VANET Services and Mobile Vehicle Clouds

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Mobile Computing Cloud

- **Internet Cloud (eg Amazon, Google etc)**
  - Data center model
  - Immense computer, storage resources
  - Broadband Connectivity
  - Services, virtualization, security
- **Mobile Cloud (traditional)**
  - What most researchers mean:
    - Access to the Internet Cloud from mobiles (eg MSR Maui)
    - Tradeoffs between local and cloud computing (eg m-health)
- **Recently, Mobile Computing Cloud (MCC)**
  - Mobile nodes increasingly powerful (storage, process, sensors)
  - Emerging distributed applications not suited for Amazon

Mobile Computing Cloud

Vehicular Cloud

Observed trends:

1. **Vehicles are powerful sensor platforms**

   GPS, video cameras, pollution, radars, acoustic, etc

2. **Spectrum is scarce => Internet upload expensive**

3. **More data cooperatively processed on vehicles**

   V2V road alarms (pedestrian crossing, electr. brake lights, etc)

   V2V signals for platooning

   V2V for shockwave prevention

   surveillance (video, mechanical, chemical sensors)

   environment mapping via “crowd sourcing”

$\Rightarrow$ Vehicular Computing Cloud

Data storage/processing on vehicles (before Internet upload)

Vehicle Cloud vs Internet Cloud

- **Both offer a significant pool of resources:**
  - computing, storage, communications

However:

- **Main vehicle cloud asset (and limit): mobility**
- **Vehicle cloud *services* are location relevant**
  - Data Sources: drivers or environment sensors
  - Services: to drivers or to community
- **Vehicle cloud can be sparse, intermittent**
- **Vehicle cloud interacts with:**
  - Internet cloud
  - Hedge cloud
- **Very different business model than Internet Cloud**

Vehicular cloud at work

Vehicles in the same geographic domain form a P2P cloud to collaborate in some activity

food and gas info.

regulating entrance to the evacuation highway

Related work:

MobiCloud – *Dijian Huang*

Maui – *MSR*

Auton Vehi Clouds-*S. Olariu*

IC Net On Wheels – *Fan Bai GM*

Sigcomm Workshops 12,13

Road Map

- Vehicle Applications Overview
- Closer look at Safety, Intelligent Transport and Security Services
- Future Outlook

The Vehicle Transport Challenge

Safety

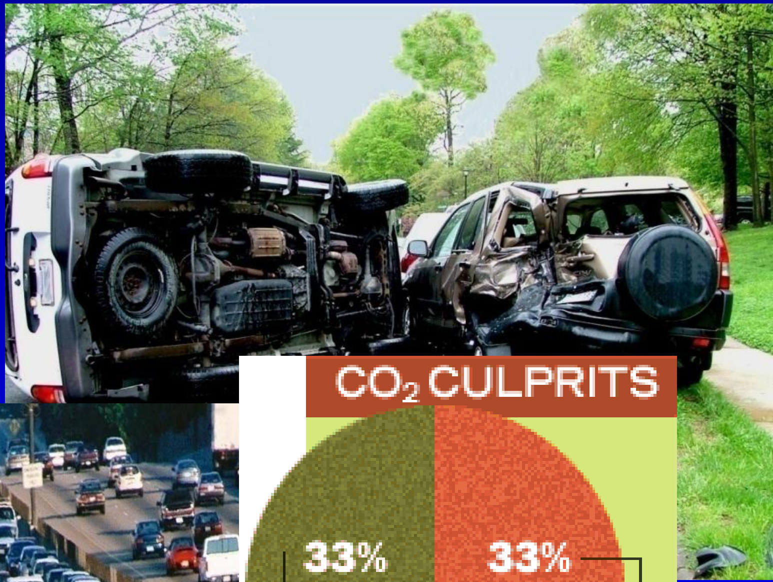
- 33,963 deaths/year (2003)
- 5,800,000 crashes/year
- **Leading cause of death for ages 4 to 34**

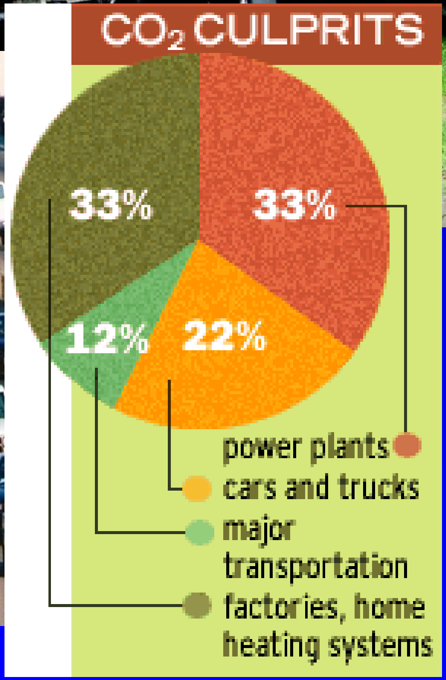
Mobility

- 4.2 billion hours of travel delay
- $78 billion cost of urban congestion

Environment

- 2.9 billion gallons of wasted fuel
- 22% CO_2 from vehicles





In 2003 DOT launches: Vehicle Infrastr. Integration (VII)

- **VII Consortium: USDOT, automakers, suppliers, ..**
- **Goal: V2V and V2I comms protocols to prevent accidents**
  - Technology validation;
  - Business Model Evaluation
  - Legal structure, policies
- **Testbeds: Michigan, Oakland (California)**
- **Most visible result: DSRC standard (5.9 Ghz)**
- **However: 10 year to deploy 300,000 RSUs and install DSRC on 100% cars**
- **Meanwhile: can do lots with 3G and smart phones**
  - Can we speed up "proof of concept"?

Enter Connected Vehicle (2009-2014)

Connected Vehicle Program(2009-14)

- ***Safety → DSRC***
  - Aggressively pursue V2V
  - Leverage nomadic devices to accelerate benefits
  - Retrofit when DSRC becomes universally available
- ***Non-safety (mobility, environment)***
  - Leverage existing data sources & communications; include DSRC as it becomes available

US DOT endorses V2V in Jan 2014

– *This stimulates research on V2V Clouds*

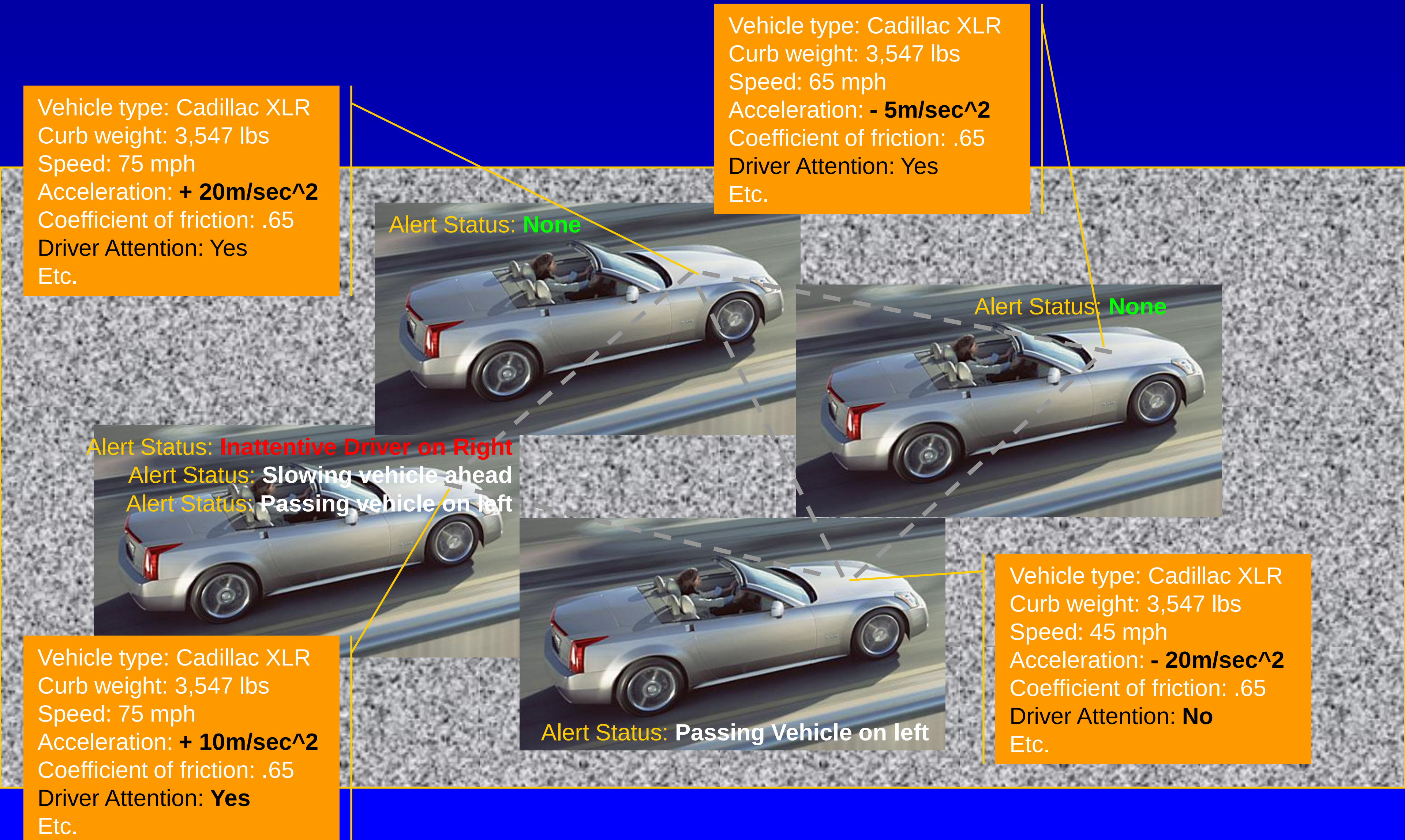
Emerging Vehicle Applications

- **Safe Navigation**
  - Crash prevention; platoon stability; shockwaves
- **Content Download/Upload**
  - News, entertainment, location relevant info download; ICN
  - Video upload (eg remote drive, Pic-on-wheels, accident scene, etc)
- **Sensor Data gathering**
  - Forensics; driver behavior; traffic crowdsource; ICN
  - Privacy preserving data analysis
- **Intelligent Transport**
  - efficient routing to mitigate congestion/pollution
- **Defense from cyber attacks**
  - Platoons, autonomous vehicles, etc

V2V for Safe navigation

- **Forward Collision Warning,**
- **Intersection Collision Warning…….**
- **Platooning (eg, trucks)**
- **Advisories to other vehicles about road perils**
  - "Ice on bridge", "Congestion ahead",….

V2V communications for Safe Driving



Future Collision Protection Requirements

- **The future:**
  - Advanced Cruise Control
  - autonomous vehicles

- **These advanced systems will require even more V2V cooperation**
  - In spite of the fact that autonomous vehicles are equipped with sophisticated on-board sensors for passive navigation:
  - Acoustic
  - Laser, Lidar
  - Video Cameras
  - Optical sensors (reading encoded tail light signals)
  - GPS, accelerometer, etc

V2V for Platooning

Studies point to need for V2V coordination

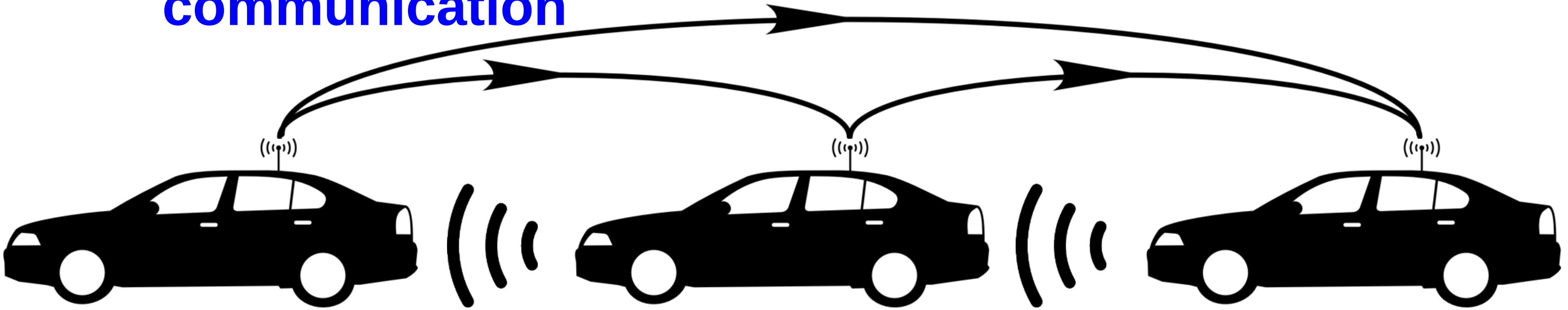
Autonomous Vehicle Control

V2V more critical as autonomous car penetration increases

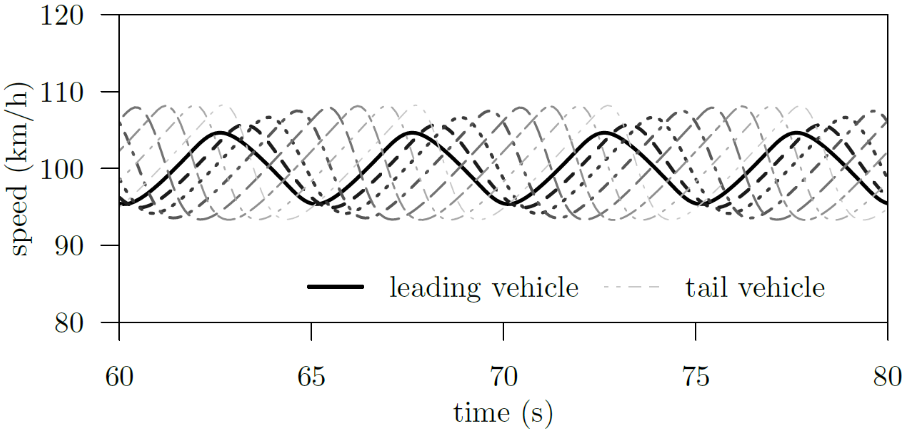
Platoon Control Systems

- **Standard ACC: radar (or lidar) based**

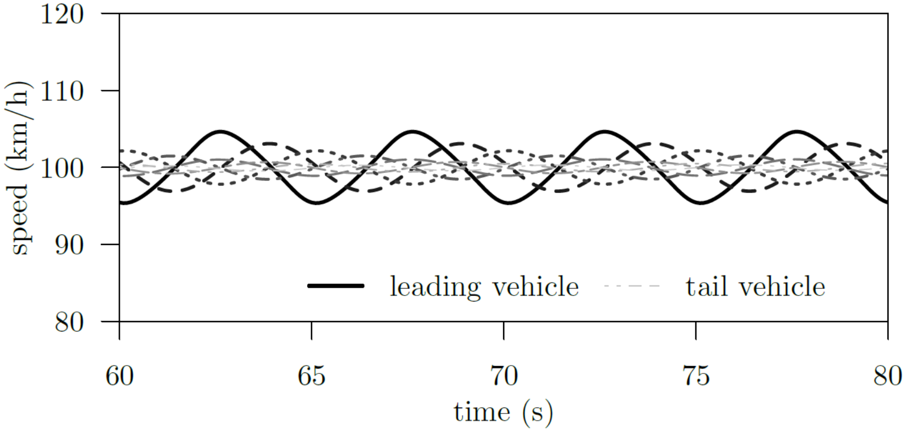
- **Cooperative ACC (CACC): radar + wireless communication**



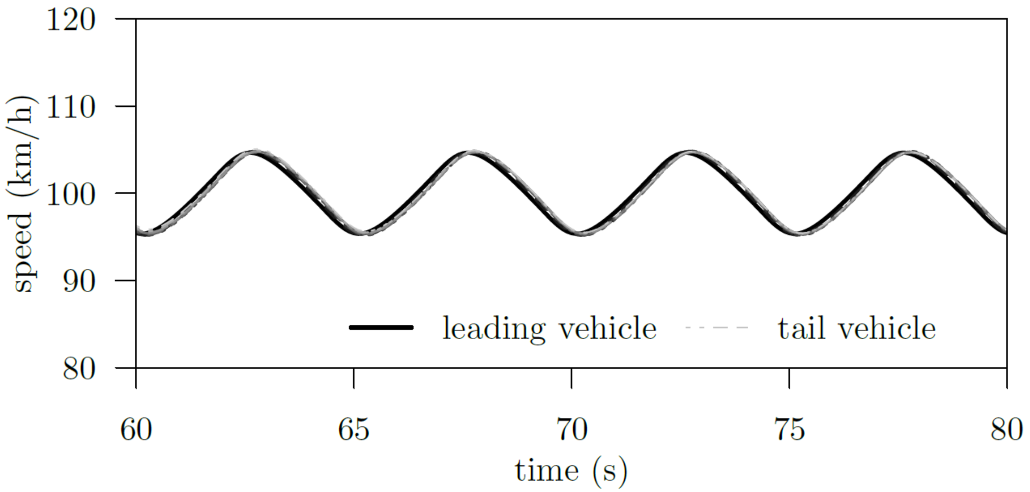
Controllers comparison



ACC – headway T = 0.3 s



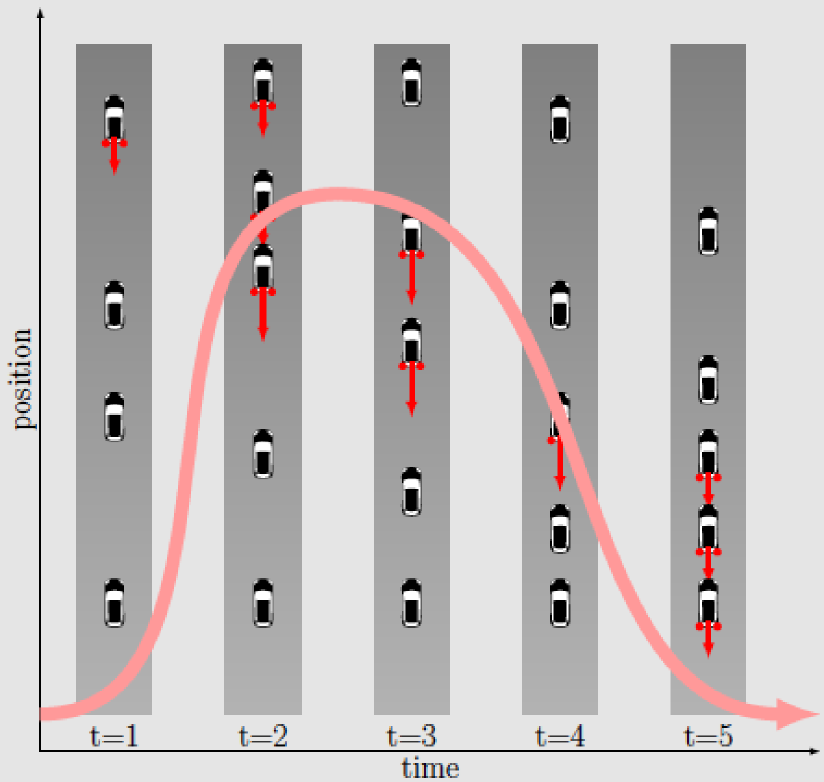
ACC – headway T = 1.2 s



CACC – distance = 5 m

Traffic Shock Waves

Traffic shock waves on congested highways



Reasons

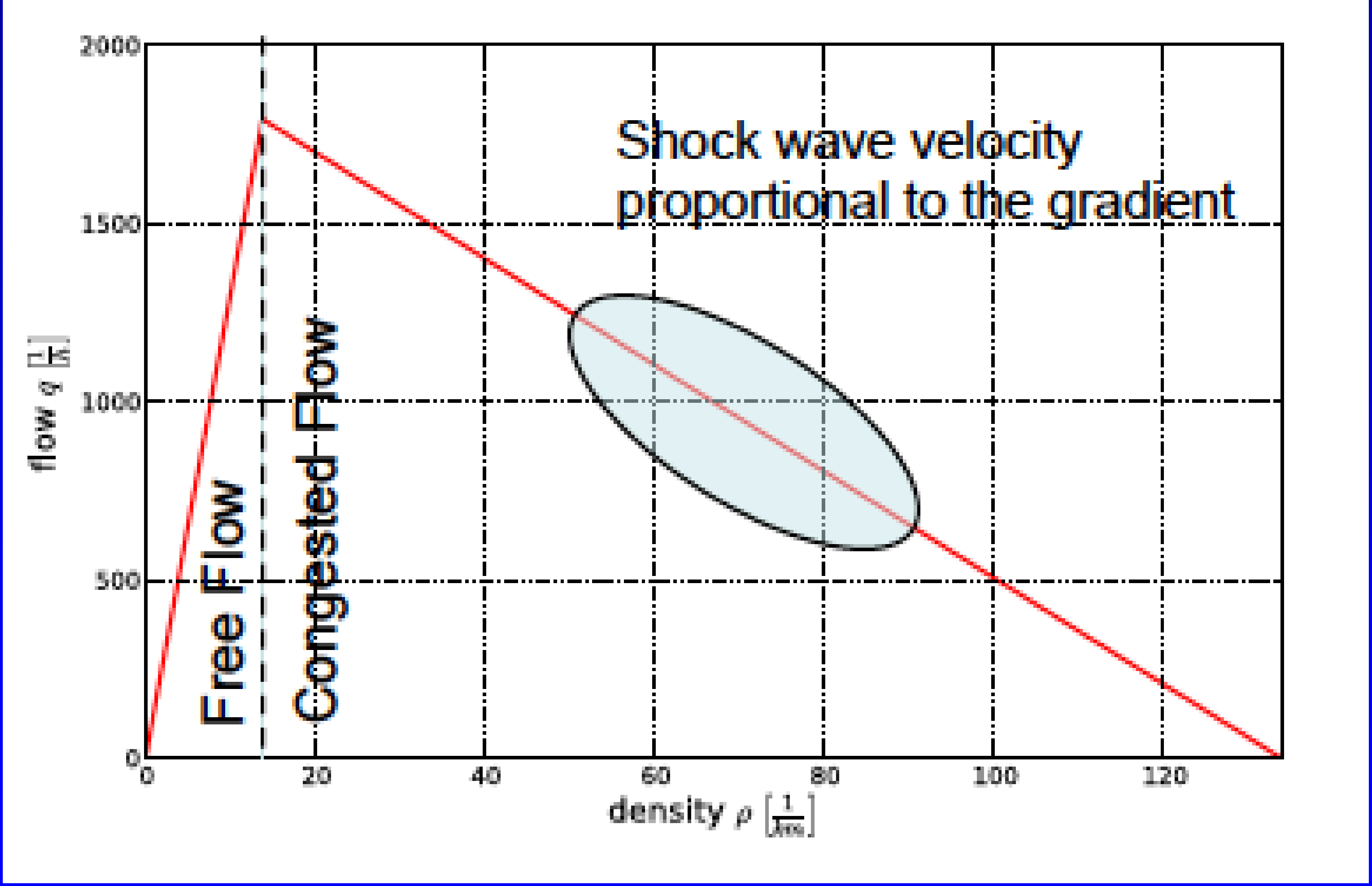
- high traffic demand
- unexpected driver actions
- human reaction time
- physical perturbations
  - ramps
  - construction sites
  - reduction of lanes

Consequences

- hard breaking maneuvers
  - waste of energy
  - increase in emissions

Shock Wave Models

Lighthill-Witham-Richards (LWR) model



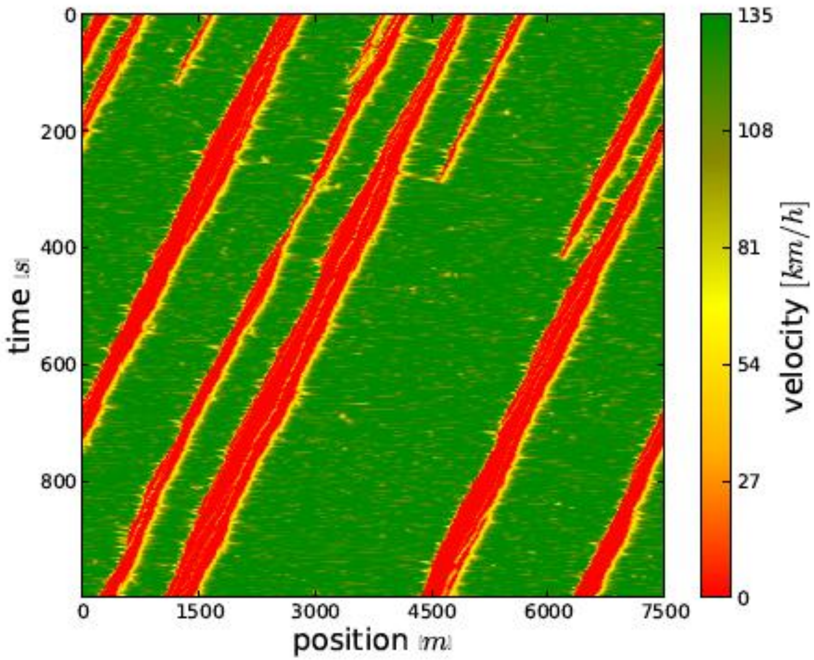
Current Technology – ADAS (Advanced Driver Assistance System)

- Features
  - one-hop information
  - unidirectional
  - limited monitoring horizon
- Applications
  - assisted breaking
  - traffic sign recognition
  - adaptive cruise control
  - variable message sign

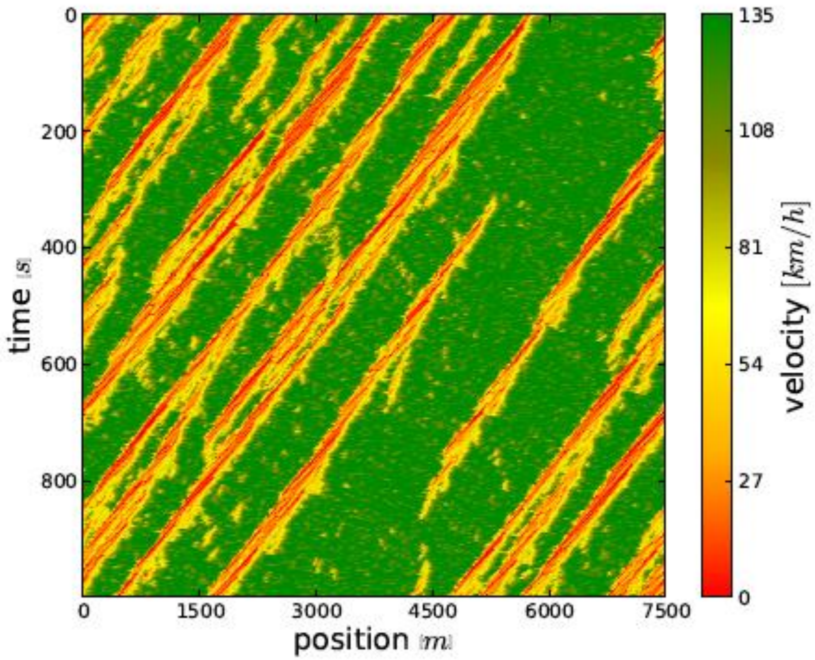
DRIVE (Density Redistribution via Intelligent Velocity Estimates)

- new Vehicle to Vehicle communication protocol
  - distributed
  - connectionless
  - event driven
  - multi-hop
- estimate traffic conditions in the interspace between two vehicles
  - in communication range
  - in the same lane
  - in congested phase
- traffic slow down ahead

V2V and cruise control to avoid Shockwave formations (Globecom 13)



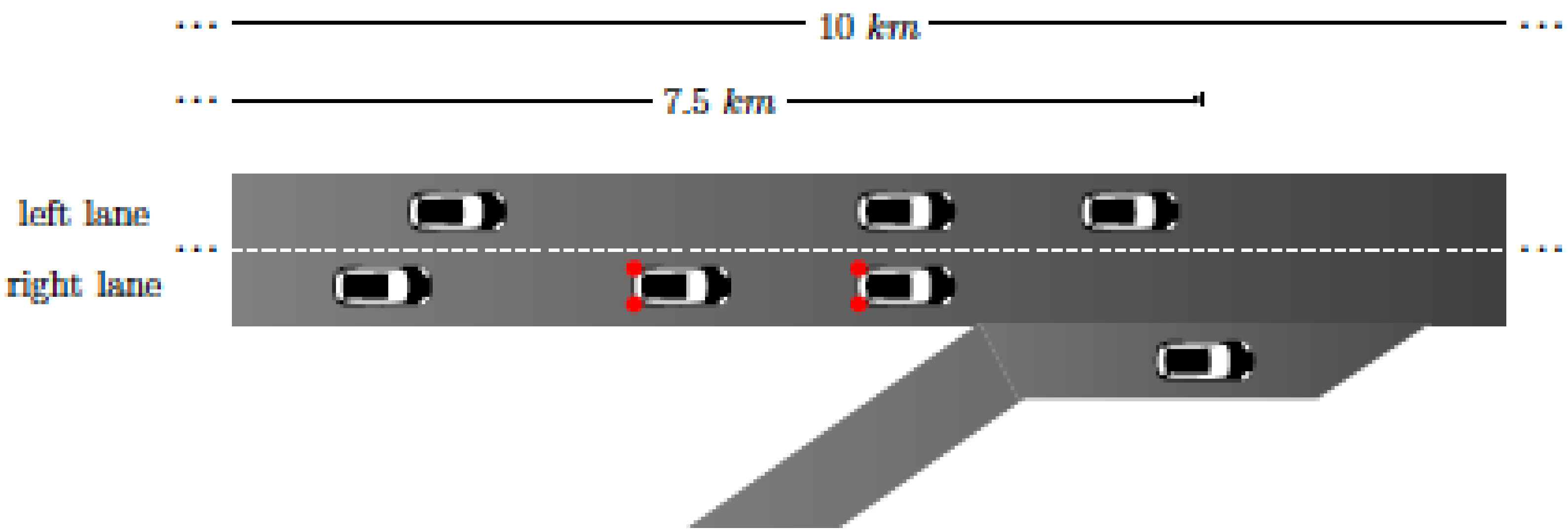
(a) VDR model



(b) PVS protocol

VDR = Velocity Dependent Randomization: ADAS
PVS = Partial Velocity Synchronization: DRIVE

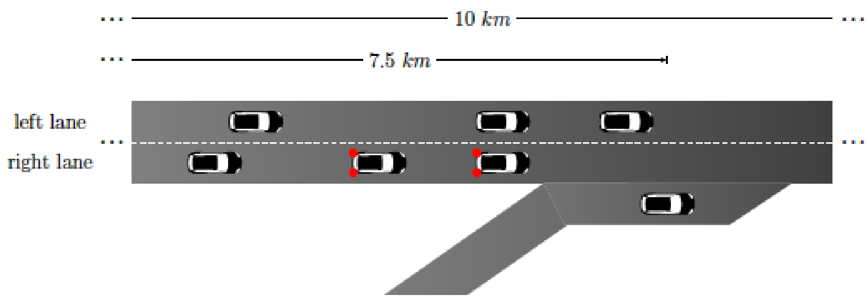
Simulation Experiment



Evaluation (INFOCOM 14)

Simulation Setup

- SUMO + TraCI
- V2V communication in Python
- Krauss car-following model
- 2 lane highway + onramp
- Different vehicle classes
- Simulation Time $T = 7200$ s



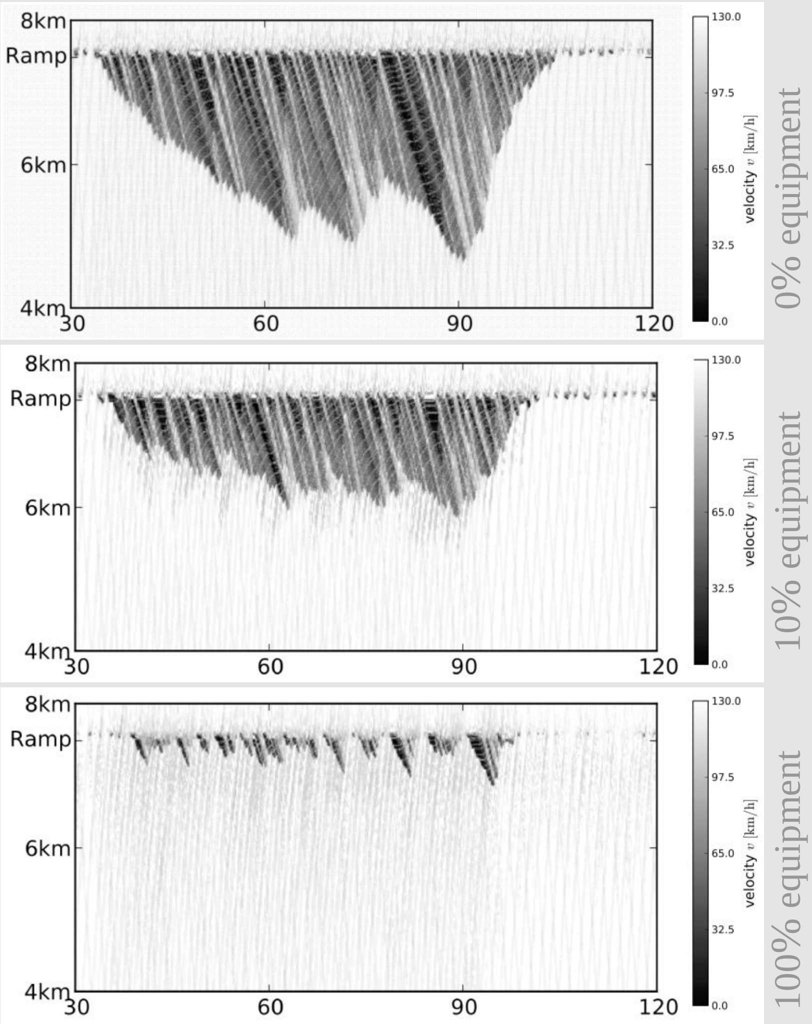
Traffic demand

- T_1 0 – 30 mins **low** 800 veh/h/lane
- T_2 30 – 90 mins **high** 1300 veh/h/lane
- T_3 90 – 120 mins **low** 800 veh/h/lane

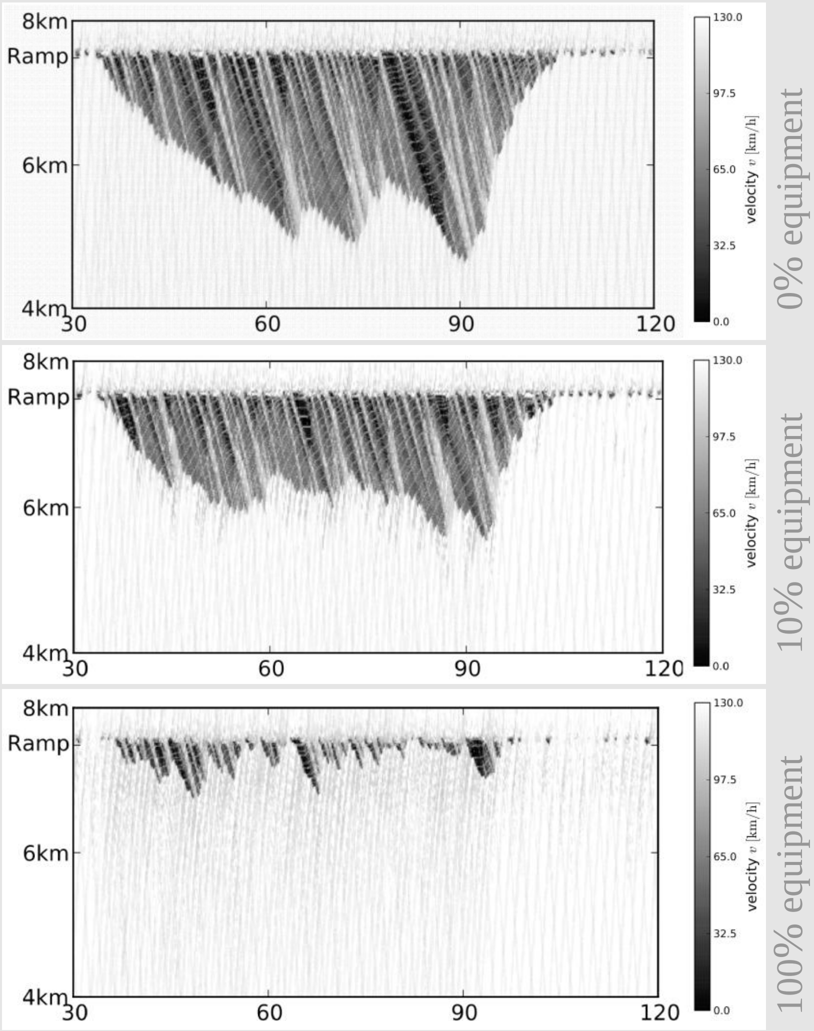
class	l_{eff} $[m]$	$a_{\max}$ $[m/s^2]$	$b_{\max}$ $[m/s^2]$	overall %
A	7.5	2.5	−4.5	47.5
B	7.0	1.5	−4.0	47.5
C	17.0	1.2	−4.0	2.5
D	20.0	0.7	−4.0	2.5

Simulation Results (cont.)

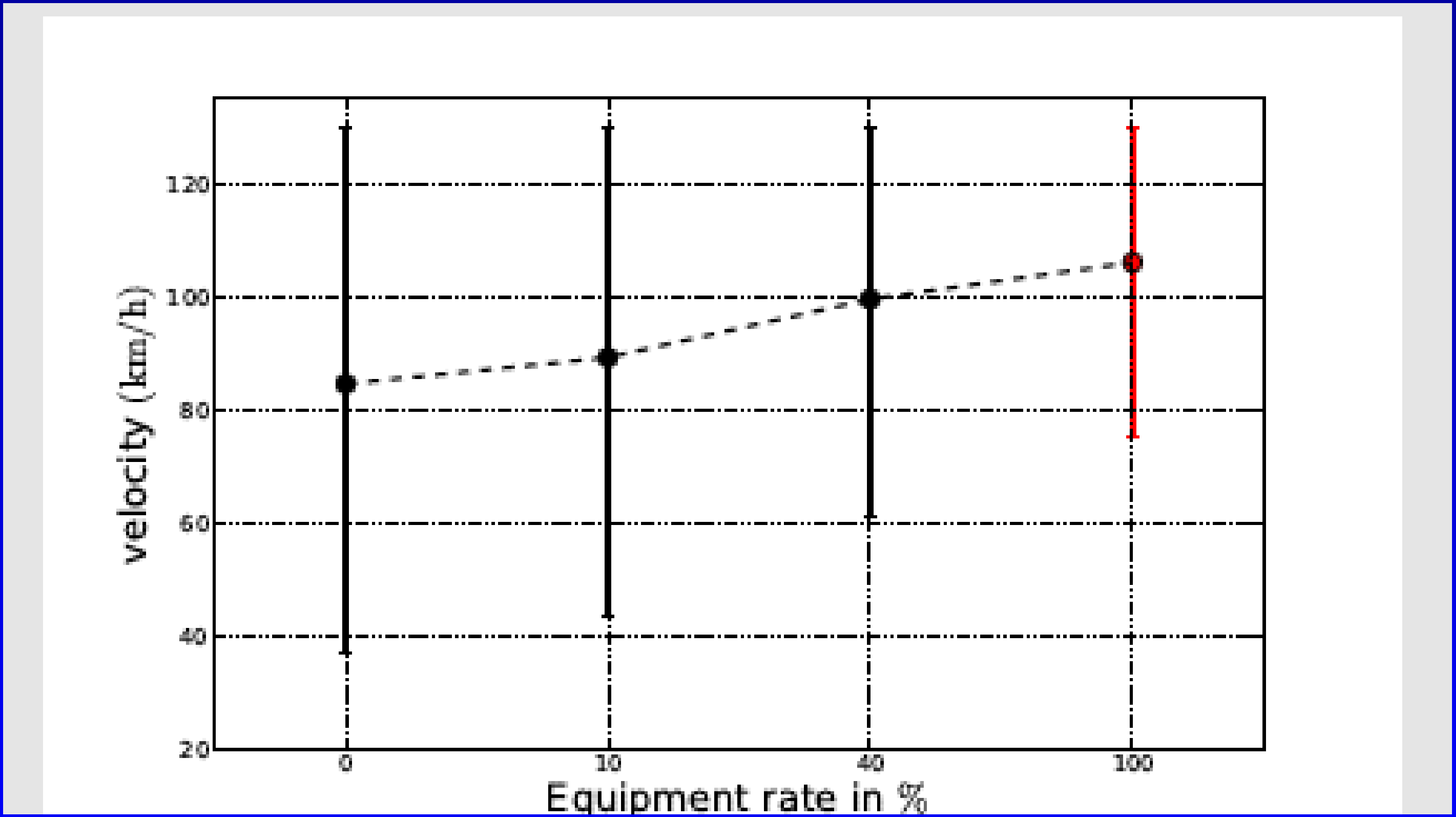
100% compliance



75% compliance



Simulation Results



Equipment rate = CADAS Market Penetration rate

V2V protocols and the Cloud

V2V based traffic control essential for stability
Simulation results are backed up by experiments

- VOLVO Platooning
- Luxemburg preliminary live DRIVE experiments

However, protocol consistency and careful coordination necessary to manage complex traffic situations:

- Platooning
- Shock Waves

Advanced V2V Protocols (CACC and DRIVE) will be implemented in the Vehicle Cloud

The Cloud implementation will assure consistency across Automakers

Emerging Vehicle Applications

- Safe Navigation
- Content Download/Upload
- Sensor Data gathering

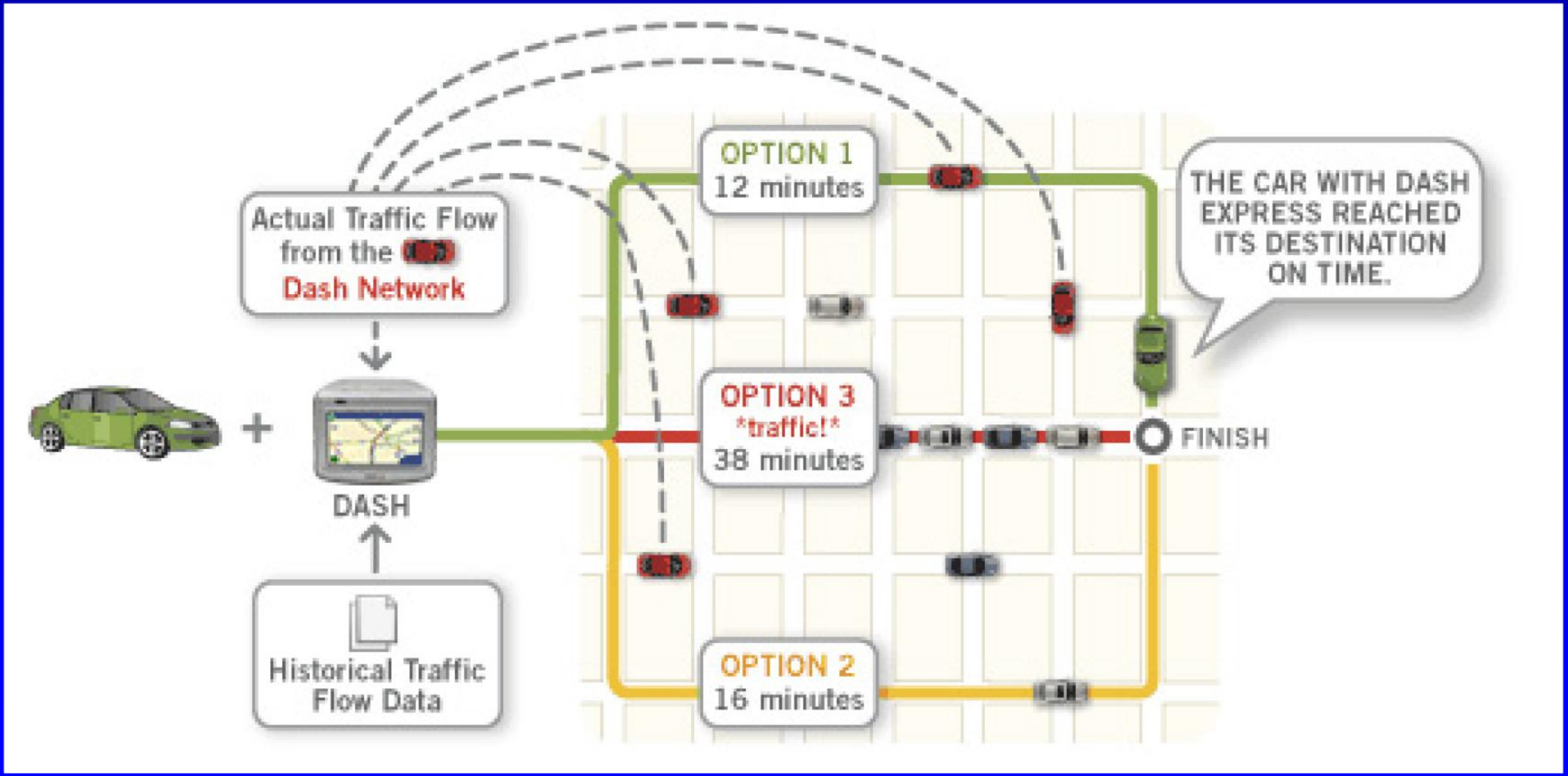
=> Intelligent Transport

- Defense from cyber attacks

Motivation: We are currently funded by NSF to solve the vehicle congestion and pollution problem with "Intelligent traffic engineering"

Intelligent navigation

- GPS Based Navigators
- Dash Express (came to market in 2008):

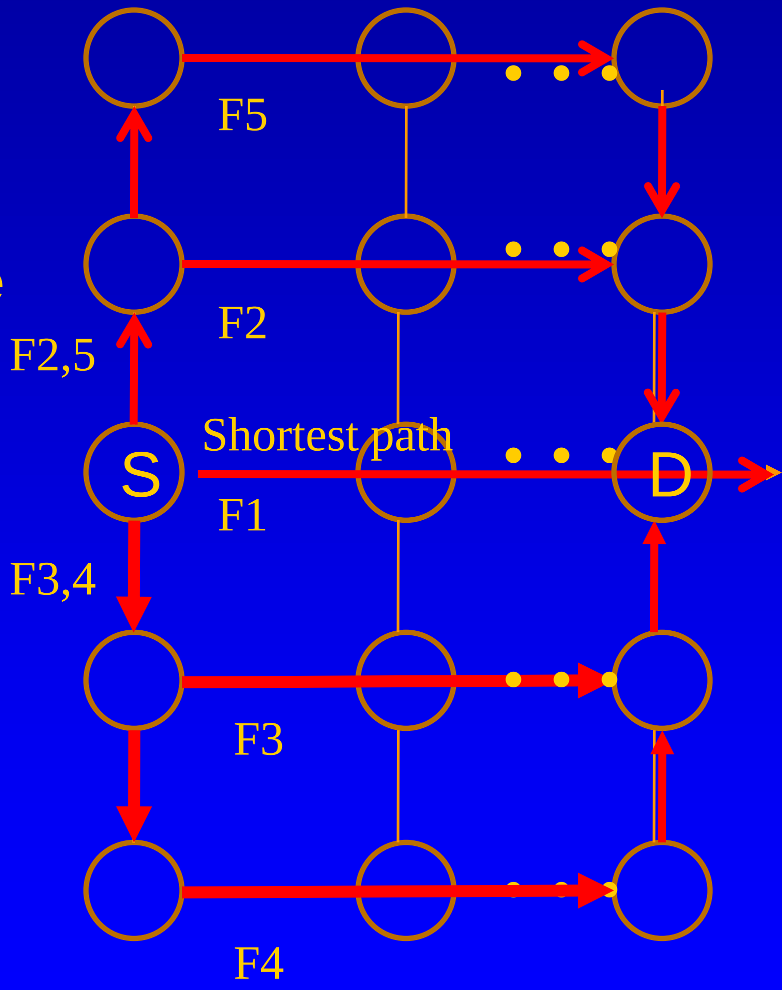


- Still run into traffic fluctuation problems (ie route flapping)

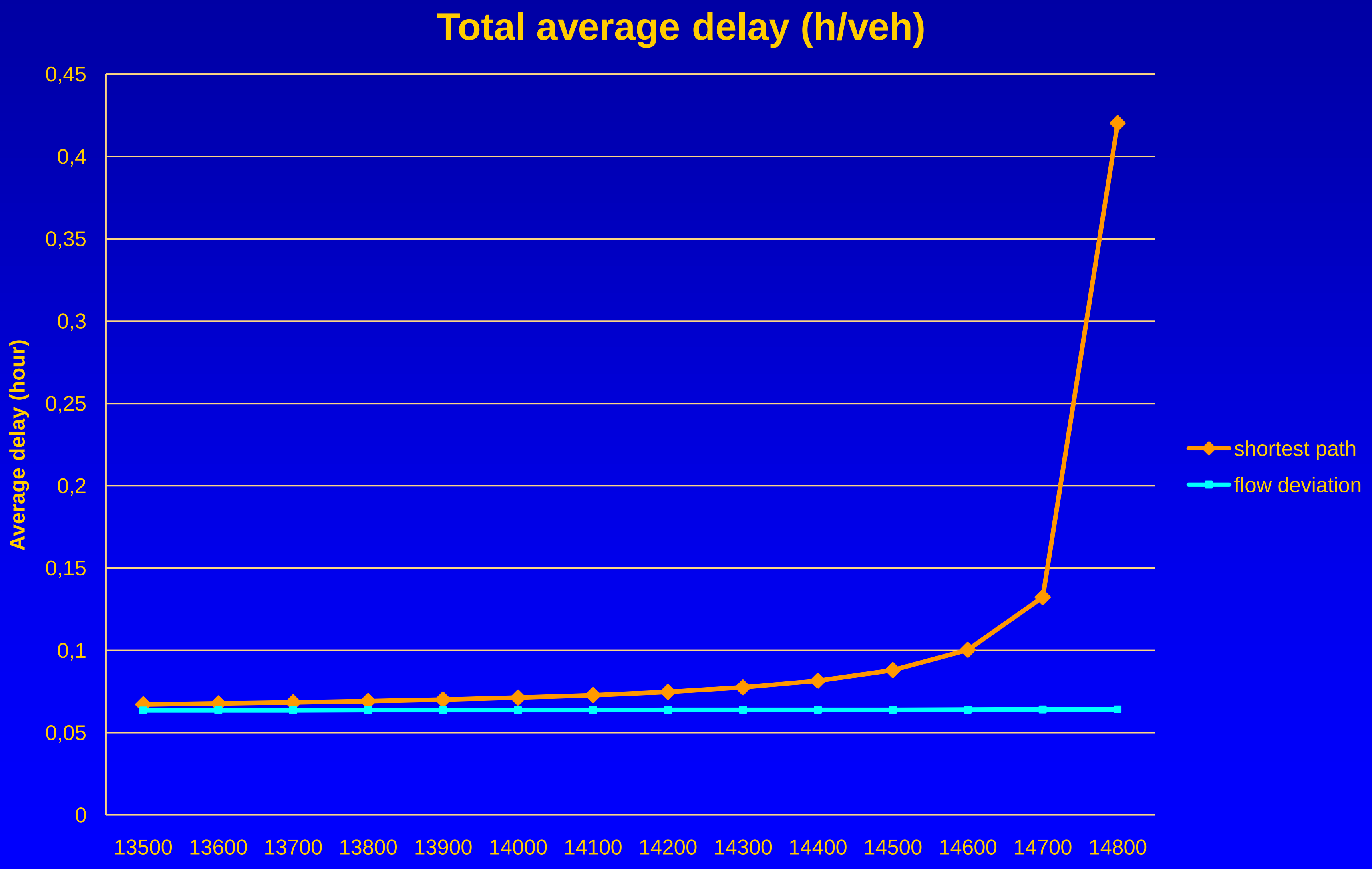
NAVOPT – Navigator Assisted Route Optimization

- **On Board Navigator**
  - Interacts with the Server
  - Periodically transmits GPS and route
  - Receives route instructions

- **Manhattan grid (10x10)**
  - 5 routes (F1~ F5) from source to destination
  - Link capacity: 14,925 [vehicles/h]

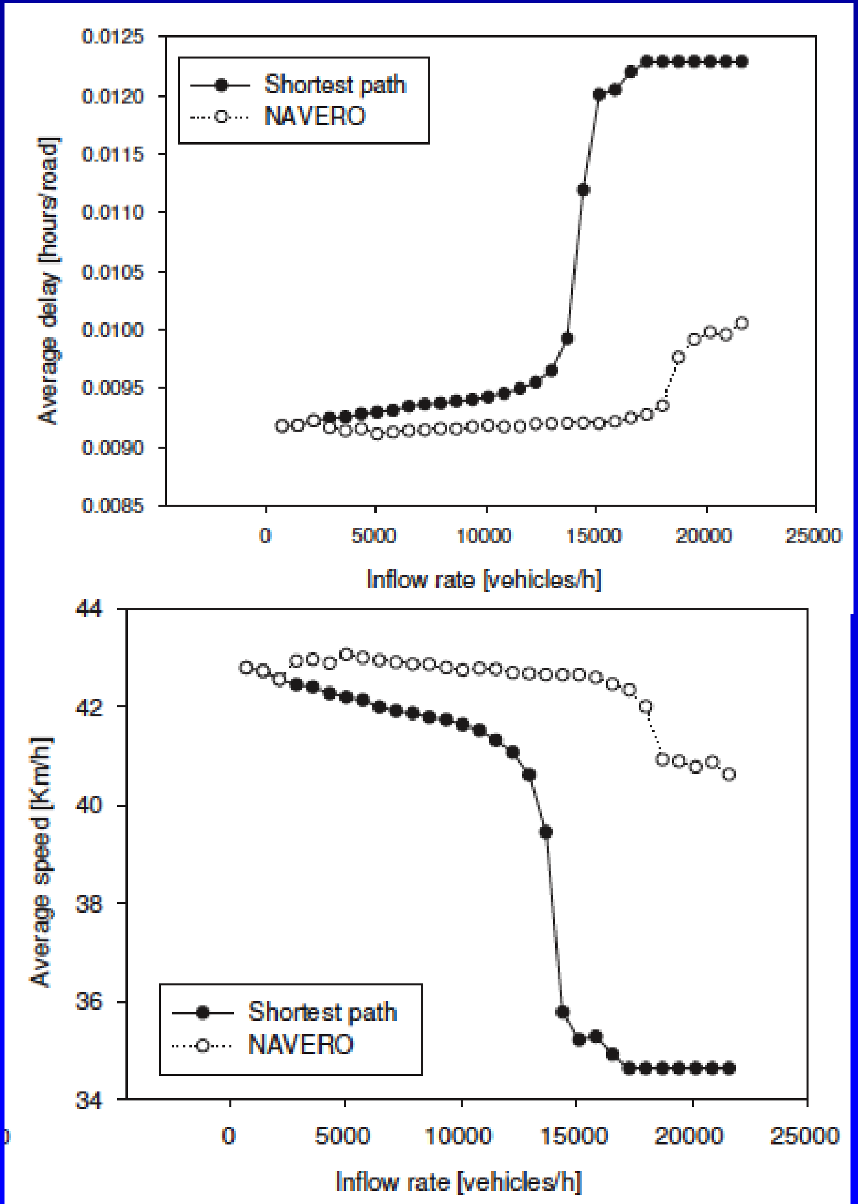


Analytic Results



Sumo simulation results

- **Sumo-0.12**
  - 10 X10 grid
  - Road segment: 400m
  - Length of vehicle: 4m
  - Max speed limit: 60Km/h
- **Average delay**
  - Delay increases drastically around 15000 rate [veh/h] in case of shortest path
  - In NAVOPT, delay slightly increases around 20000



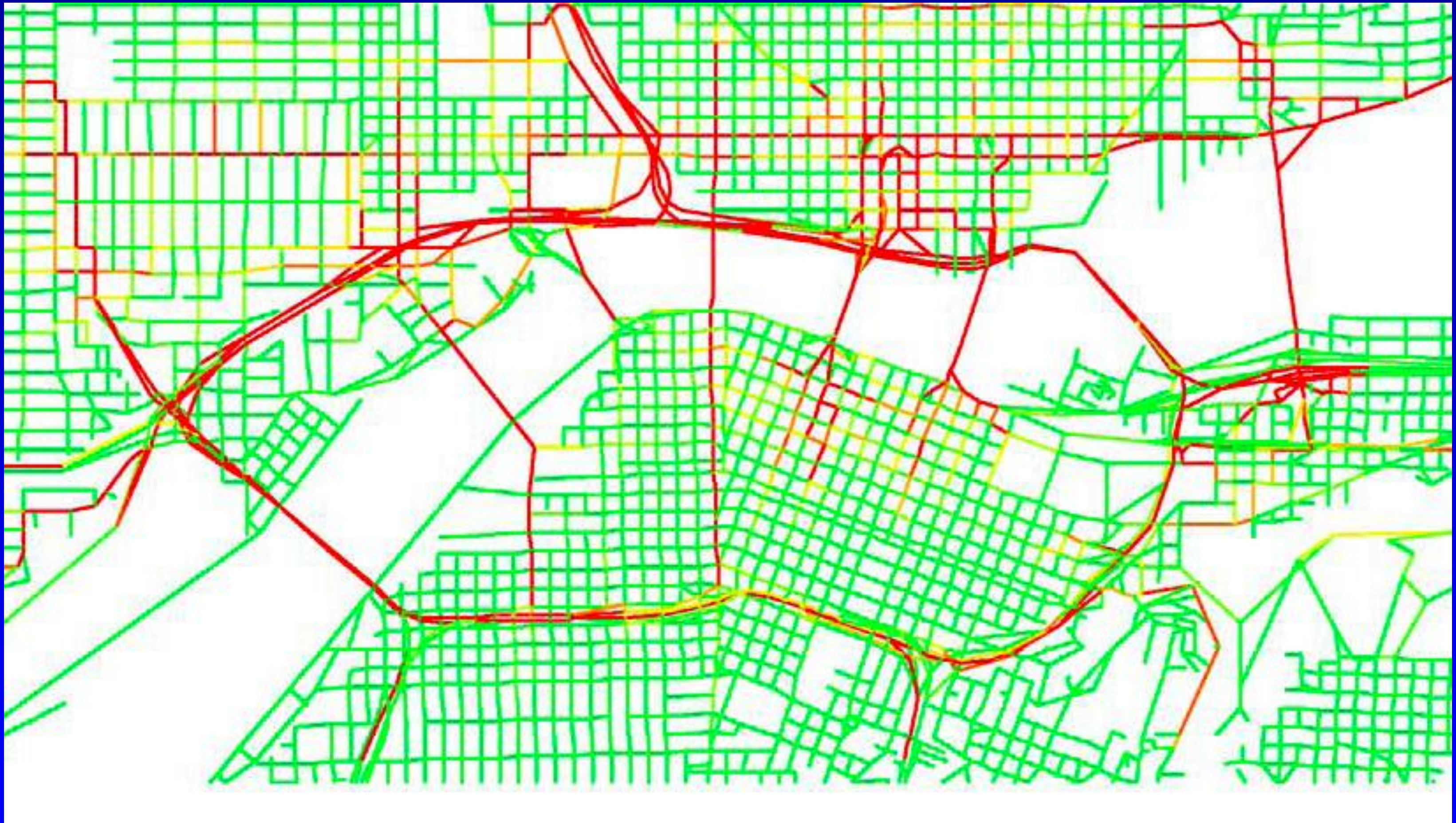
Distributed traffic management

- **Centralized traffic management is Internet Cloud based**
- **It cannot react promptly to local traffic perturbations**
  - A doubled parked truck in the next block; a traffic accident; a sudden surge of traffic
  - Internet based Navigator Server cannot micro-manage traffic for scalability reasons
- **Enter distributed, v-cloud based traffic mgmt**
  - Distributed approach a good complement of centralized supervision
  - *"On the Effectiveness of an Opportunistic Traffic Management System for Vehicular Networks", Leontiadis et al, IEEE Trans on ITS Dec 2011*

CATE: Comp Assisted Travl Environment

- **Vehicles estimate/exchange traffic stats and build traffic load data base:**
  - 1) estimate traffic from own travel time;
  - 2) share it with neighboring vehicles (in an ad hoc manner); and
  - 3) dynamically recompute the best route to destination
- **The study was done by simulation:**
  - QUALNET a popular event driven MANET simulator, and
  - MobiDense, a mobility simulator that combines topology and traffic flow information to generate a mobility trace.
  - Case Study: Traffic pattern for Portland obtained from Los Alamos Lab
- **Potential limitations of CATE:**
  - Delay in traffic loads propagation; lack of trip destination info

Traffic loading w/o CATE



(a)

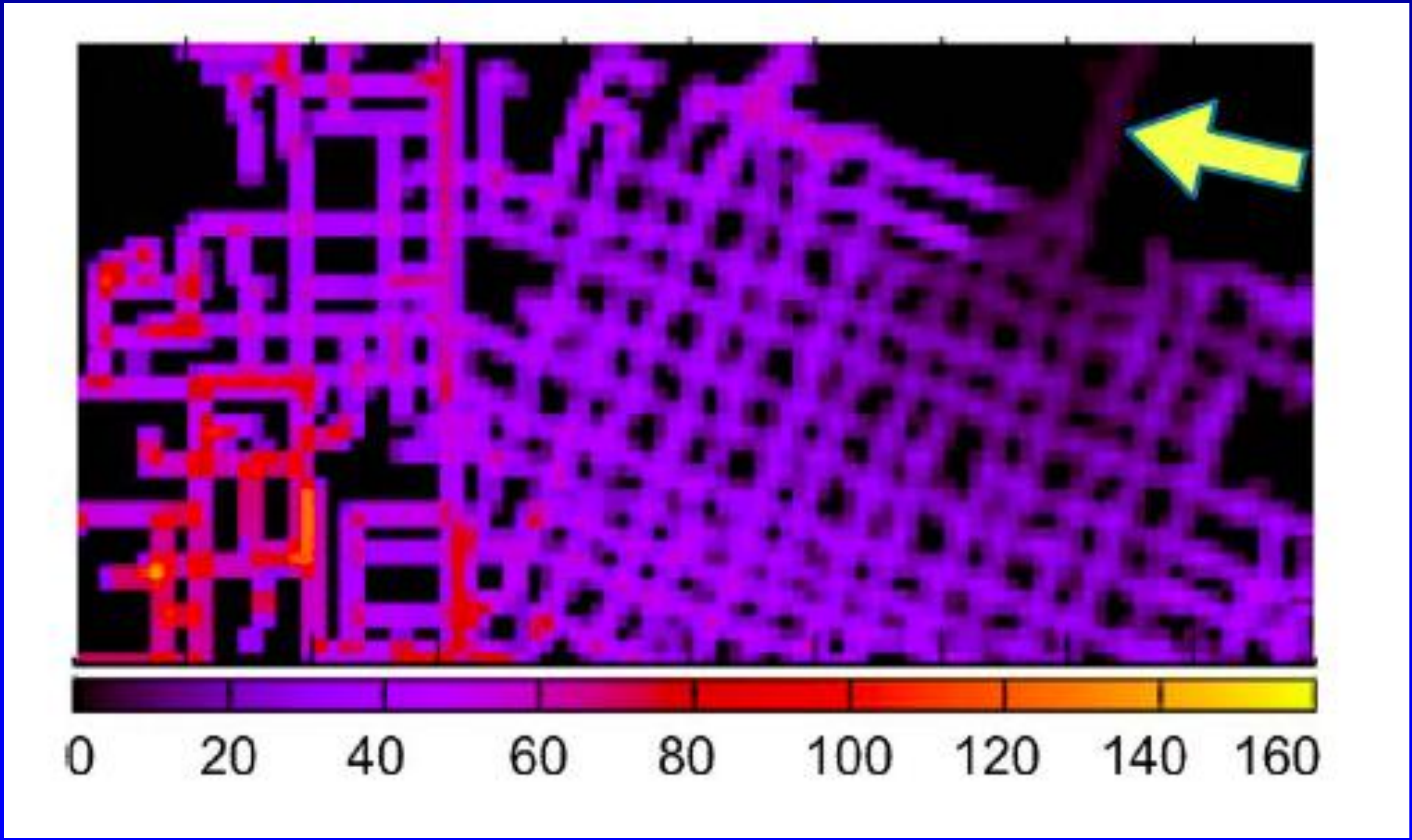
Green no congest Yellow moderate Red heavy congest

Traffic loading with CATE

(b)

Green no congest   Yellow moderate   Red heavy congest

Information Propagation Speed



Two-dimensional Heatmap of age of received information (in seconds) about the link highlighted by the arrow (bridge).

CATE tested on C-VET

- **Up to 8 vehicles roaming the Campus with GPS, WiFi radios and 250m range**
  - Static throughput between two nodes = 30Mps
  - At 30km/h throughput = 7Mbps
- **Propagation of a 2MB block (traffic sample) from one node to the other 7 nodes:**
  - First vehicle received full block in 20s
  - Next four in < 72s
  - Last two in < 125s
- **C-VeT testbed results are consistent with Portland simulation (120 s over a few blocks)**

Integrating Centralized and Distributed traffic management

- **Central Navigator Server (in the Amazon cloud):**
  - Provides MACRO traffic hints (also, multimode instructions)
  - Is aware of user destinations
  - Accounts for possible congestion fees
  - Can perform ECO-Routing (accounting for pollution)
  - Interacts with City Traffic/Planning Department (traffic lights, Green waves, access ramp control)
- **Distributed (CATE-like) traffic management in the Vehicular Cloud:**
  - Can handle sudden traffic jams, accidents, other anomalies
  - Provides “myopic” traffic redirections w/o preempting Server
  - Can be a safety net when infrastructure fails
- **Amazon Cloud + Vehicle Cloud :**
  - Improves scalability, reaction time, robustness to disasters

Which Cloud to use?

After major road chemical spill:

- V2V Cloud alerts vehicles of peril - instantaneous
- Edge Cloud determines which roads, schools to close - seconds
- Internet Cloud computes plume dynamics based on wind etc - minutes

Emerging Vehicle Applications

- Safe Navigation
- Content Download/Upload
- Sensor Data gathering
- Intelligent Transport

=> Defense from cyber attacks

The Autonomous Car: BOT Attacks

- **Autonomous vehicle drivers are allowed to "be distracted" and may even go to sleep while the car "drives" them.**
- **This open the door to BOTNET type attacks:**

A malicious organization can penetrate (via radio) and compromise several cars – ie turn them into BOTS

The compromised cars send false (but fully "authenticated") advertisements and force the legitimate traffic to go into a trap, causing traffic jams

BOT Cars Attack

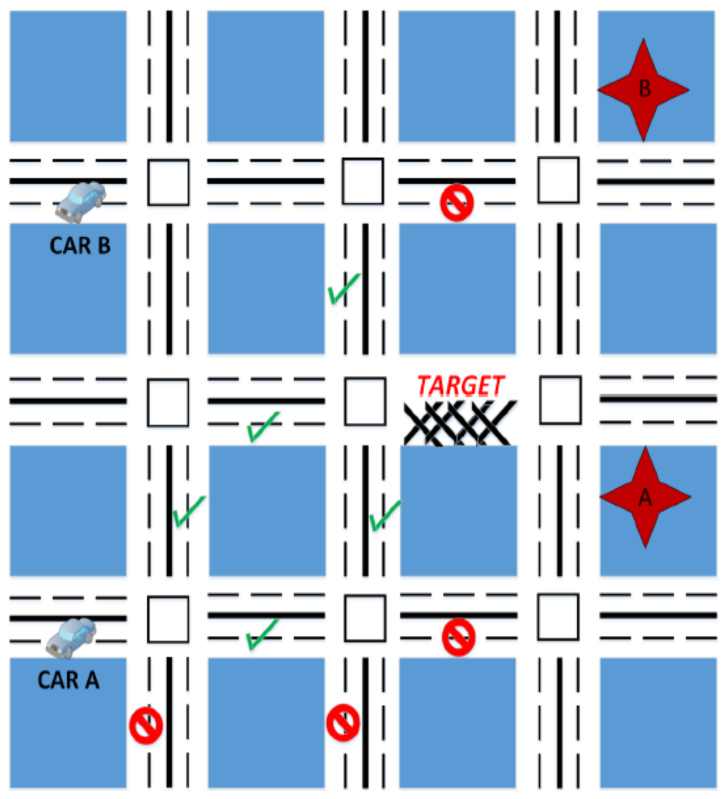


Figure 2: Malicious advertisements for the cars that are considering taking the targeted road

The BOT Cars lure Car A and B intro the target (a TRAP)

They advertise heavy loads on all routes (marked by red circles) except for routes to Target

Effect of BOT attack on speed

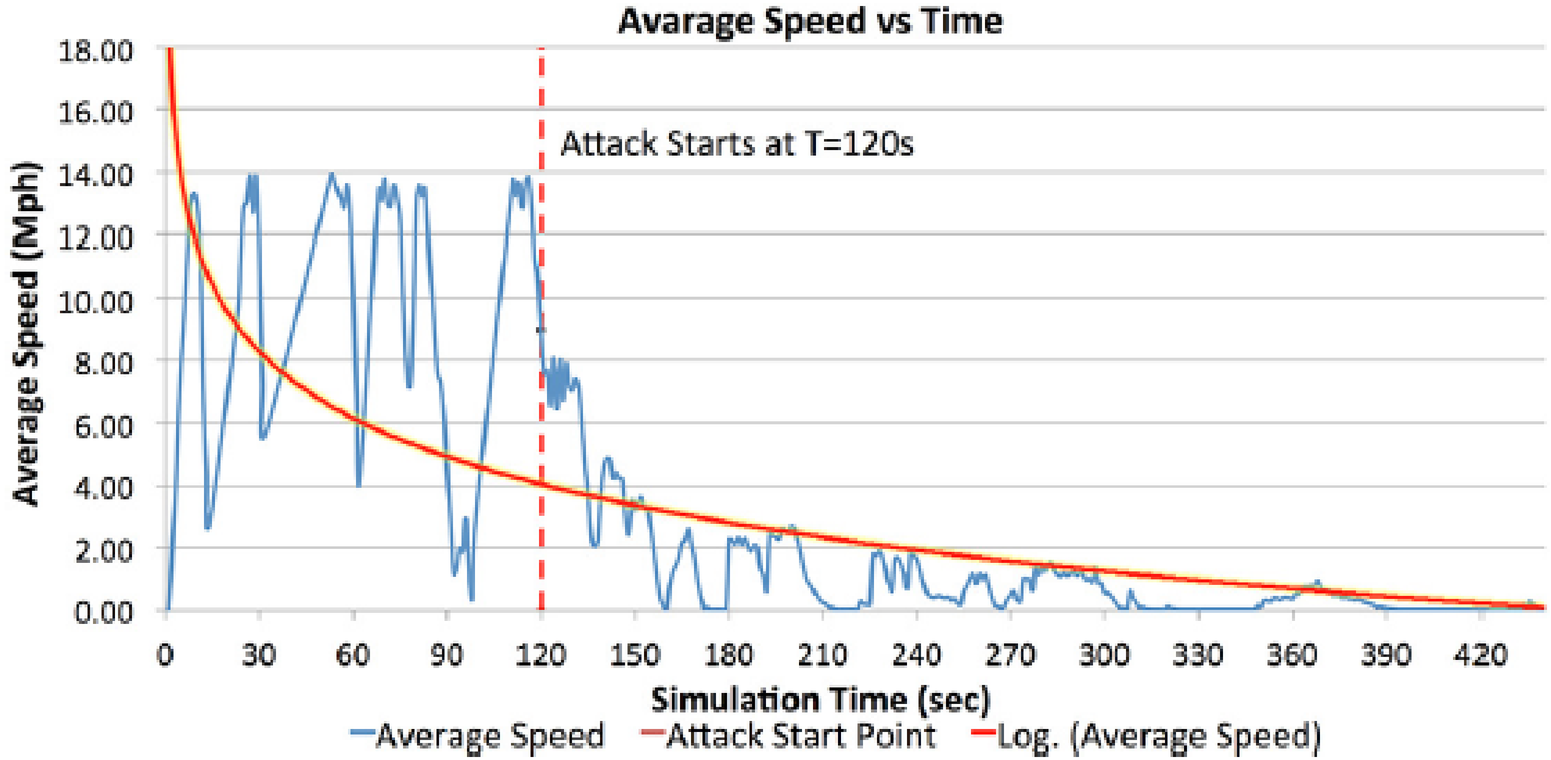


Figure 8: Average speed graph where attack starts 120 seconds after the beginning of the experiment

What Have we Learned?

- V2V enables a broad set of apps – from intelligent transport to surveillance
- However, developing each one of these applications bottom/up is hard and inefficient
- Moreover, it is not guaranteed that different manufacturer implementations (eg BMW, Audi, Benz) will be consistent
- Can one re-utilize common basic functions?
- Enter:

Open Vehicle Cloud Platform

Open Vehicle Cloud Platform

- **A Platform with Basic Services and APIs**
  - Applications can be built on top of common building blocks
  - A variety of physical radio layers are supported
- **Platform's "Narrow waist" – Network Layer**
  - Naming, routing (eg, NDN, ICN, OLSR, GeoRouting, etc)
  - Unicast. Multicast, DTN, (epidemic) dissemination
- **Basic Services**
  - Sensor Services: Unified sensor APIs; CAN bus sensors; sensor aggregation; Spectrum availability crowd sourcing;
  - Data Services: data mining; correlated searches
  - Security Services: privacy; security; DDoS protection
  - Social Network Services: Proximity enabled social networking on the mobile cloud
  - Virtualization Support: eg multi sensor virtual platform

UCLA Vehicle Testbed Deployment

- **We are installing our node equipment in:**
  - 30 Campus operated vehicles (including shuttles and facility management trucks).
    - Exploit “on a schedule” and “random” campus fleet mobility patterns
  - 12 Private Vehicles: controlled motion experiments
  - Cross campus connectivity:10 node WiFi Mesh + 2 WiMAX base stations
- **Support: NSF GENI**

Campus Coverage Using MobiMesh

Work in progress in the UCLA V-Cloud project

- **Efficient urban spectrum usage**
  - Coexistence strategies (vehicles + residential)
- **Content downloading**
- **Integration of Internet centric and distributed vehicular traffic routing**
- **Urban sensing & surveillance applications**
- **Named Data Networking VANET implementation**

Summary about Vehicular Cloud

- **Vehicular Cloud: a model for the systematic implementation of services in the vehicular grid**
  - Services to support vehicle app (eg, alarm dissemination, traffic congestion reporting, intelligent transport, etc)
  - Services to support external apps (eg, surveillance, forensic investigation, etc)
- **Recent events favor the development of V2V and thus of Vehicular Cloud services**
  - USDOT V2V endorsement
  - The emergence of autonomous vehicles (Google Car etc)
- **The proliferation of Mobile Cloud Computing workshops confirms this trend**

Thank You

Questions?