles
- How can preview information of the road be used for platooning?
- Minimize the fuel consumption of the whole platoon while keeping the average velocity constant

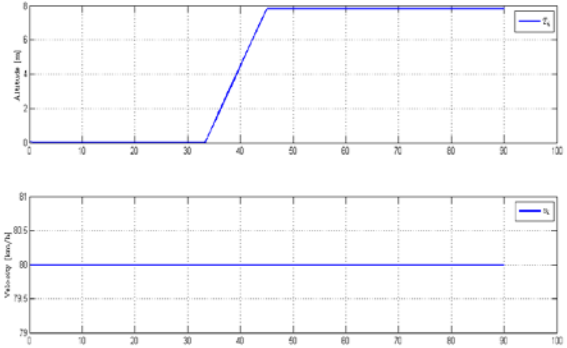


Available cruise controllers

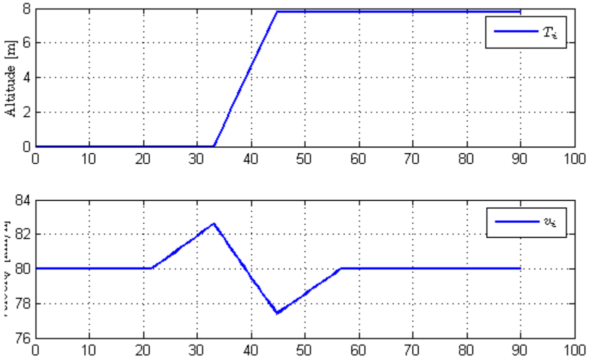
- Cruise Control (CC): Maintains a constant velocity
- Adaptive Cruise Control (ACC): Maintains a constant headway time or distance to the vehicle ahead
- Look Ahead Cruise Control (LAC): Fuel-optimal velocity profile based on preview information

Look-ahead Control for Single Vehicle

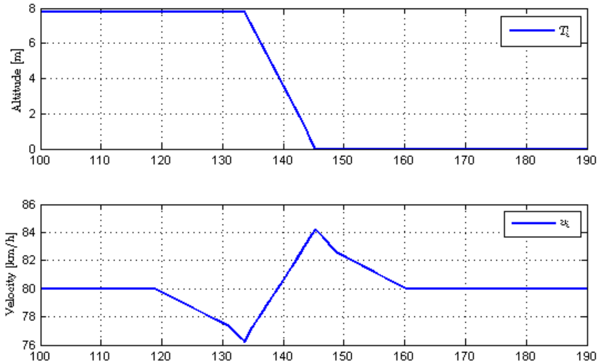
Minimize fuel while keeping average velocity constant



Maintain velocity when possible



Increase velocity before uphill



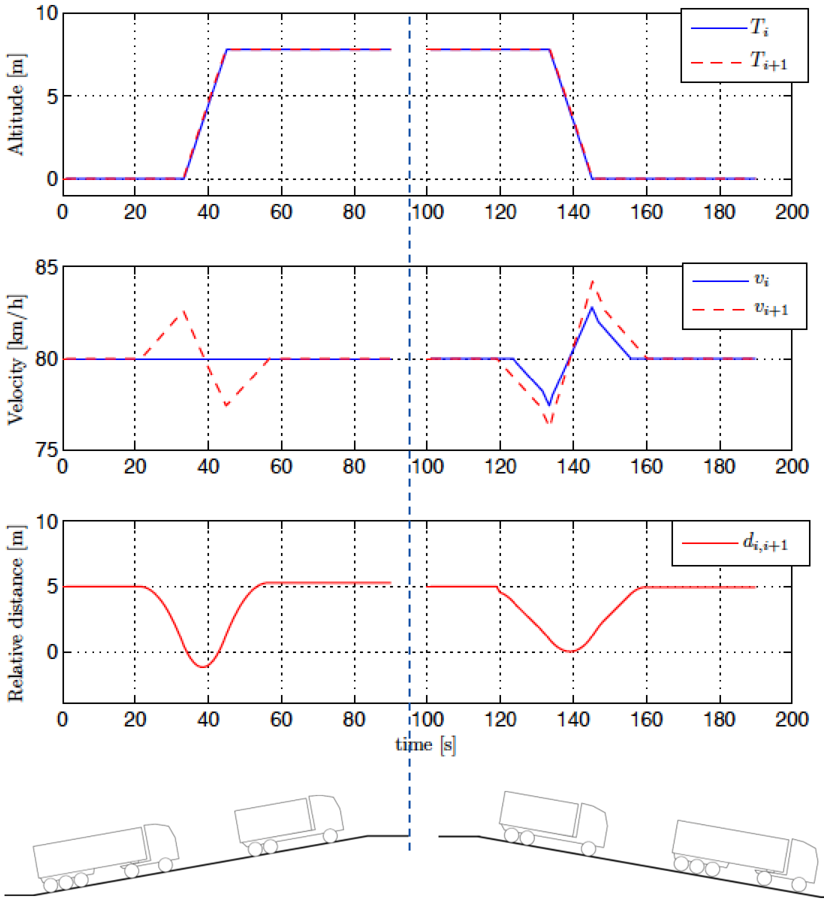
Decrease velocity before downhill

[Hellström, 2010] [Scania Active Prediction, 2012] [Volvo I-See, 2013]

Problems when LAC is used in a platoon

- Individual look-ahead control cannot be used in heterogeneous platoons, unless the distance is increased before the hill

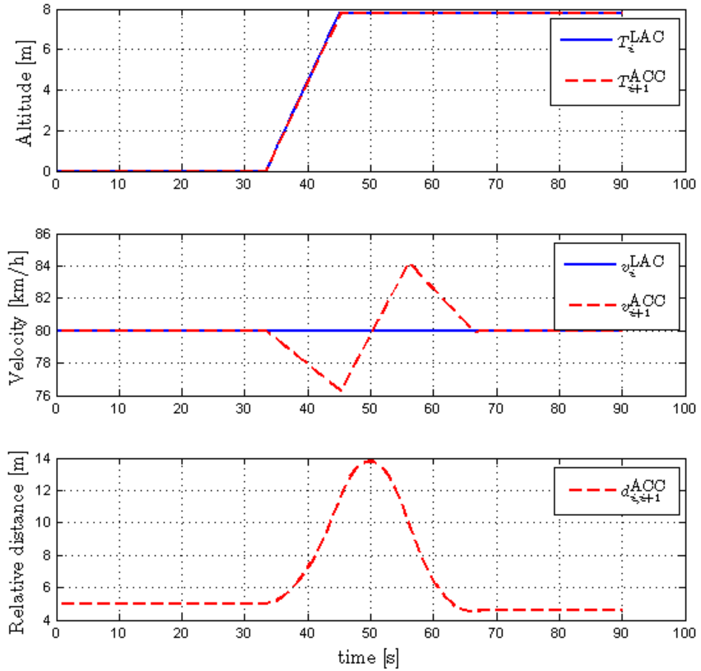
- Multi-body look-ahead control is infeasible due to computational complexity

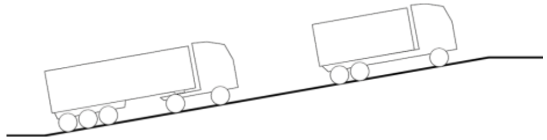


Cruise control strategies for platoons

First vehicle runs with LAC;
the followers with ACC

- Distance may not be maintained if follower is weaker/heavier
- Sometimes vehicles need to brake in downhill or accelerate in uphill
- Following vehicle slows down before uphill and speeds up before downhill

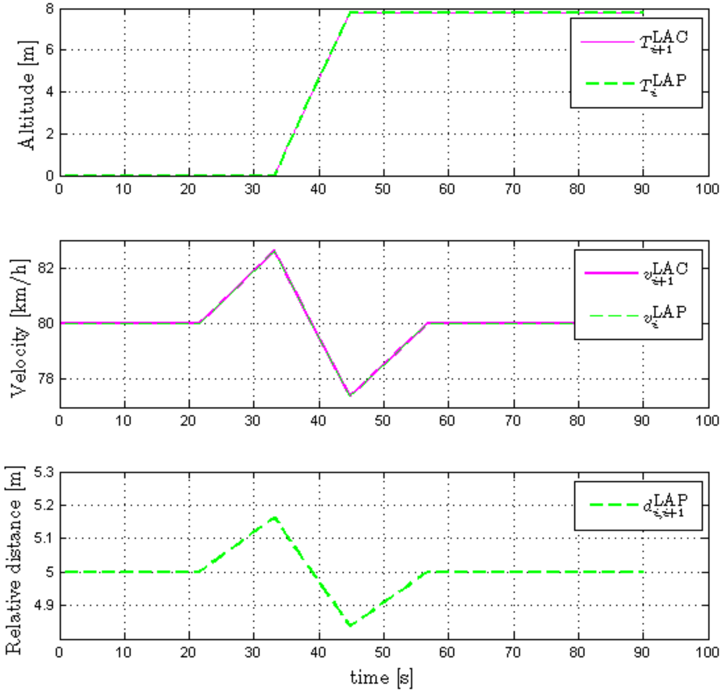


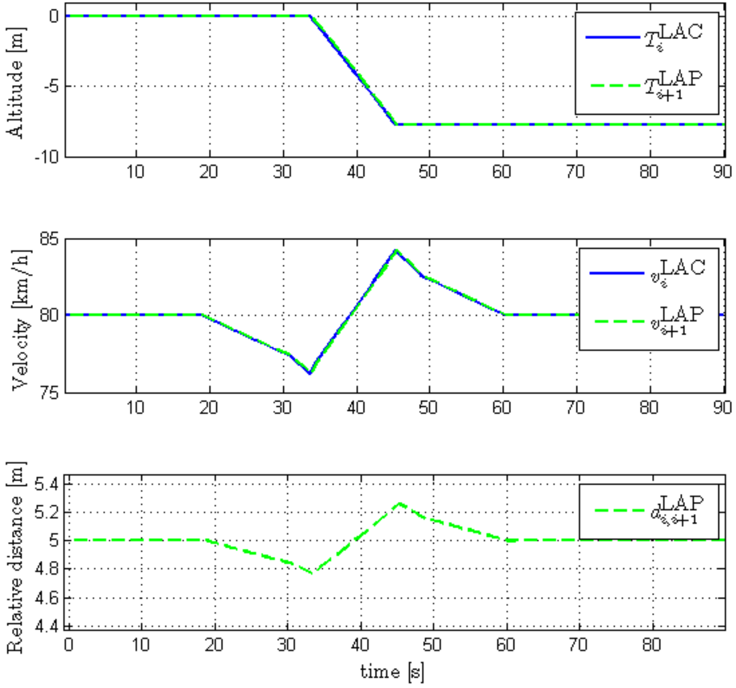


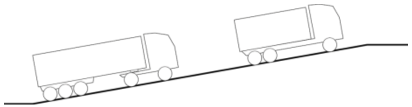
Solution: Cooperative look-ahead control

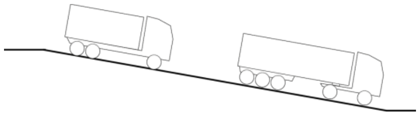
- All vehicles follow the look-ahead velocity profile of the heaviest/weakest vehicle
- The velocity profile is a function of position on the road, not of time
- Small deviations in distance over the hill, but the original distance is retained after the hill
- Sub-optimal velocity profile for stronger/lighter vehicles

Cooperative look-ahead control



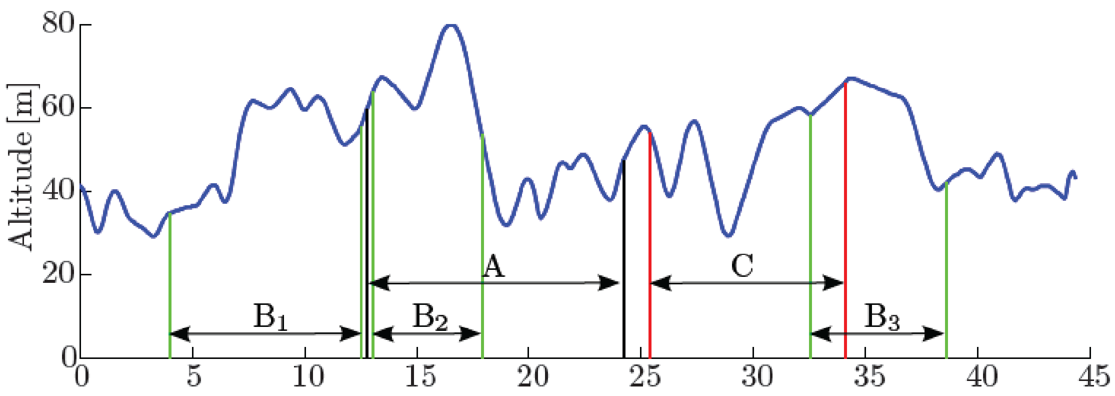






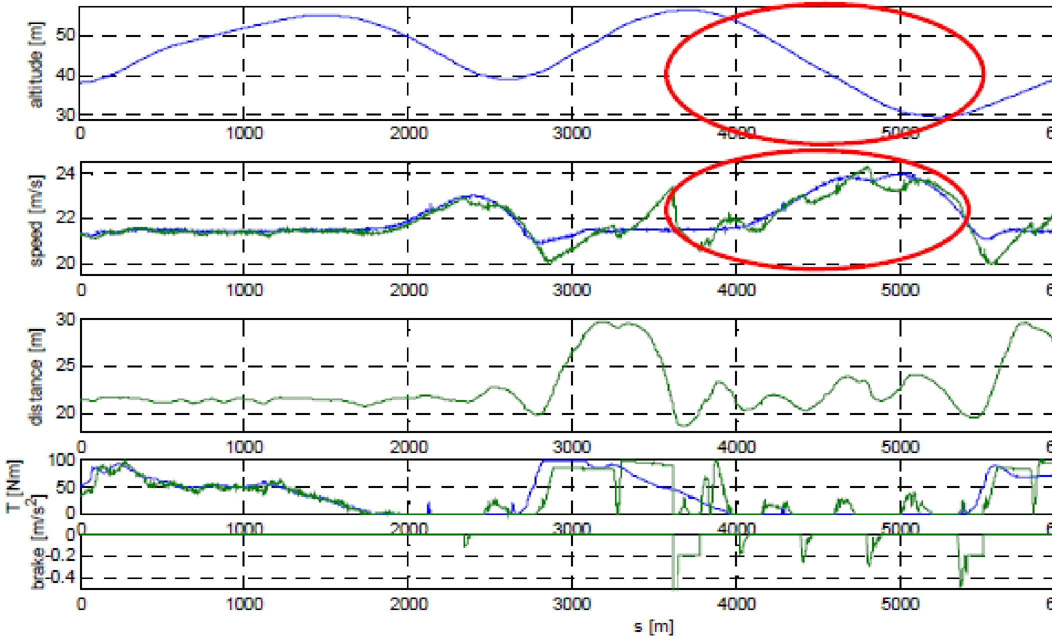
Real platooning tests with Scania

- Three standard 40t HDV
- CACC (linear models)
- No look-ahead
- Fuel savings?
  - Yes, on flat sections
  - No, on hilly sections



Analysing the data

- Different dynamics in hills
- Gear shifts
- Accelerations in uphills
- Larger velocity variations



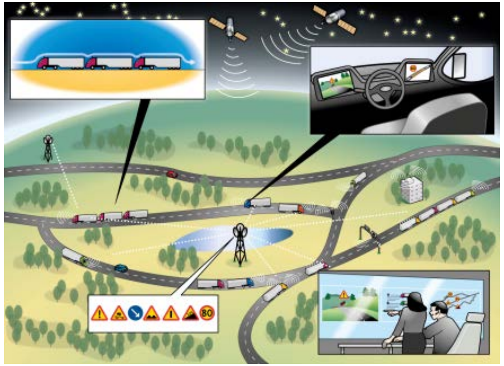
Conclusion:
- Coordination needed
- Communication needed
- Topography data needed

- Proposed solution works in simulation – more real test are needed

Real platooning tests with Scania

- Safety
- Control performance
- Fuel efficiency
- Driver acceptance

Smart Mobility Lab



- Indoor positioning
- Communication
- Virtual and physical sensors
- On- and offboard computing
- Visualization tools