Vehicular cloud computing: from intelligent transport to urban surveillance

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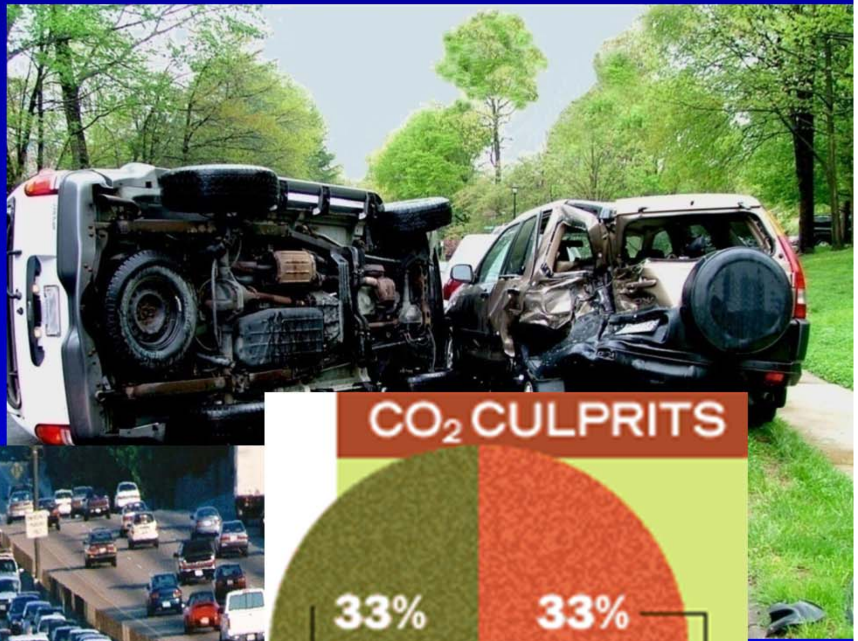
Outline

- **The emergence of vehicular communications: VII and “Connected Vehicle”**
  - Initial applications: safety and content distrinution
- **Vehicular Cloud computing**
  - Principles and Challenges
  - Vehicle Cloud vs Internet Cloud
- **Two Vehicle Cloud Applications:**
  - Urban surveillance
  - Vehicular Traffic Management
- **Future Directions**

The Vehicle Transport Challenge

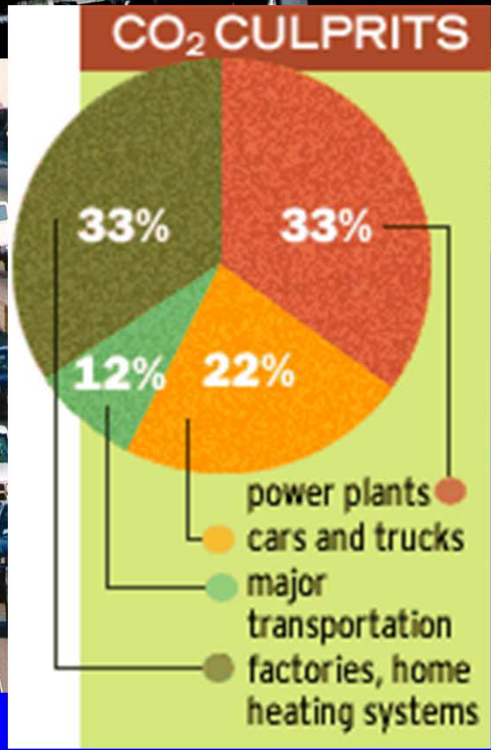


Safety

- 33,963 deaths/year (2009)
- 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)**
- **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)

The Connected Vehicle Program

- **Previous Veh Infrastr Integr (VII) Model (2003-9)**
  - DSRC based for all applications
  - Start with V2I (for all application types) and evolve into V2V (safety)
- **Current DOT's Connected Vehicle Plan**
  - *Non-safety (mobility, environment)*
    - Leverage existing data sources & communications; include DSRC as it becomes available
  - *Safety → DSRC*
    - Aggressively pursue V2V;
    - Can leveraging of nomadic devices & retrofitting accelerate benefits?

Emerging Application Areas

- Safe Navigation
- Location Relevant Content Distr.
- Entertainment, Games
- Urban Sensing
- Efficient, Intelligent, Clean Transport

V2V for Safe navigation

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

Car to Car communications for Safe Driving

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 75 mph
Acceleration: **+ 20m/sec^2**
Coefficient of friction: .65
Driver Attention: Yes
Etc.

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 65 mph
Acceleration: **- 5m/sec^2**
Coefficient of friction: .65
Driver Attention: Yes
Etc.

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 45 mph
Acceleration: **- 20m/sec^2**
Coefficient of friction: .65
Driver Attention: **No**
Etc.

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 75 mph
Acceleration: **+ 10m/sec^2**
Coefficient of friction: .65
Driver Attention: **Yes**
Etc.

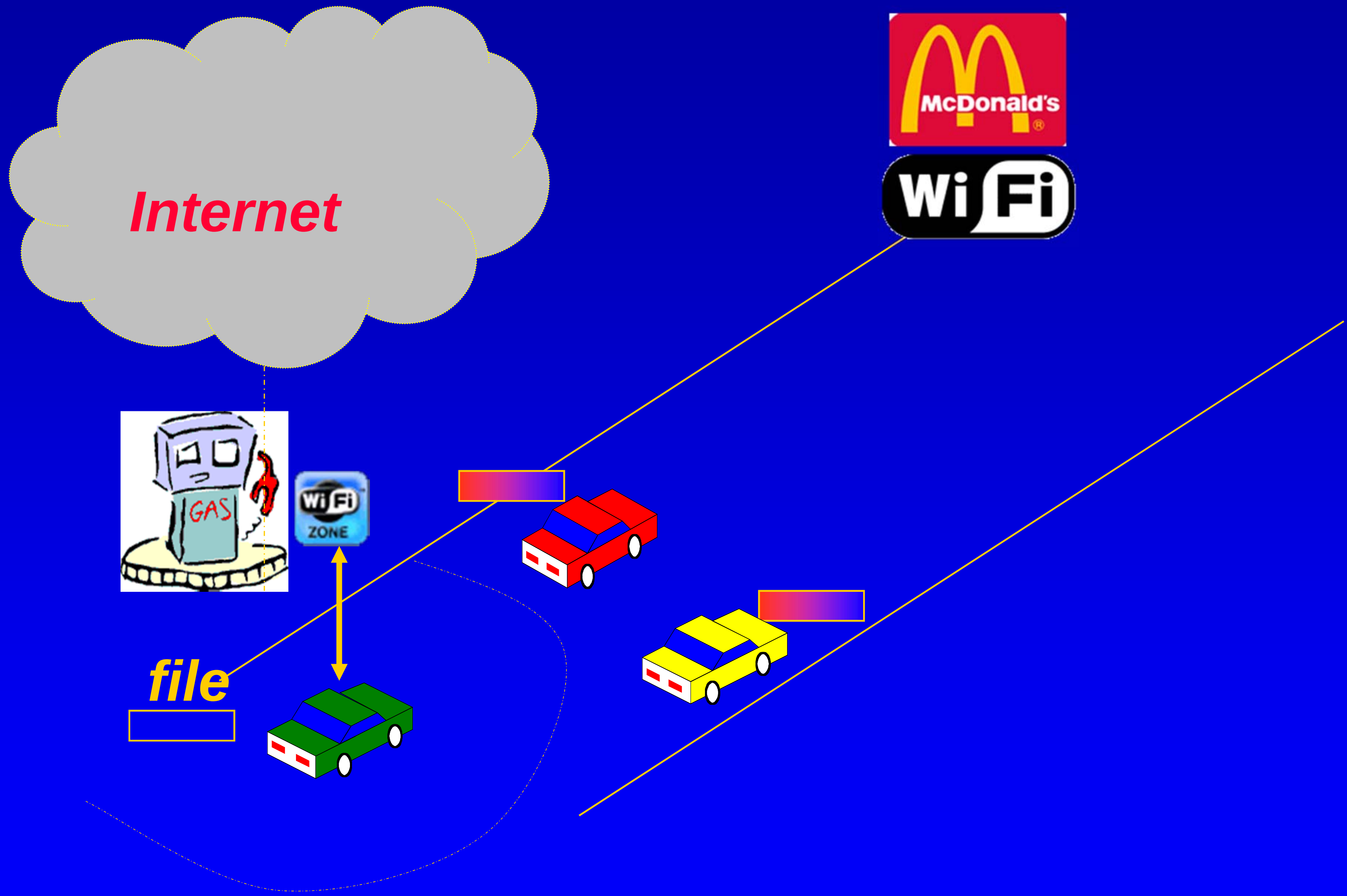
Location relevant content delivery

- **Traffic information**
- **Local attractions, advertisements**
- **Tourist information, etc**

CarTorrent : cooperative download of location multimedia files

You are driving to Vegas
You hear of this new show on the radio
Video preview on the web (10MB)

One option: Highway Infostation download



Incentive for opportunistic "ad hoc networking"

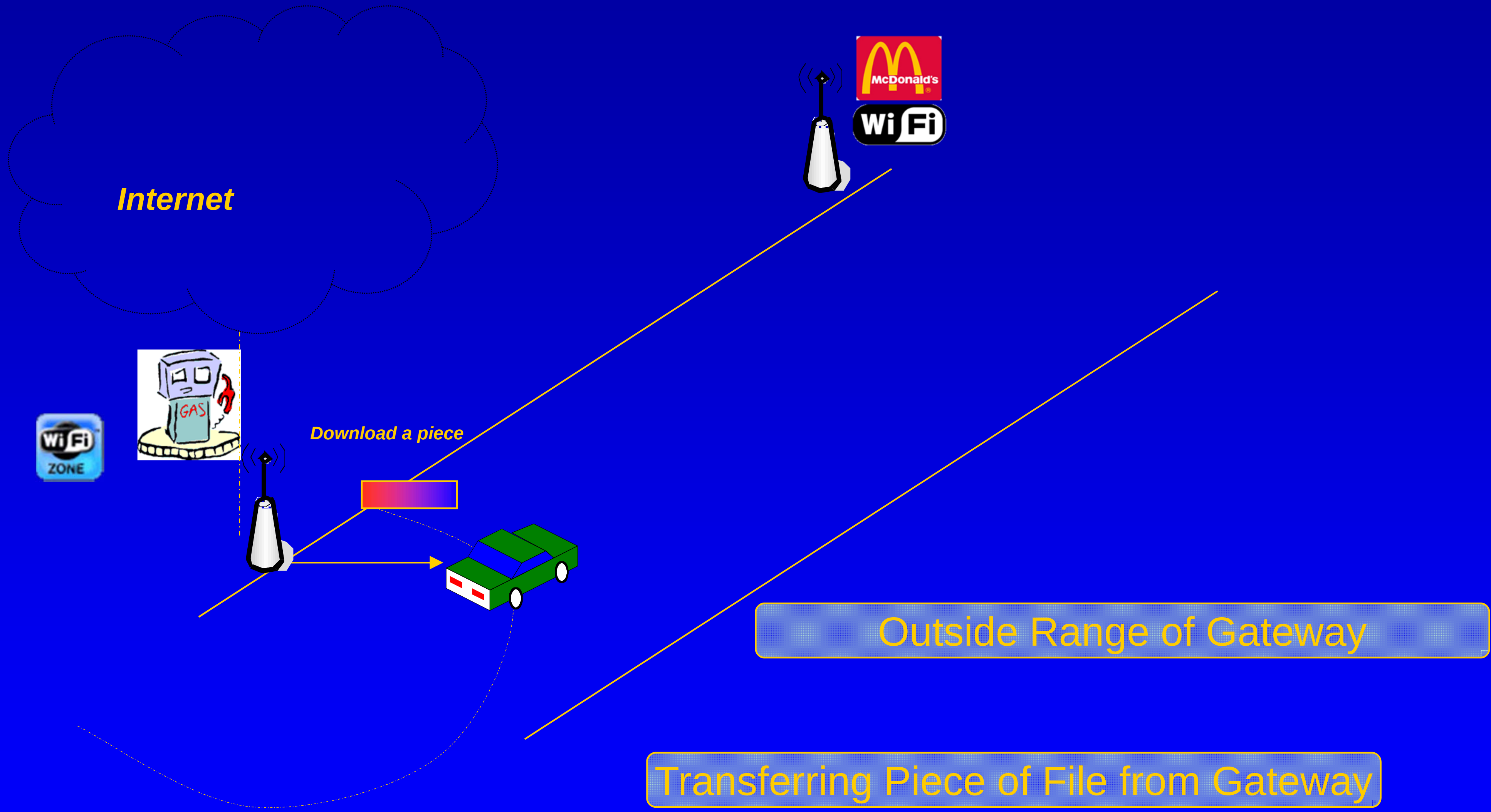
Problems:

- *Stopping at gas station for full download is a nuisance*
- *Downloading from GPRS/3G too slow and quite expensive*
- *3G broadcast services (MBMS, MediaFLO) only for TV*

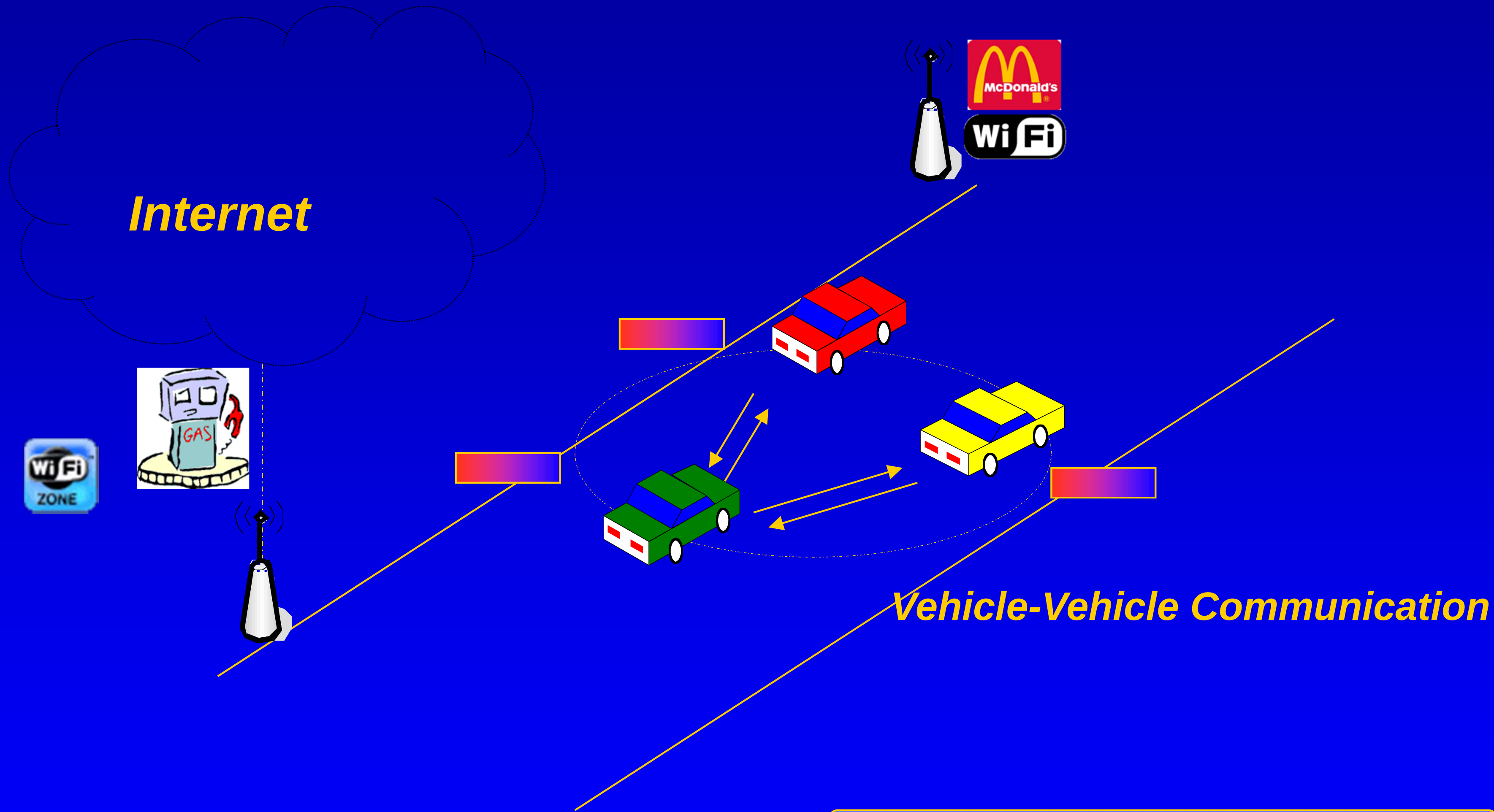
Observation: many other drivers are interested in download sharing

Solution: Co-operative P2P Downloading via Car-Torrent (like Bit Torrent in the Internet)

CarTorrent: Basic Idea



Co-operative Download: Car Torrent



Exchanging Pieces of File Later

Vehicular Cloud computing

Observed trends:

1. **Vehicles perform increasingly more complex (sensor) data collection/processing**

   - road alarms (pedestrian crossing, electr. brake lights, etc)
   - cooperative content downloading via P2P car- torrent
   - surveillance (video, mechanical, chemical sensors)
   - road mapping via “crowd sourcing”
   - accident, crime witnessing (for forensic investigations, etc)

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

Enter Vehicular Cloud Computing:

Keep and process data on *vehicle cloud* instead of uploading to *Internet cloud*

Vehicle Cloud vs Internet Cloud

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

However:

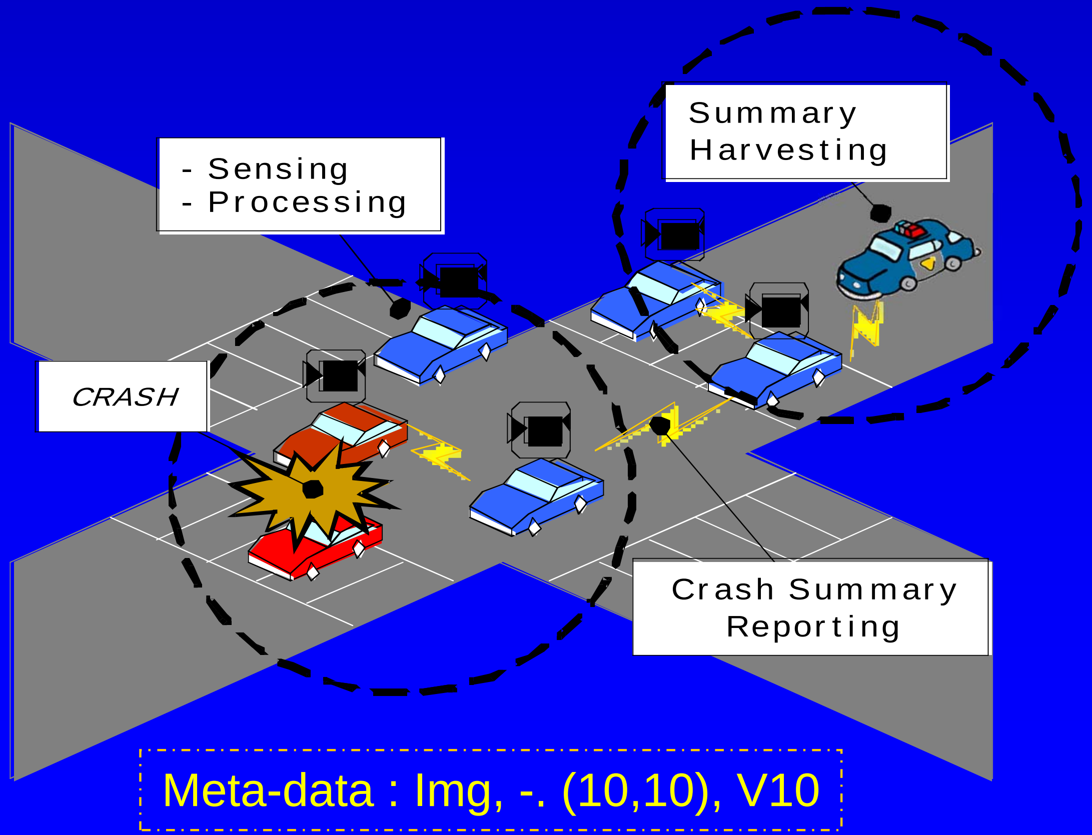
- **Vehicular applications are mainly location relevant**
  - Data Sources: Drivers or environment
  - Customers: generally the drivers
- **Vehicle cloud interacts with:**
  - Internet cloud
  - Personal (smart phone) cloud
- **Exception: emergency VANET**
  - During an emergency the infrastructure is destroyed
  - Emergency cloud is isolated, works on its own power
  - Vehicle (especially E-vehicles) become the ONLY available computing/comms resource

We review two emerging Vehicle Cloud applications

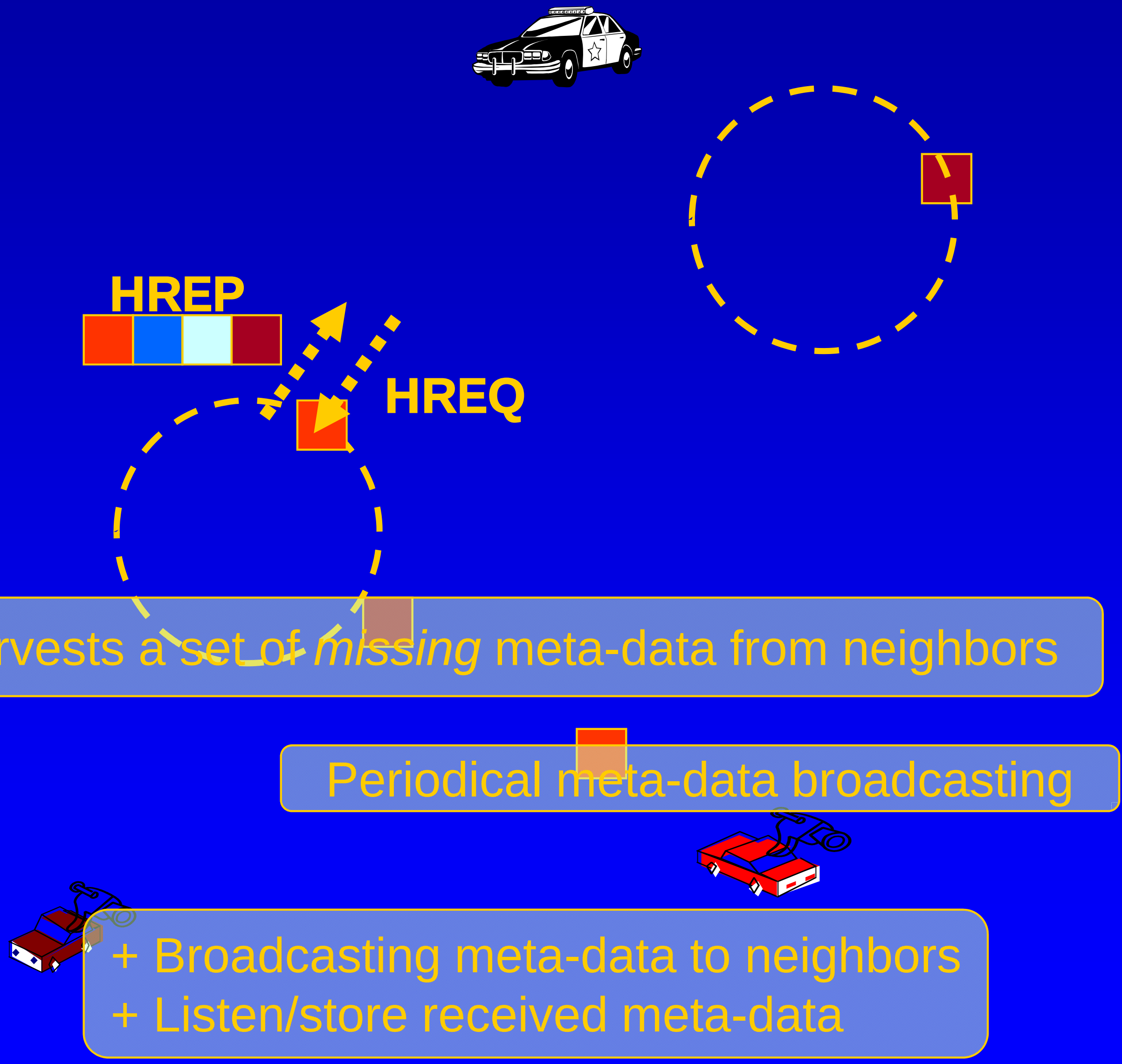
- **Surveillance**
  - Monitoring the environment events (natural or manmade)
- **Urban Traffic management:**
  - From totally centralized to locally distributed to evacuation

Surveillance Scenario: storage and retrieval

- **Participating Cars (busess, taxicabs, commuters):**
  - Continuously **collect** images from the street (store data locally)
  - Process the data and **detect** an event
  - **Classify the event as Meta-data** (Type, Option, Loc, time,Vehicle ID)
- **Question: how to access this info?**



Mobility-assisted Meta-data Diffusion/Harvesting (*Mobeyes 2007*)



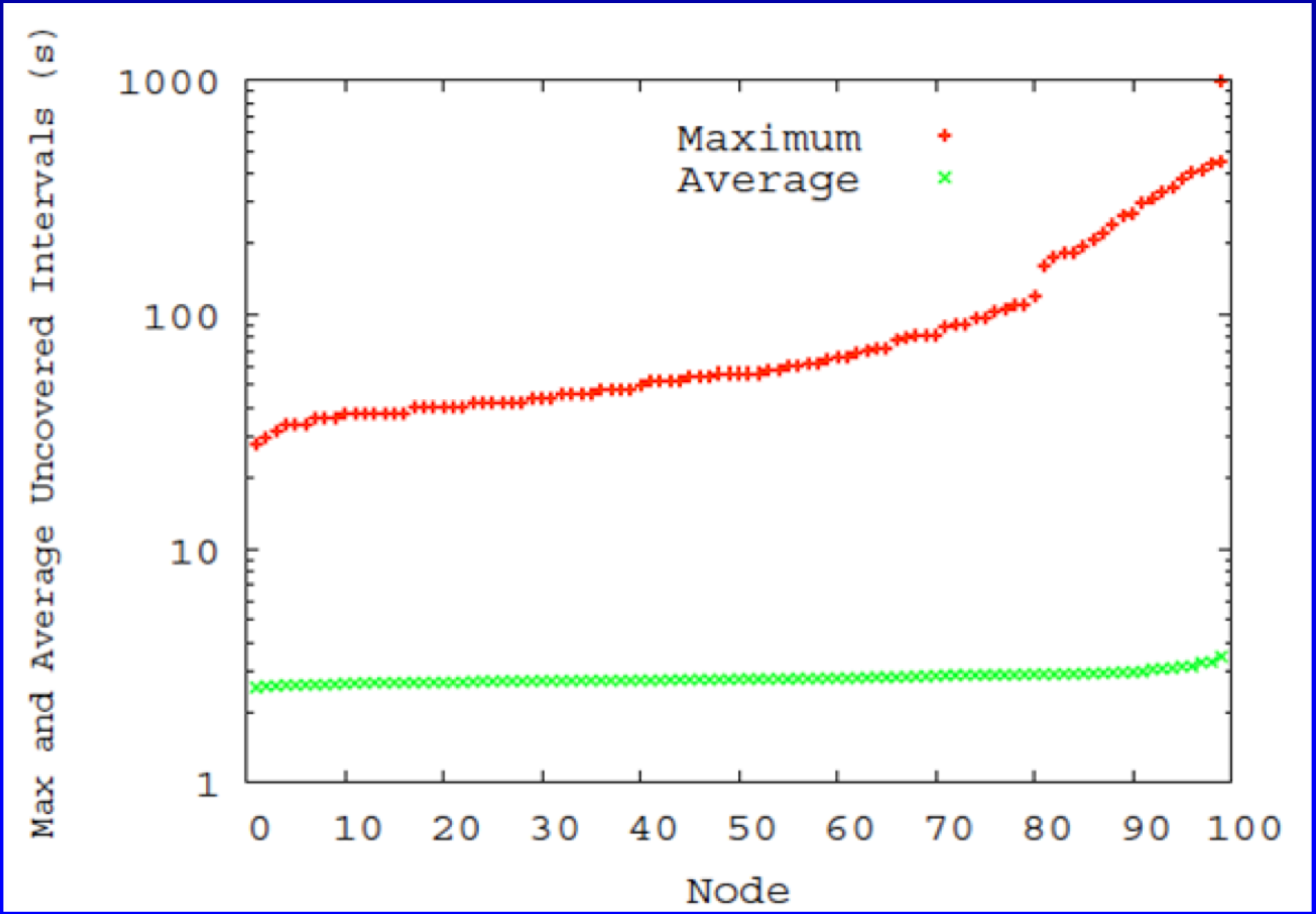
MobEyes: Mobility-assisted Epidemic Dissemination

- **Mobeyes exploit "mobility" to disseminate meta-data!**
- ***Source*** **periodically broadcasts meta-data to neighbors**
  - Only source can advertise meta-data
  - Neighbors store advertisements in their local memory
  - Drop stale data
- **A** ***mobile agent*** **(the police) harvests meta-data from vehicles by querying them (with Bloom filter)**

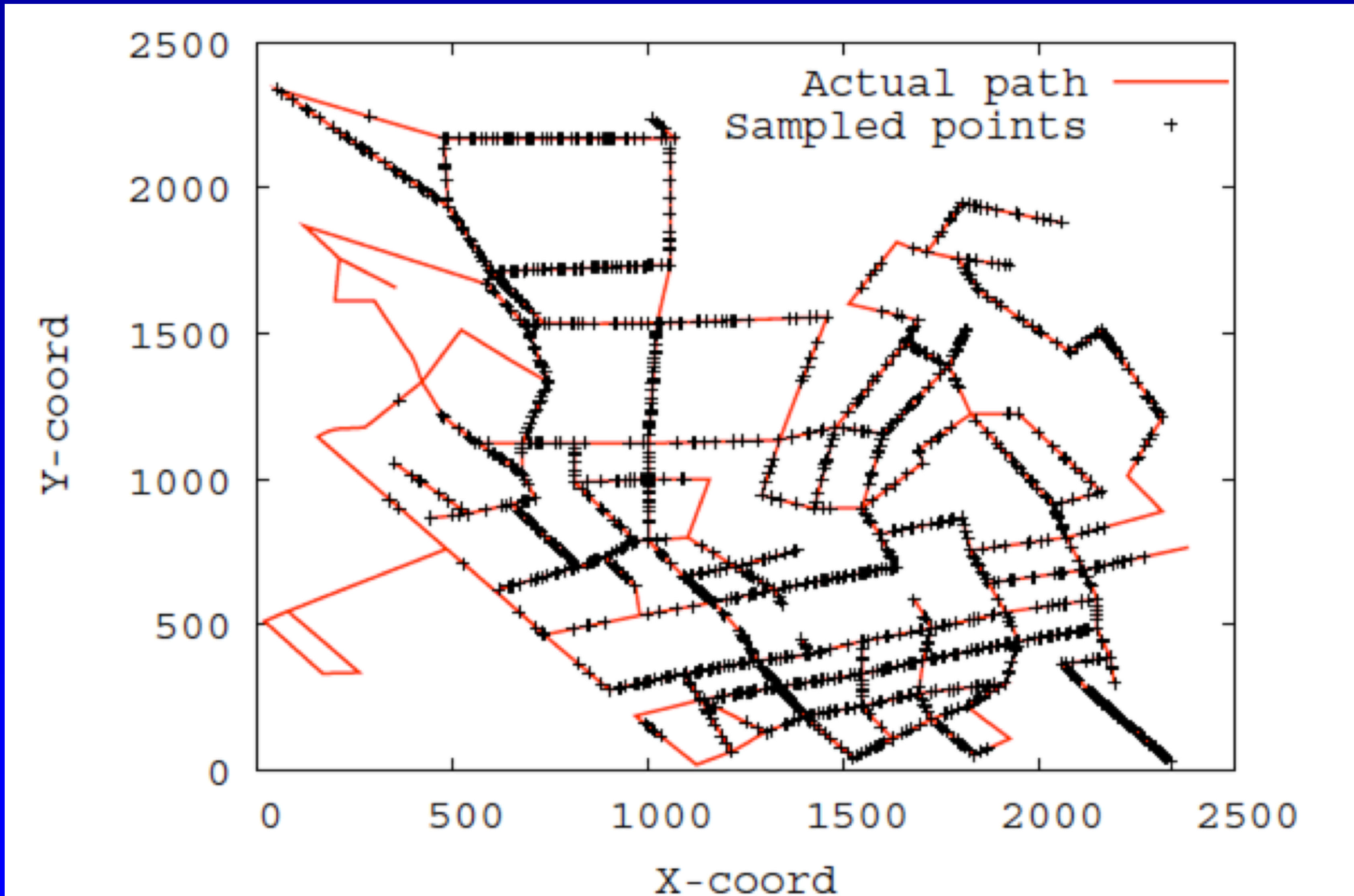
Urban Surveillance as a Service

- **Suppose a green truck was involved in a suicidal terrorist attack**
  - The truck blows up
  - The Agency wants to find out the approach path of the vehicle
  - Wants to learn if any accomplices drove along with the truck up to the target
- **Conventional solution: “road side” video cameras**
  - Sophisticated attacker can avoid video cameras, or disable them
- **Mobeyes based solution:**
  - Reconstruct the path by using the other vehicles video cameras
- **We have run a simulation experiment in a 2kmx2km area, with 100 vehicles roaming**
  - Vehicles watch each other and agent reconstructs all paths

Trace Reconstruction

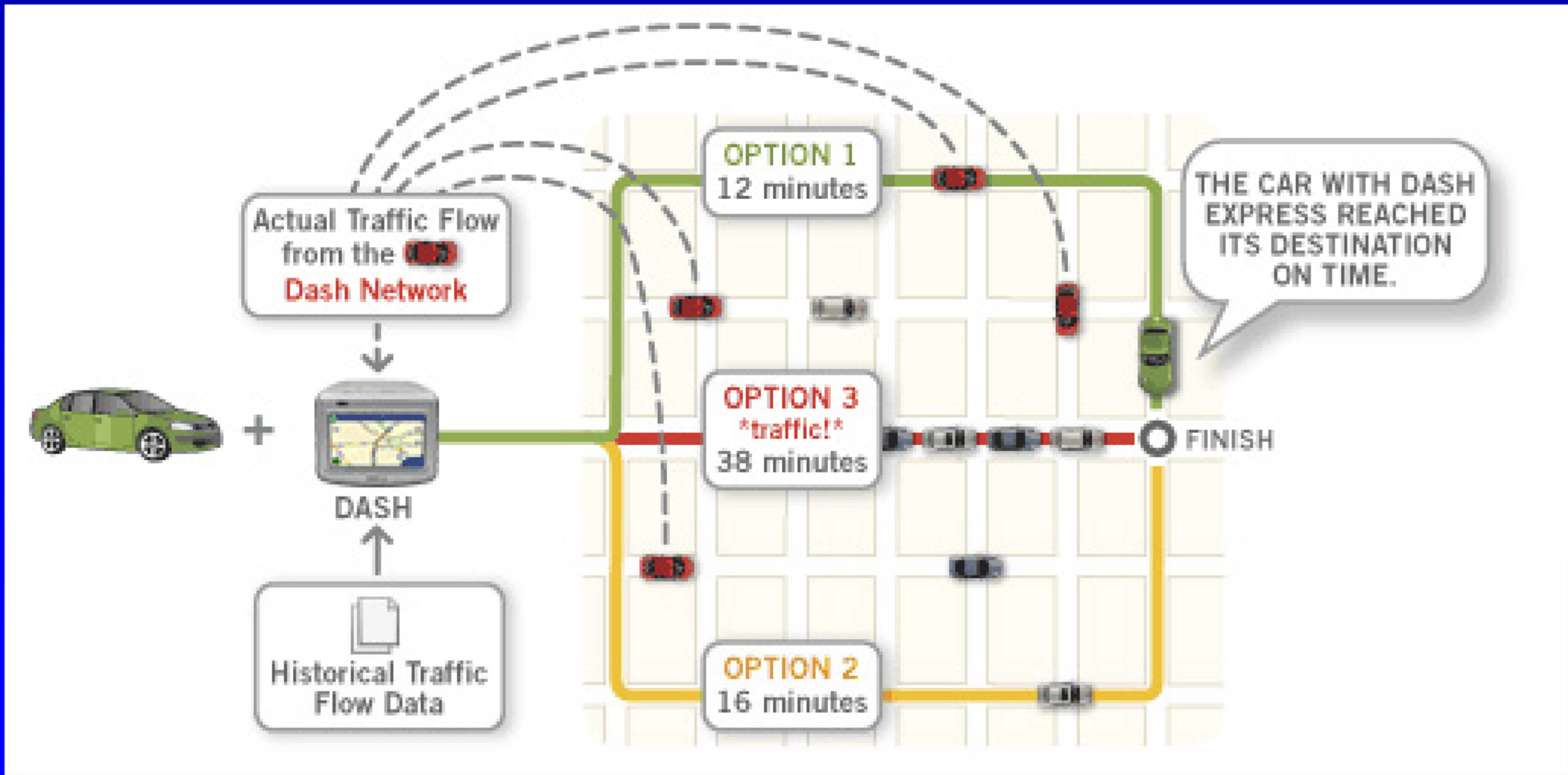


Trace Reconstruction



Vehicle Cloud for intelligent navigation

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

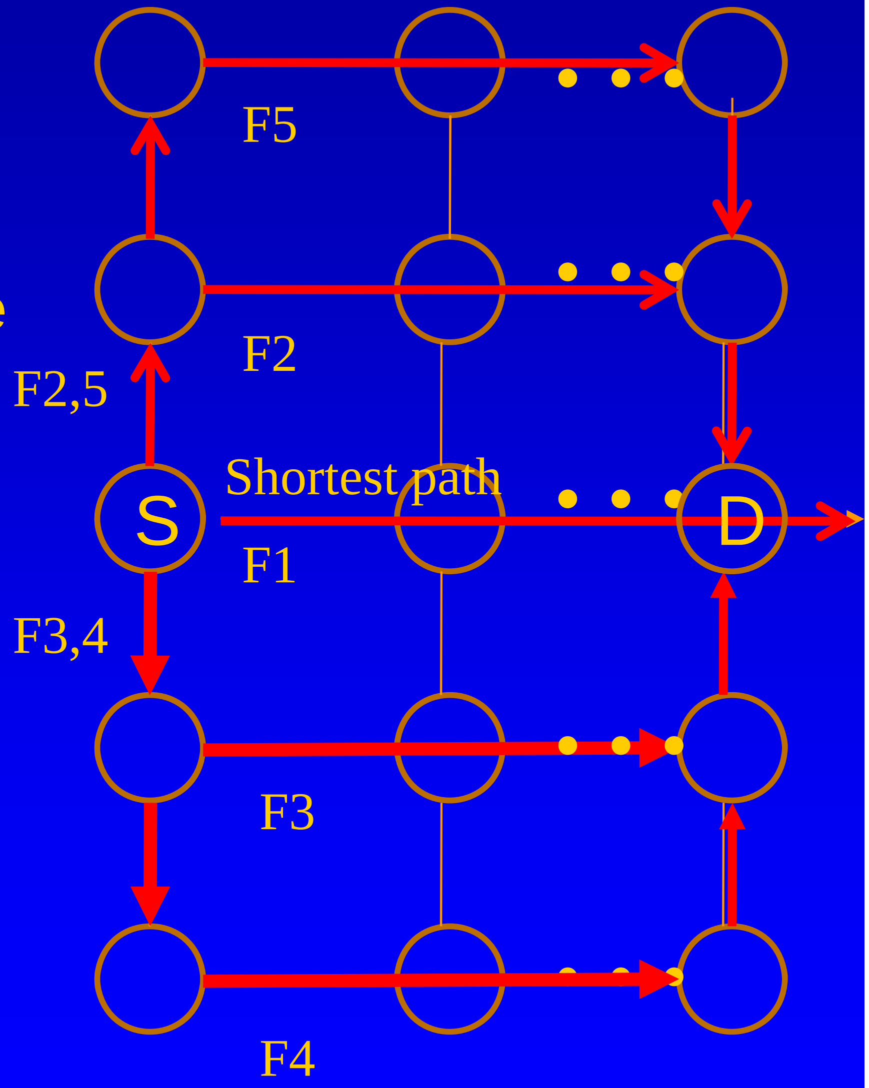


- **Synergy between Navigator Server and City Transport Authority**

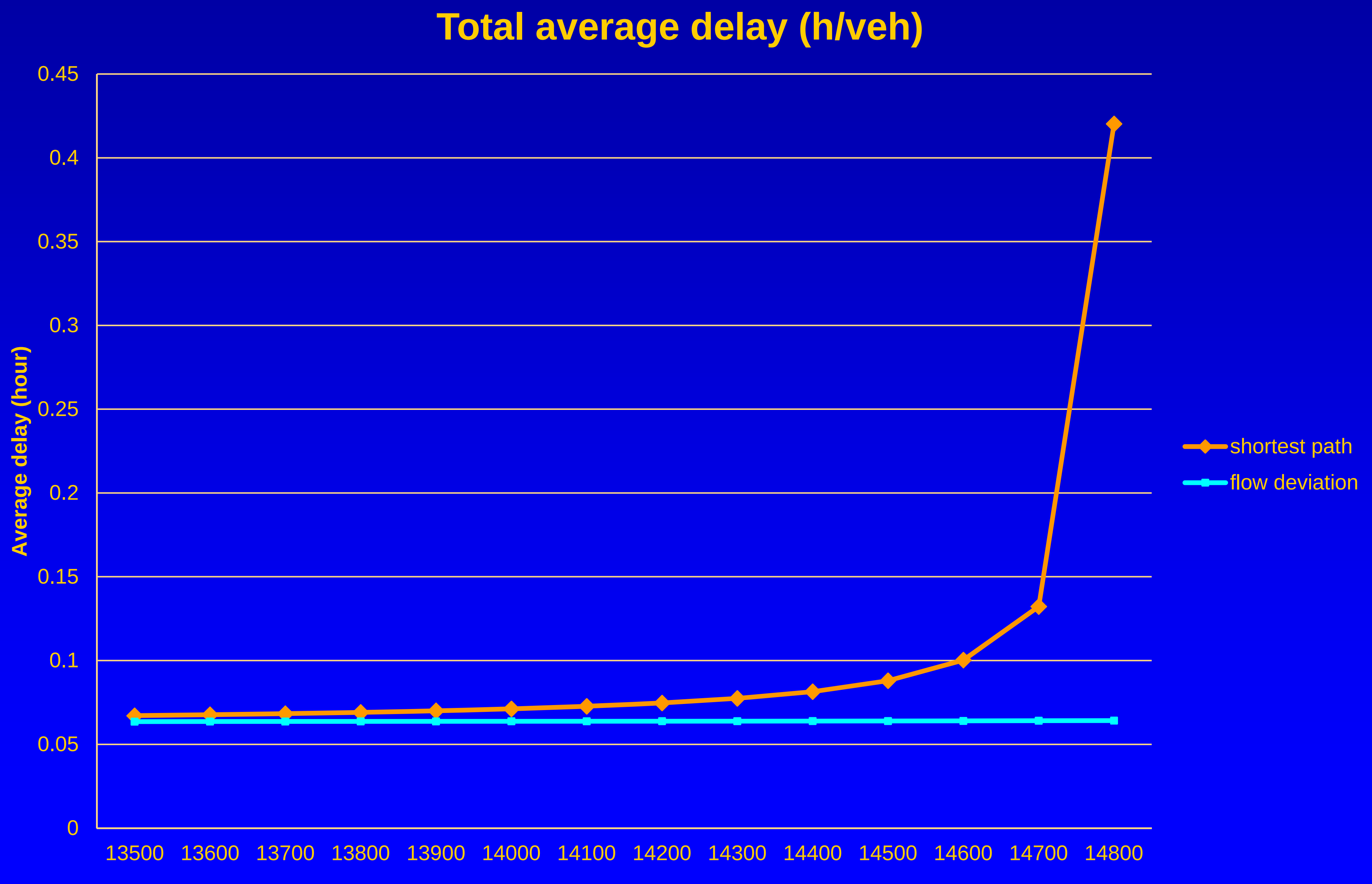
NAVOPT – Navigator Assisted Route Optimization

- **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]

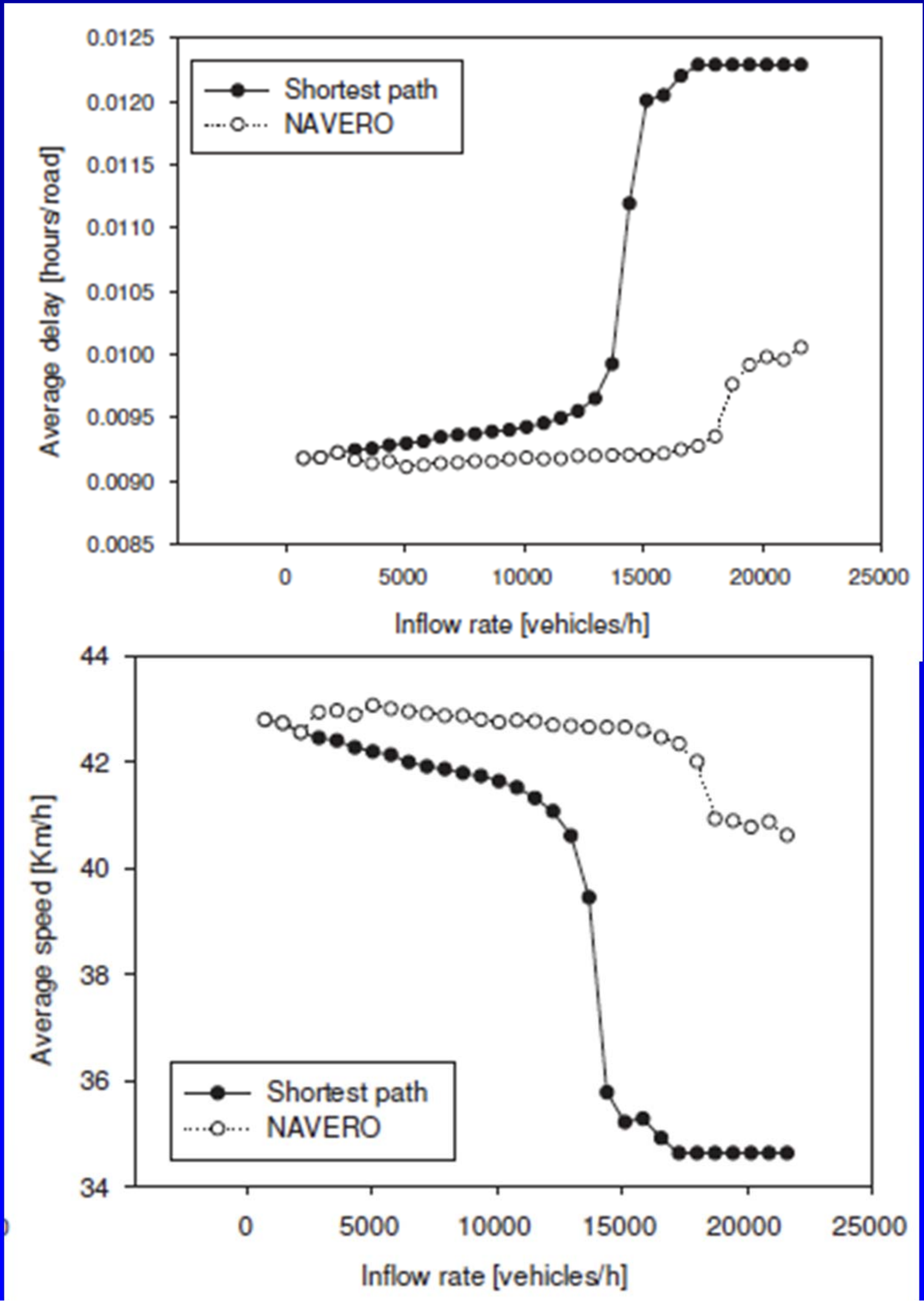


Analytic Results



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



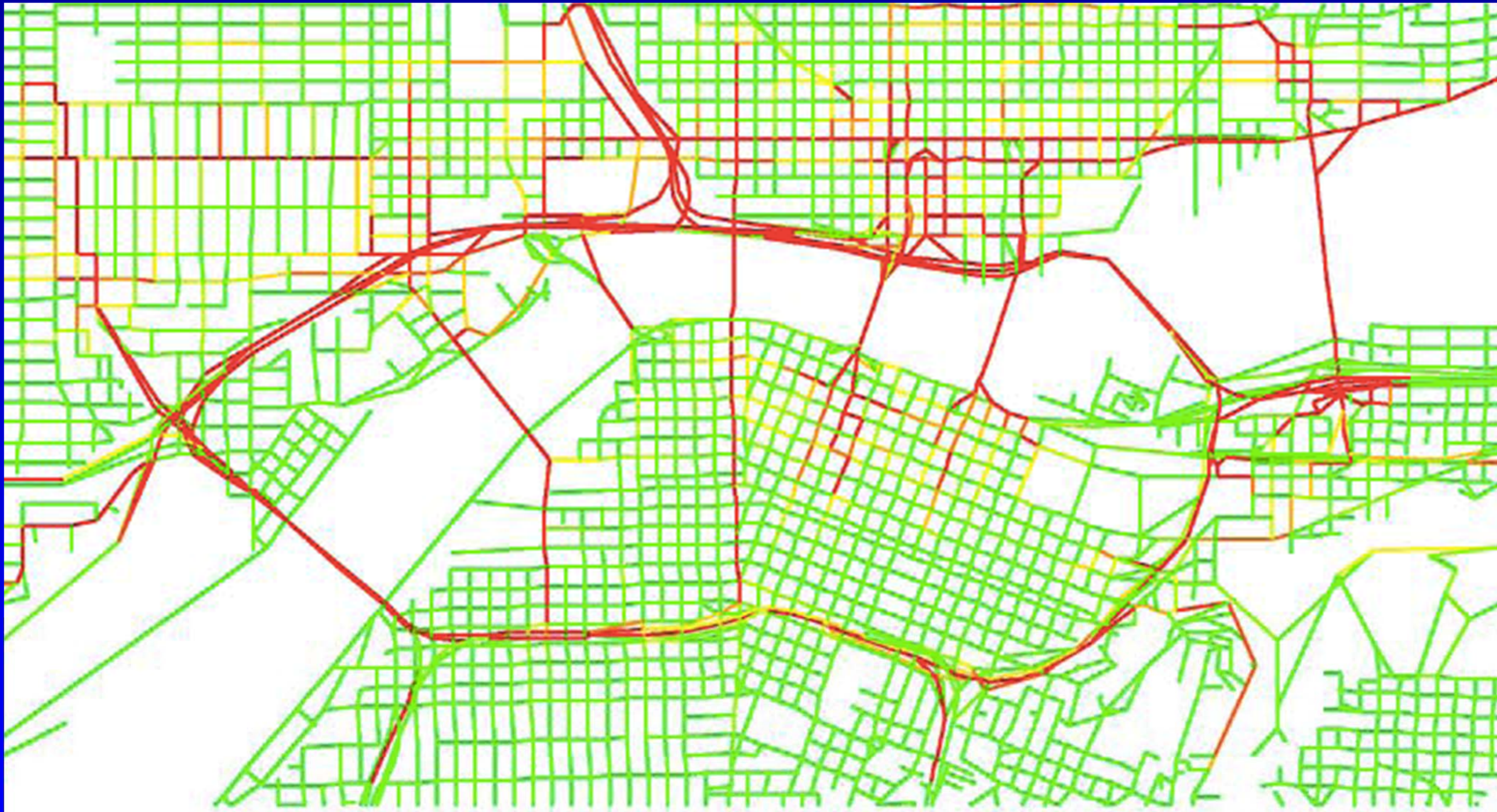
Distributed traffic management

- **Centralized traffic management 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 crowd source traffic information and traffic load data base:**
  - 1) sensing traffic information;
  - 2) sharing it with neighboring vehicles (in an ad hoc manner); and
  - 3) dynamically recomputing the best route to destination from the current position based on the collected information.
- **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

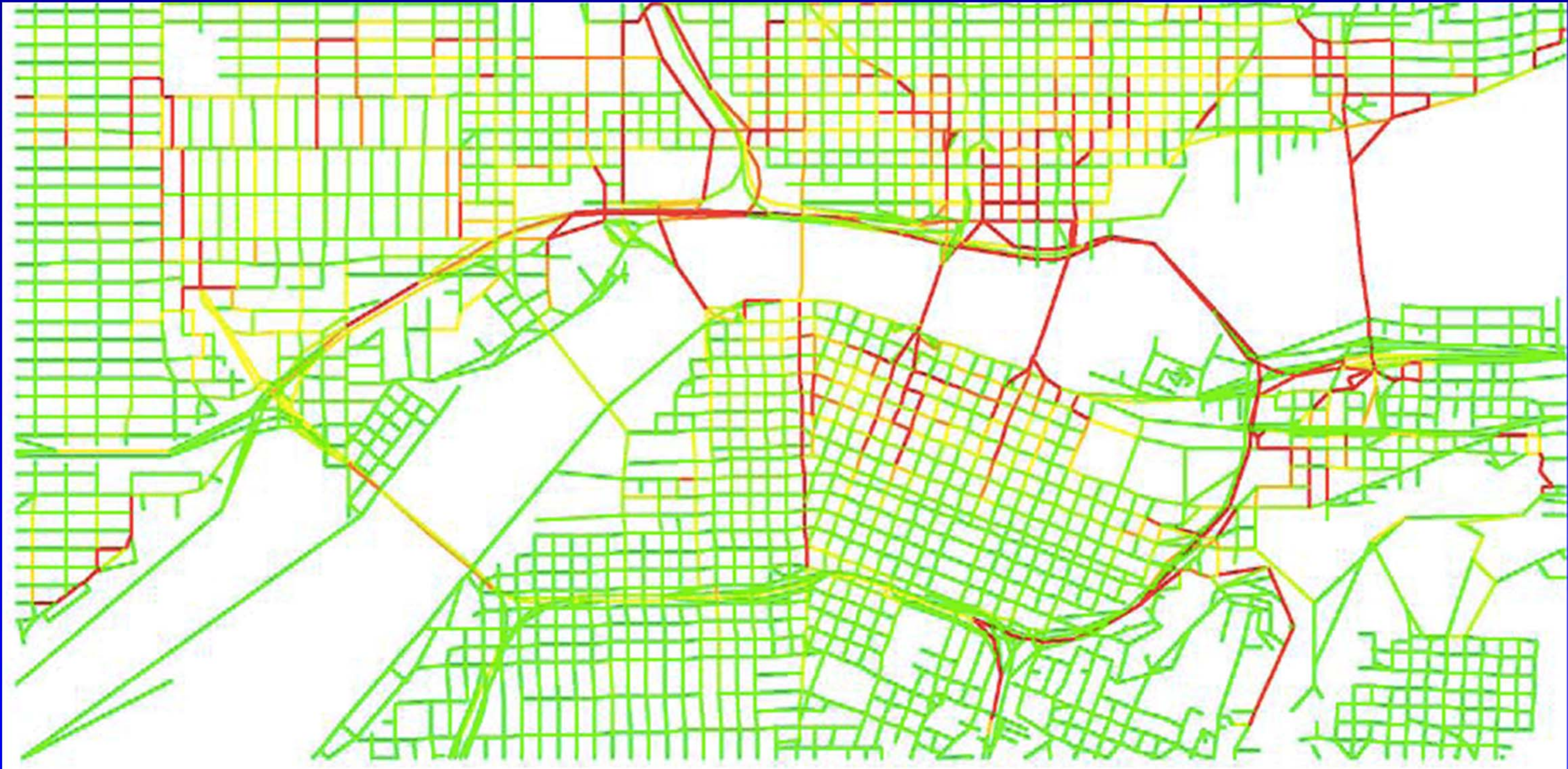
Traffic loading w/o CATE



(a)

Green no congest   Yellow moderate   Red heavy congest

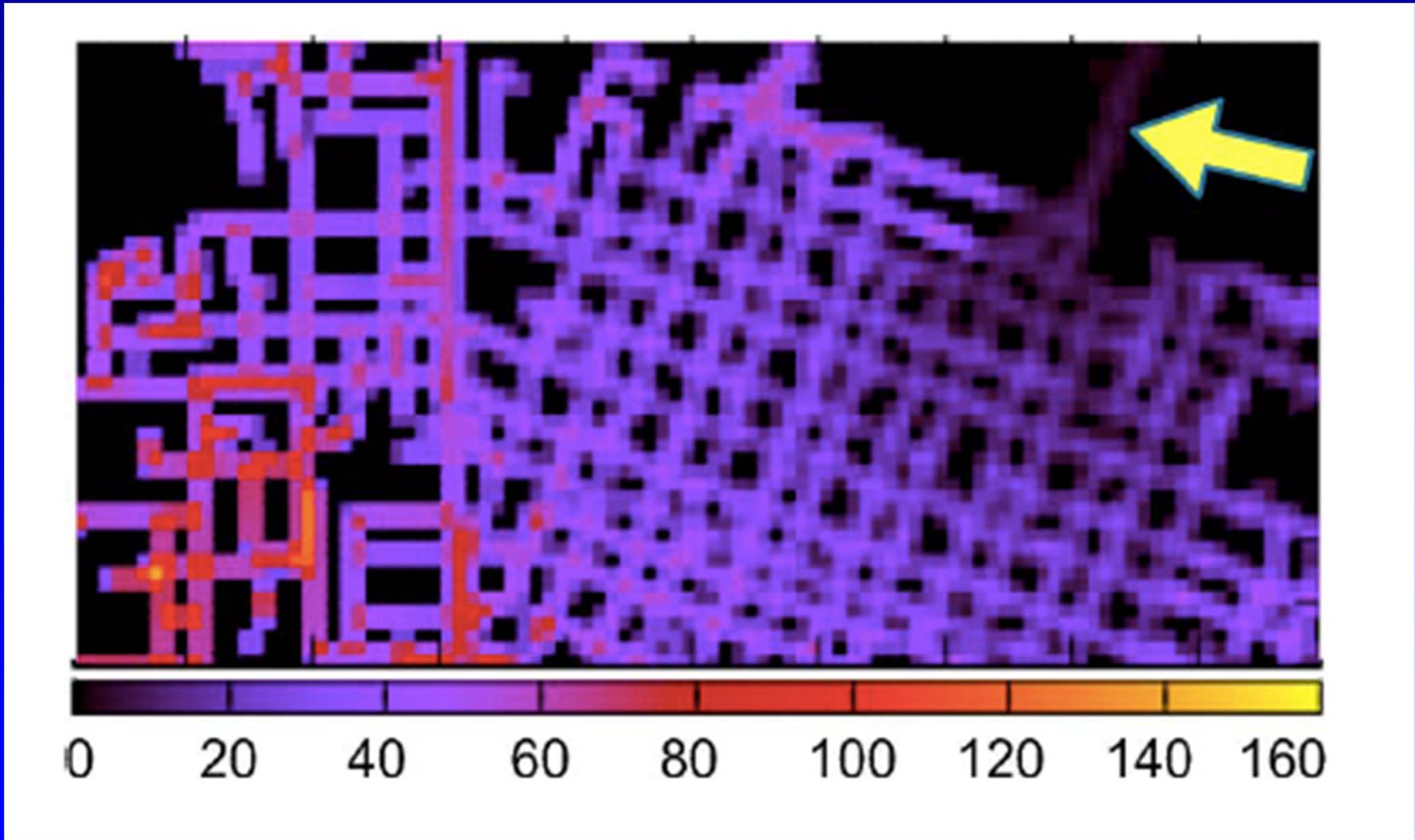
Traffic loading with CATE



(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 througput = 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

Work ahead in Vehicle Cloud research

- **Vehicle cloud formation and maintenance**
  - Subclouds with common “social” interests
- **In-Cloud networking**
  - Cloud Content dissemination, storage, indexing, search (Content Centric Networking)
- **Efficient spectrum usage** (via cog radios)
  - Exploit WiFi spectrum – short range
  - Exploit TV spectrum – long range connections (to other vehicle clouds)
- **User-centric security and privacy protection**
- **Interaction with Internet Cloud**
- **Interaction with pedestrian (people) clouds**

The End

Thank You