

Vehicular Urban Sensing: Dissemination and Retrieval

**National Sun Yat-sen University
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Outline

- **Vehicular Ad Hoc Networks (VANETs)**
 - Opportunistic ad hoc networking
- **V2V applications**
 - Content distribution
 - Urban sensing
 - Mobeyes (UCLA)
 - Security implications
- **The UCLA CAMPUS Testbed**

Traditional MANETs

- Instantly deployable, re-configurable (no fixed infrastructure)
- Satisfy a “temporary” need
- Mobile (eg, PDAs)
 - Low energy
- Multi-hopping (to overcome obstacles, etc.)
- Challenges: Ad hoc routing, multicast, TCP, etc

Examples: military, civilian disaster recovery

Vehicular Ad Hoc Network (VANET)

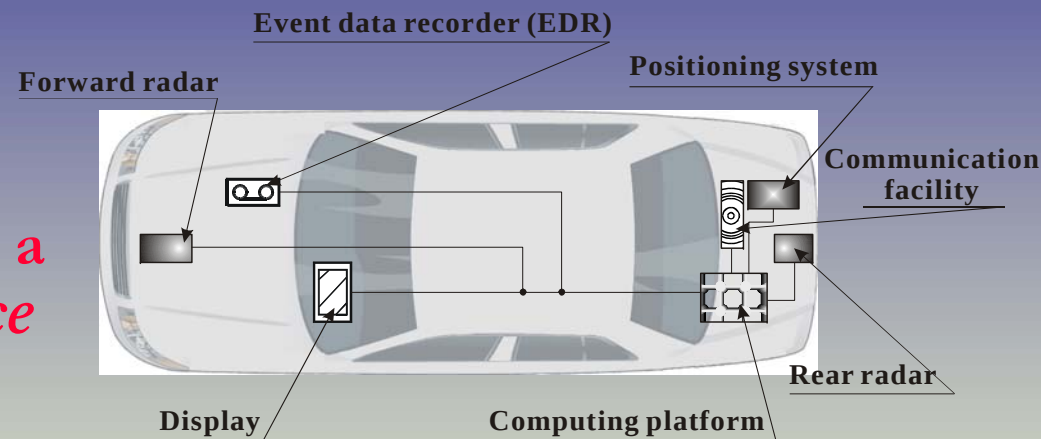
- **No fixed infrastructure?**
 - Several “infrastructures”: WiFi, Cellular, WiMAX, Satellite..
- **“Temporary” need?**
 - For vehicles, well defined, permanent applications
- **Mobile?**
 - YES!!! But not “energy starved”
- **Multi-hop routing?**
 - Most of the applications require broadcast or “proximity” routing
 - Infrastructure offers short cuts to distant destinations
 - Multihop routing required only in limited situations (eg, Katrina scenario)
- **VANET => Opportunistic Ad Hoc Network**
 - Access to Internet readily available, but..
 - opportunistically “bypass it” with “ad hoc” if too costly or inadequate

VANET New Research Opportunities

- **Physical and MAC layers:**
 - Radios (MIMO, multi-channel, cognitive)
 - Positioning in GPS deprived areas
- **Network Layer & Routing:**
 - Mobility models
 - Network Coding
 - Geo routing
 - Content based routing
 - Delay tolerant routing
- **Security and privacy**
- **New Applications:**
 - Content distribution , mobile sensing, safety, etc

The Enabling Standard: DSRC / IEEE 802.11p

- Car-Car communications at 5.9Ghz
- Derived from 802.11a
- three types of channels: Vehicle-Vehicle *service*, a Vehicle-Roadside *service* and a *control broadcast* channel .
- Ad hoc mode; and infrastructure mode
- 802.11p: IEEE Task Group for Car-Car communications



V2V Applications

- Safe Navigation
- Efficient Navigation/Commuting (ITS)
- Urban Sensing
- Location Relevant Content Distr.
- Advertising
- Commerce
- Entertainment/Games

V2V Applications

- **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/sec²**
Coefficient of friction: .65
Driver Attention: Yes
Etc.

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 65 mph
Acceleration: **- 5m/sec²**
Coefficient of friction: .65
Driver Attention: Yes
Etc.

Alert Status: **None**

Alert Status: **None**

Alert Status: **Inattentive Driver on Right**
Alert Status: **Slowing vehicle ahead**
Alert Status: **Passing vehicle on left**

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 75 mph
Acceleration: **+ 10m/sec²**
Coefficient of friction: .65
Driver Attention: **Yes**
Etc.

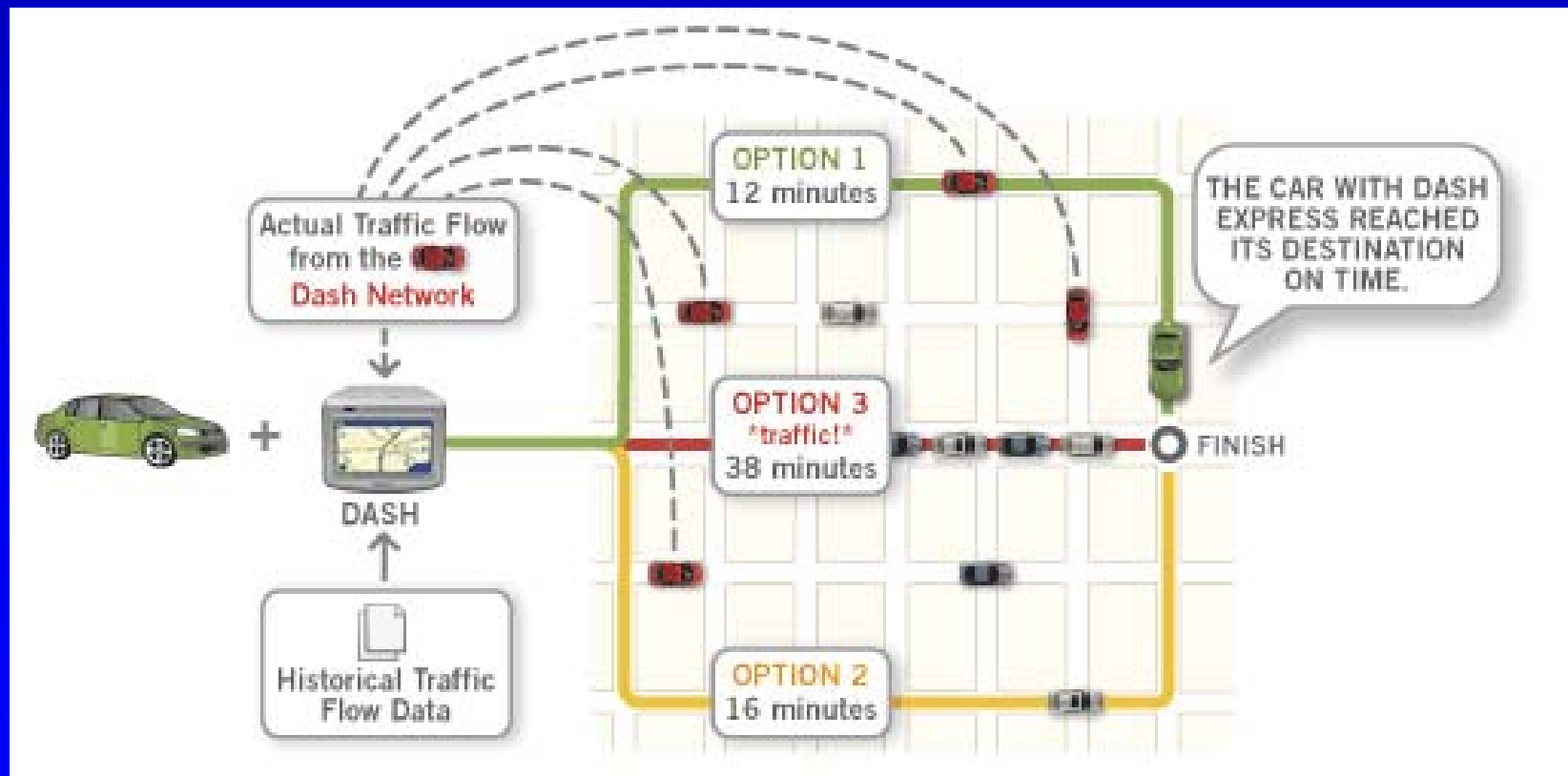
Alert Status: **Passing Vehicle on left**

Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 45 mph
Acceleration: **- 20m/sec²**
Coefficient of friction: .65
Driver Attention: **No**
Etc.

V2V Applications (cont)

- **Efficient Navigation**

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



Intelligent Transport Systems

intelligent lane reservations

QuickTime? and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

V2V Applications (cont)

- **Environment sensing/monitoring:**
 - Traffic monitoring
 - Pollution probing
 - Pavement conditions (eg, potholes)
 - Urban surveillance (eg, disturbance)
 - Witnessing of accidents/crimes

V2V Applications (cont)

- **Location related content delivery/sharing:**
 - Traffic information
 - Local attractions
 - Tourist information, etc

V2V Applications (cont)

Advertising (Ad Torrent):

- Access Points push Ads to passing cars
- Advertisement: multimedia file (data, image, video)
- Movie trailer; restaurant ad; club; local merchant..

Commerce (Flea Net):

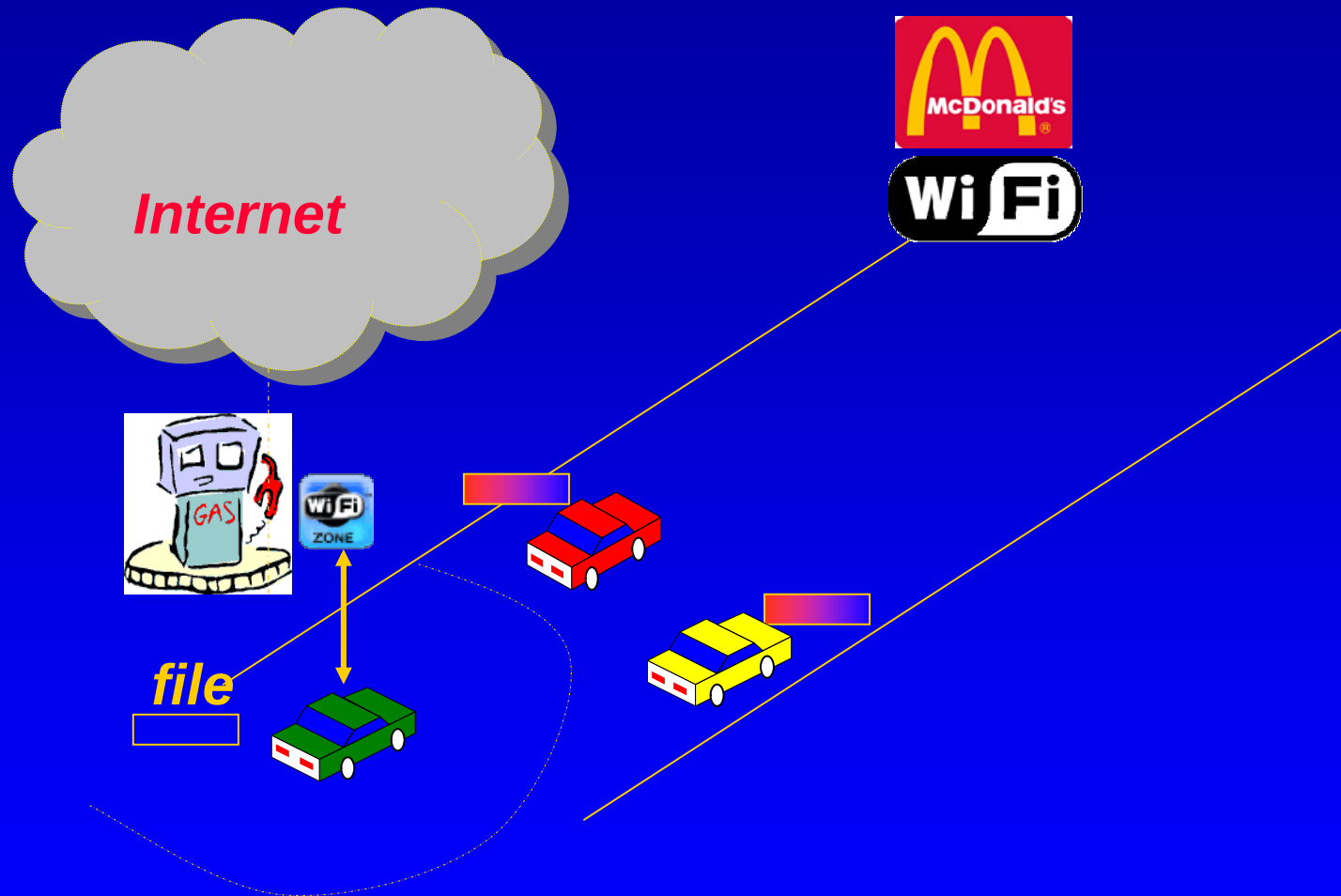
- virtual market (bazaar) concept in VANET
- A mix of mobile and stationary users buy/sell goods using the vehicular network

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*

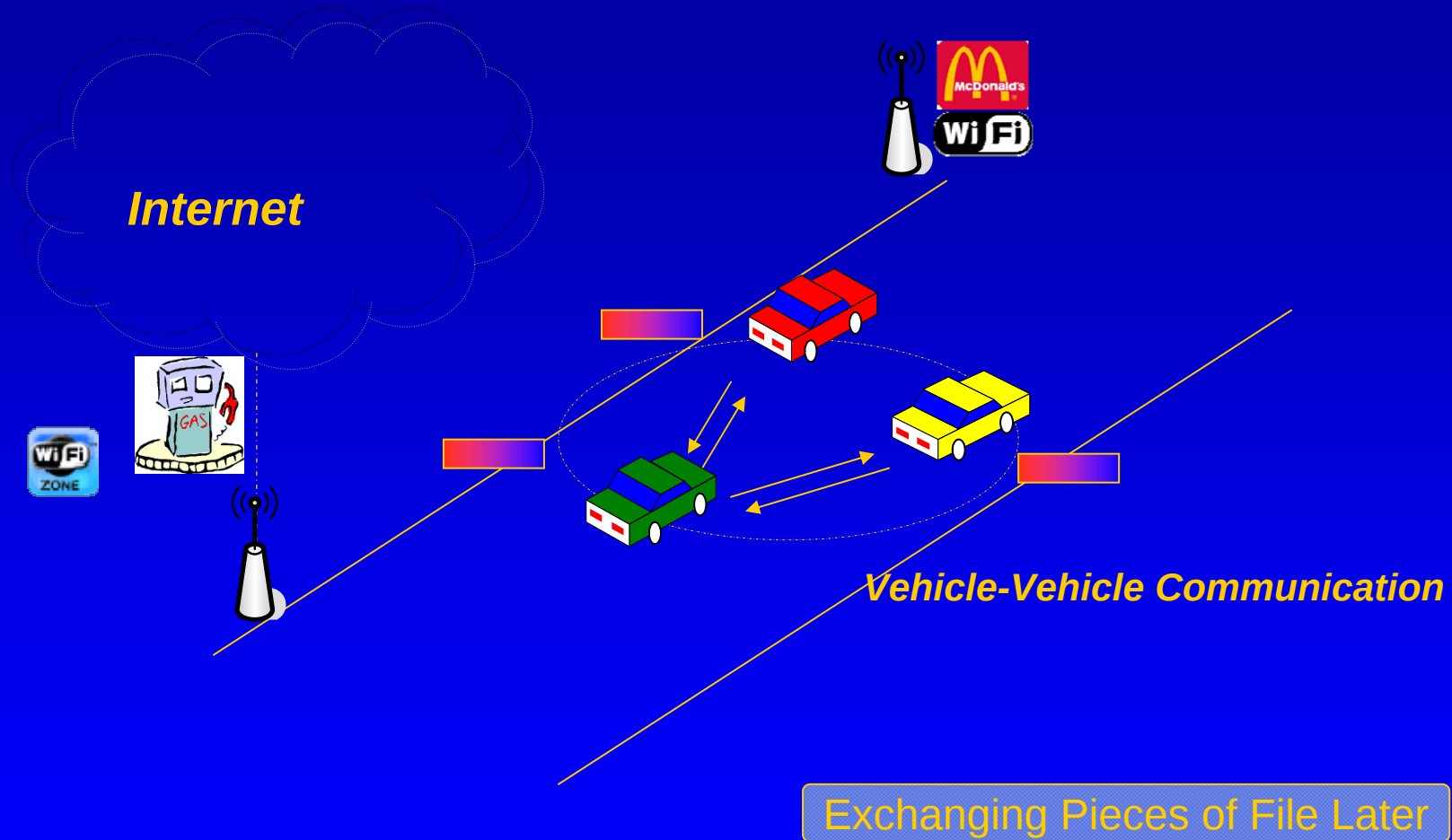
Observation: many other drivers are interested in download sharing (like in the Internet)

Solution: Co-operative P2P Downloading via Car-Torrent

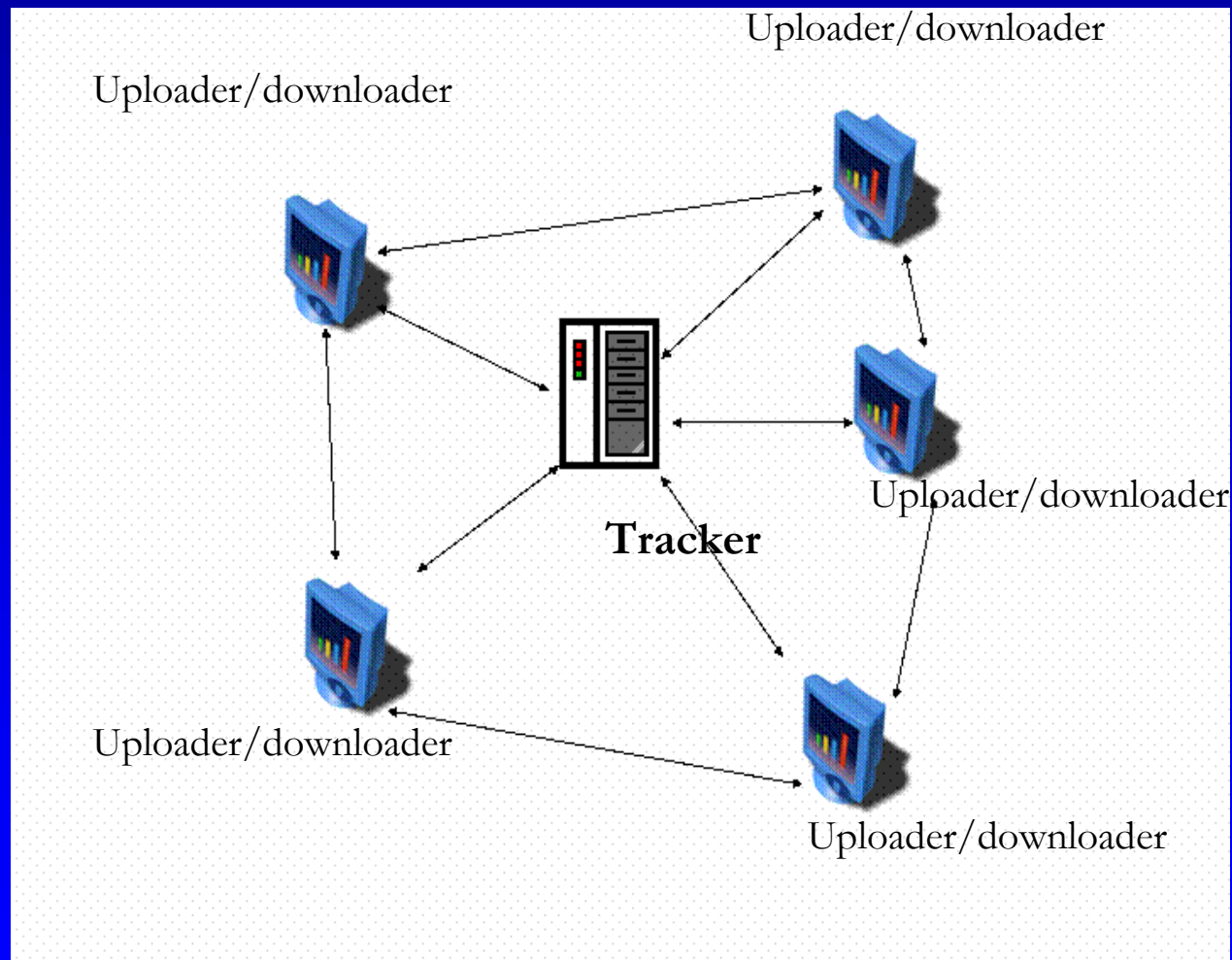
CarTorrent: Basic Idea



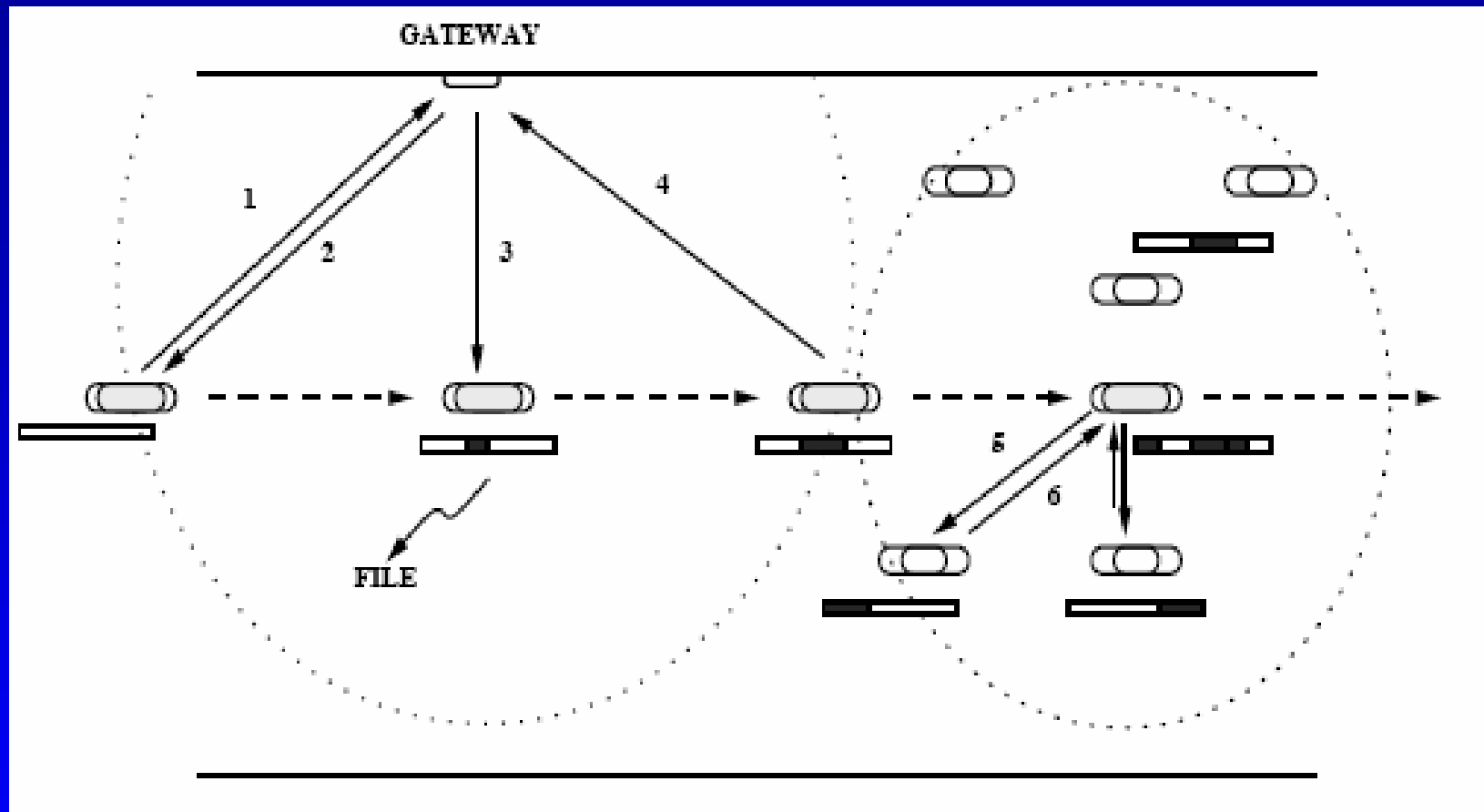
Co-operative Download: Car Torrent



Car Torrent inspired by BitTorrent: Internet P2P file downloading



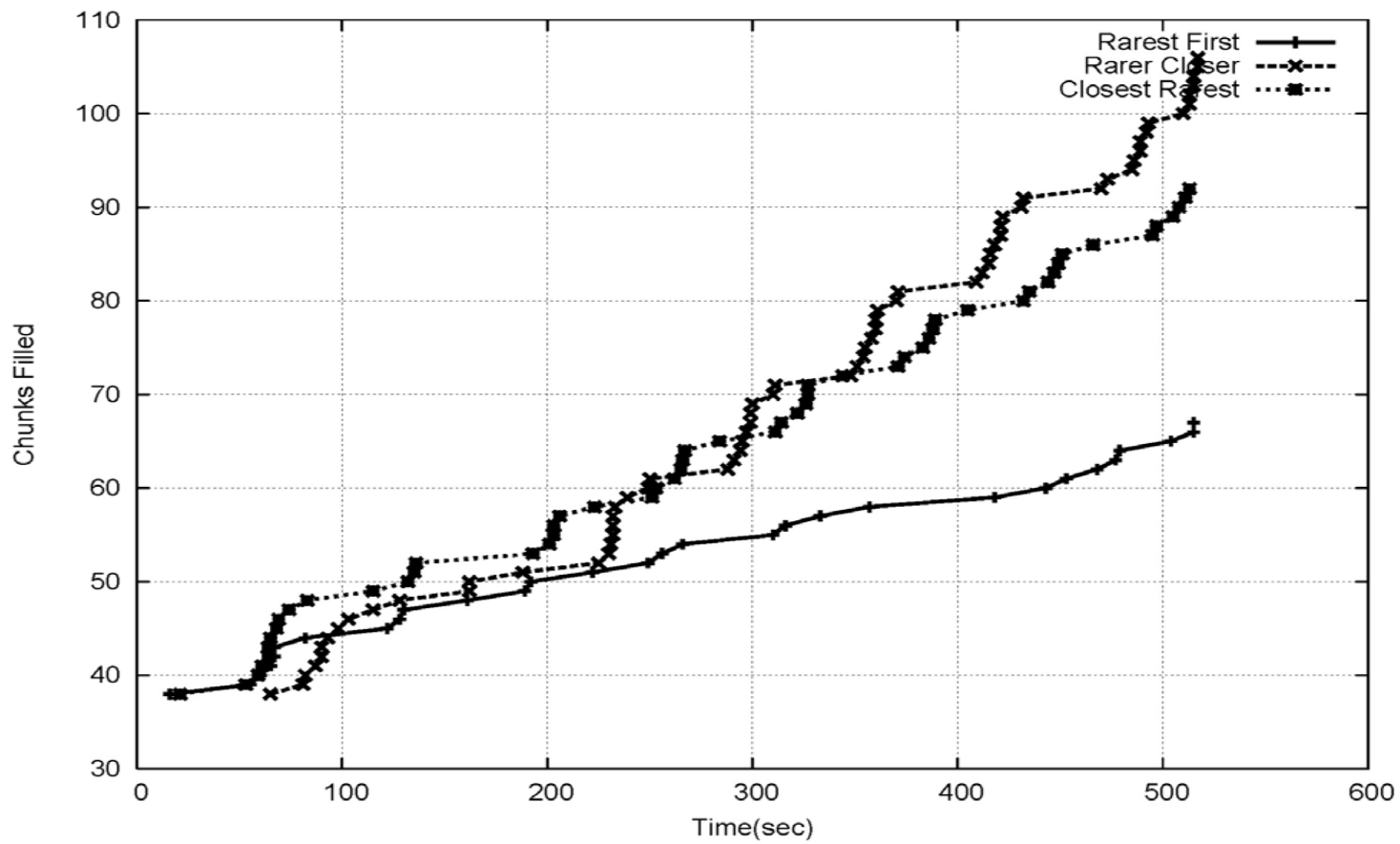
CarTorrent: *Gossip* to discover peers



A *Gossip message* containing Torrent ID, Chunk list and Timestamp is “propagated” by each peer

Problem: how to *select the peer* for downloading?

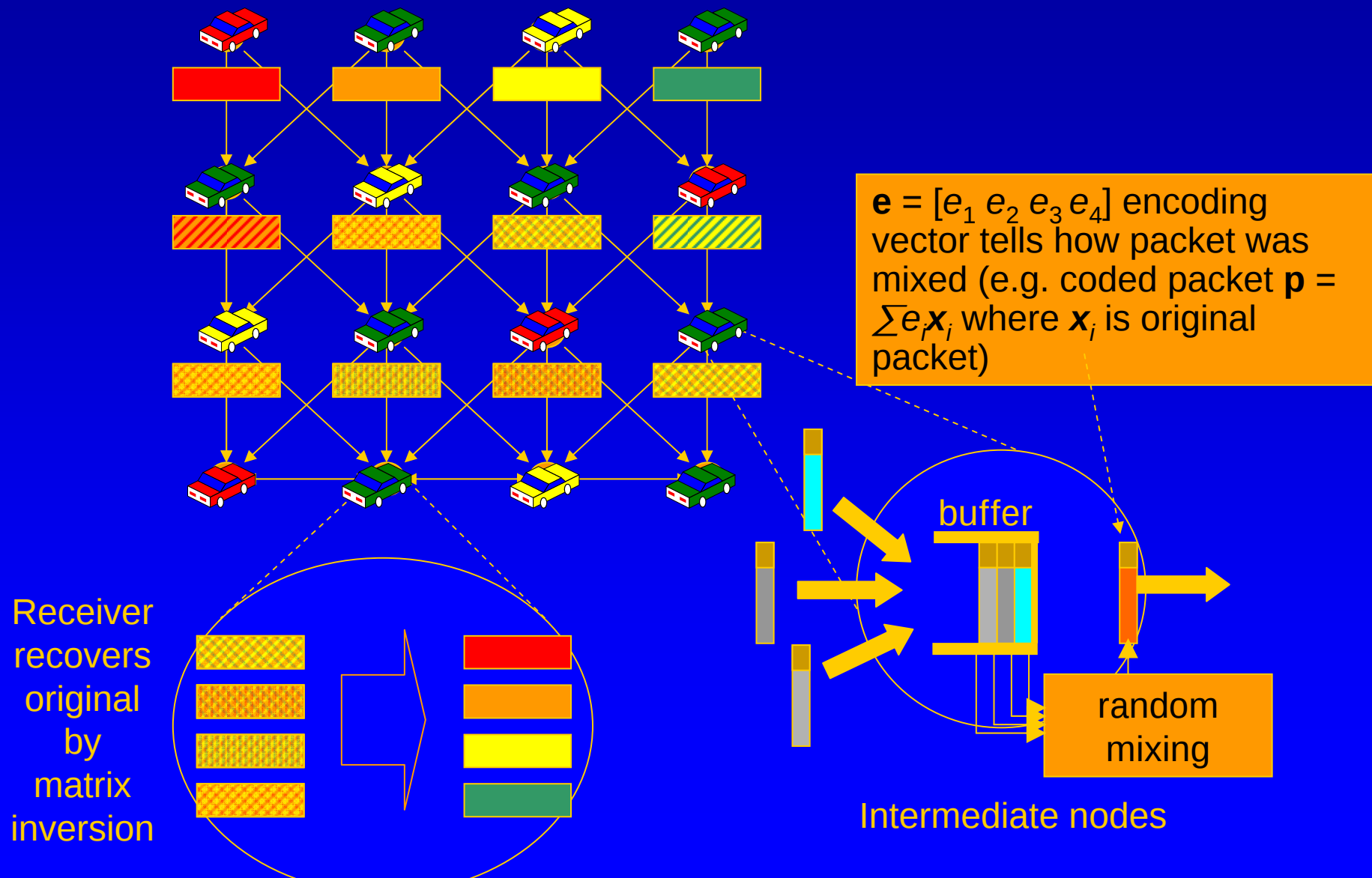
Selection Strategy Critical



CarTorrent with Network Coding

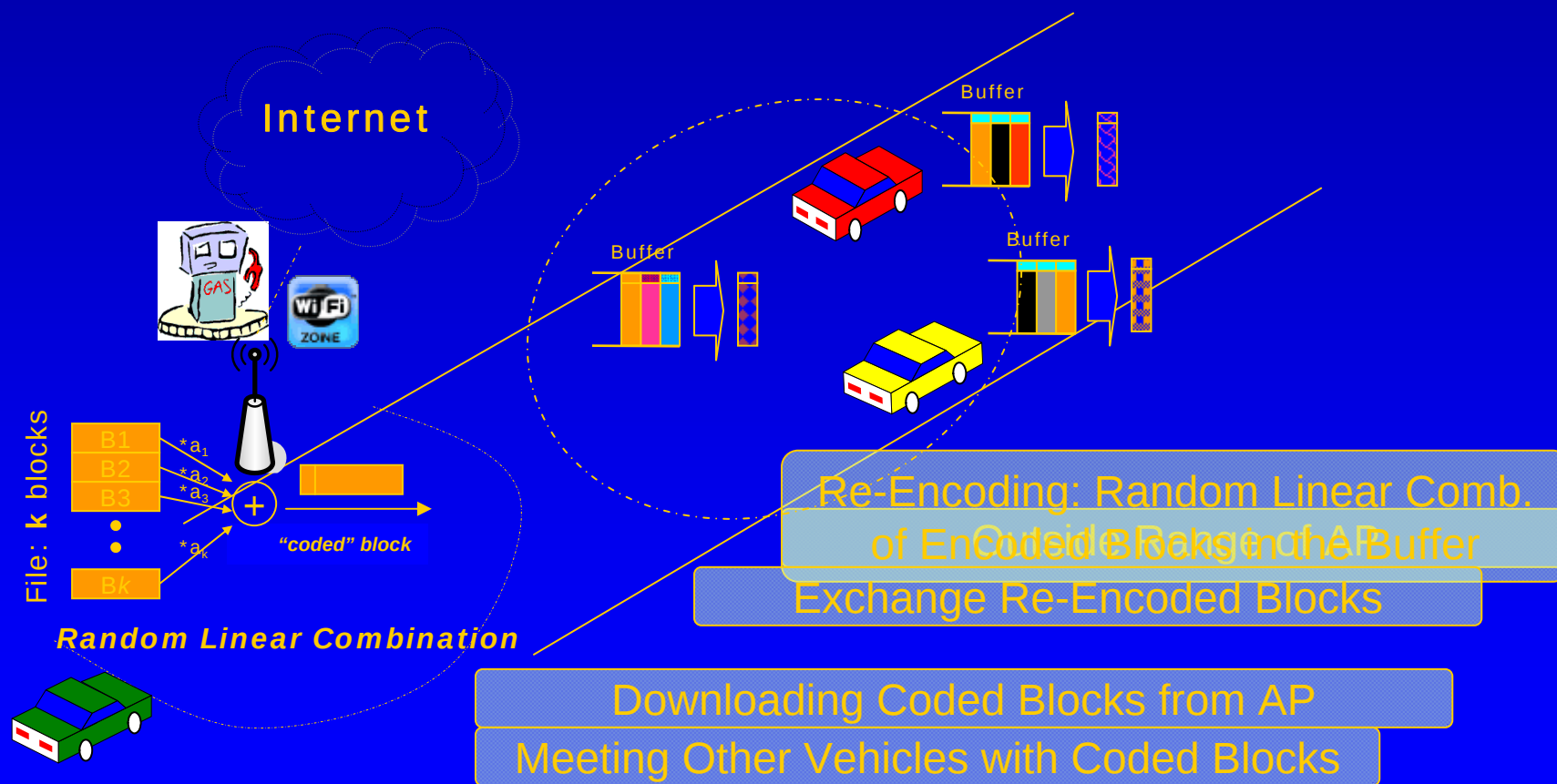
- Limitations of Car Torrent
 - Piece selection critical
 - Frequent failures due to loss, path breaks
- New Approach – network coding
 - “Mix and encode” the packet contents at intermediate nodes
 - Random mixing (with arbitrary weights) will do the job!

Network Coding



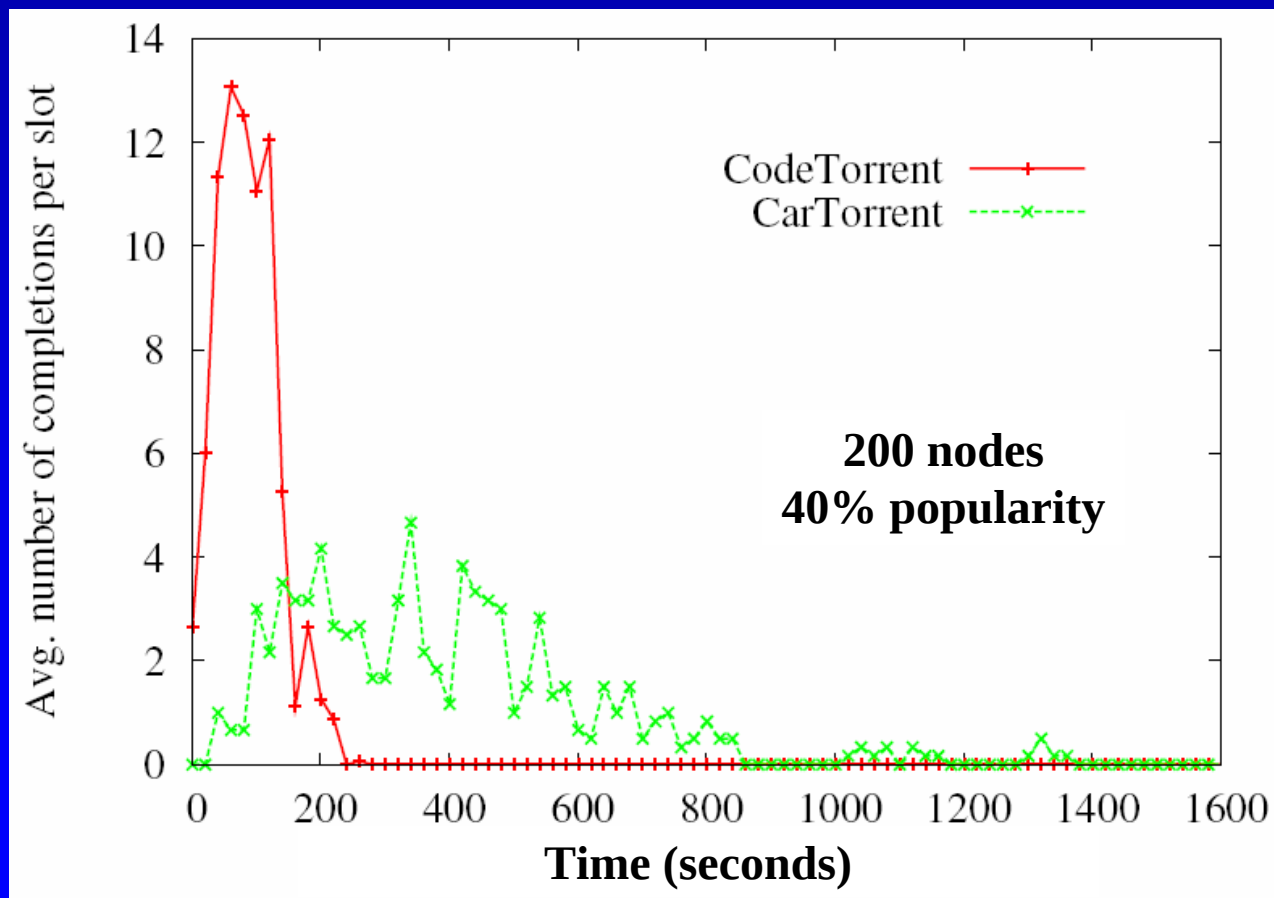
CodeTorrent

- Single-hop pulling (instead of *CarTorrent* multihop)



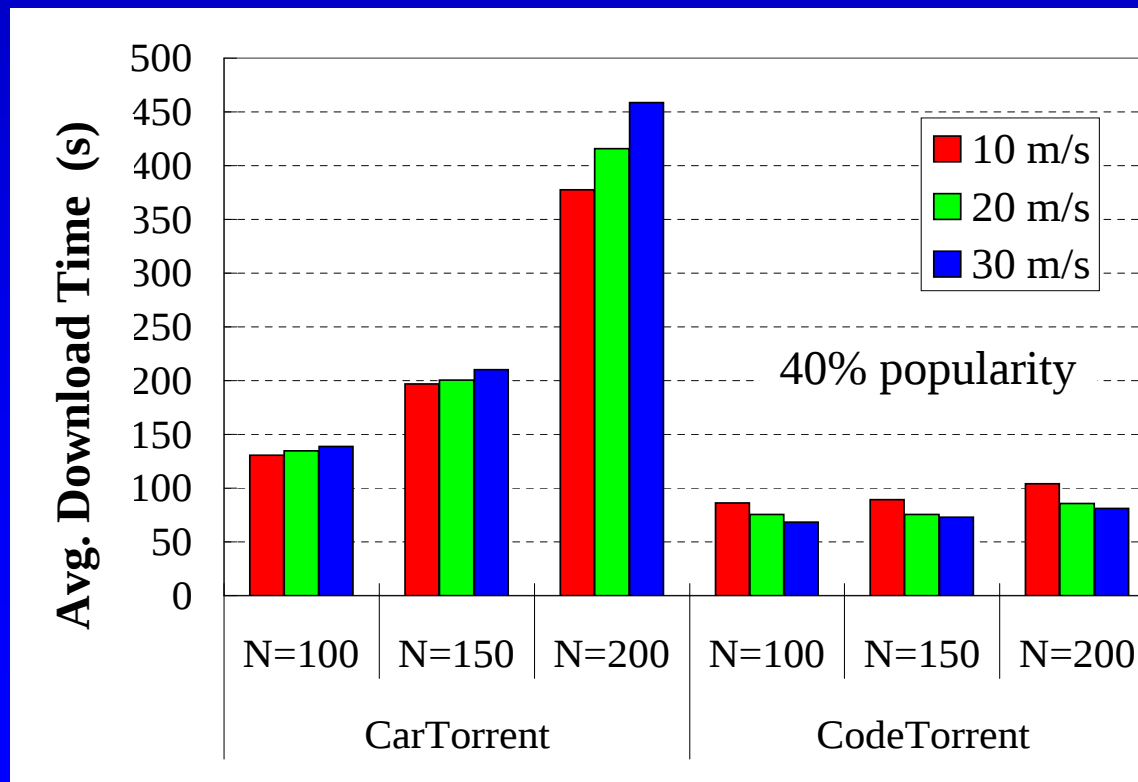
Simulation Results

- Completion time density

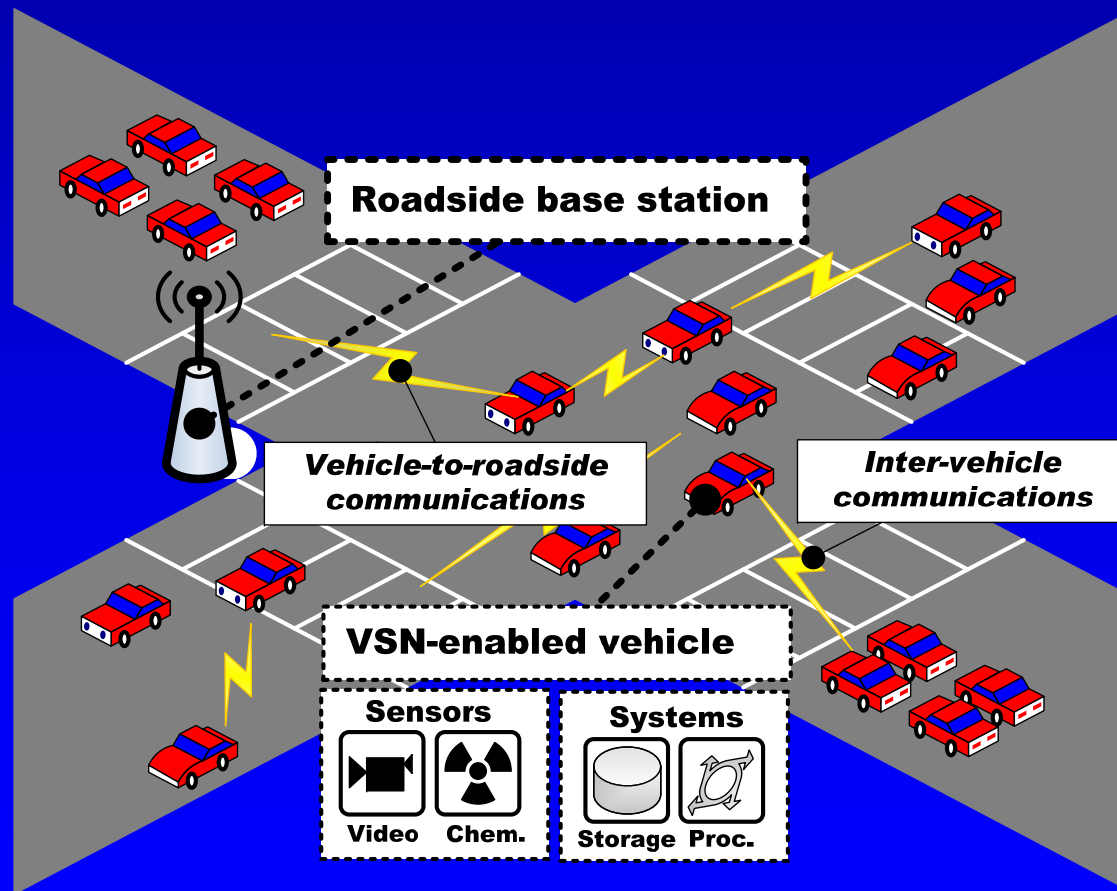


Simulation Results

- Impact of mobility
 - Speed helps disseminate from AP and among vehicles
 - Speed hurts multihop routing (*CarTorrent*)
 - Car density+multihop promotes congestion (*CarTorrent*)



Vehicular Sensor Network

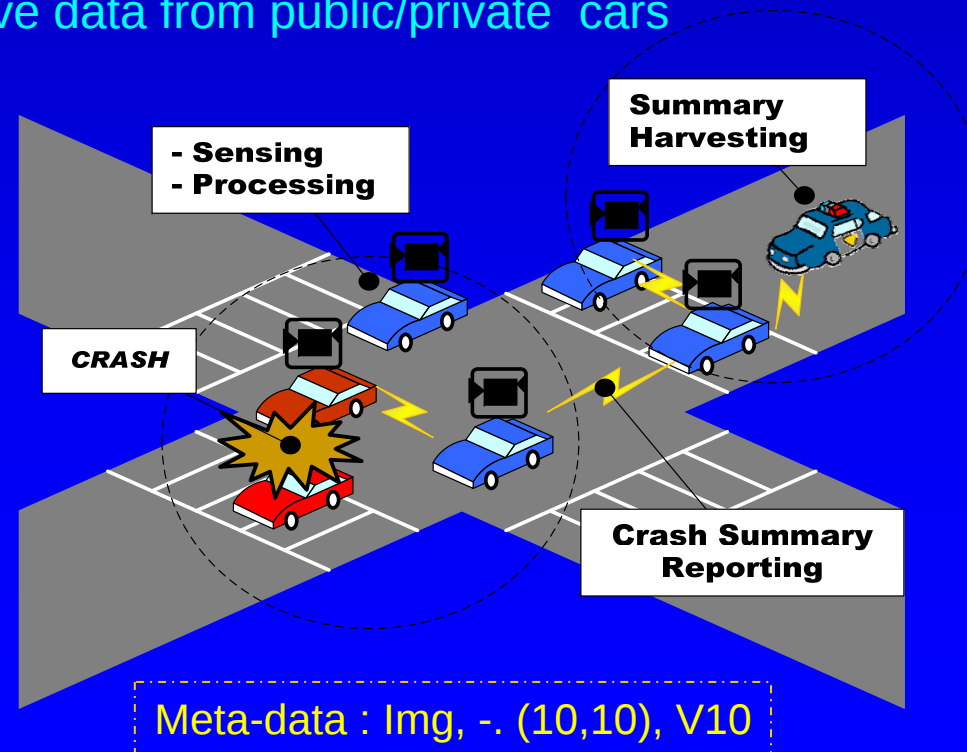


Vehicular Sensor Applications

- **Environment**
 - Traffic density/congestion monitoring
 - Urban pollution monitoring
 - Pavement, visibility conditions
- **Civic and Homeland security**
 - Forensic accident or crime site investigations
 - Terrorist alerts

Accident Scenario: storage and retrieval

- Public/Private Cars (eg, busses, taxicabs, police, commuters, etc):
 - Continuously **collect** images on the street (store data locally)
 - Process the data and **detect** an event
 - **Classify the event as Meta-data** (Type, Option, Loc, time, Vehicle ID)
 - **Distribute Metadata to neighbors probabilistically** (ie, “gossip”)
- Police retrieve data from public/private cars



Mobility-assist Meta-data Diffusion/Harvesting



How to store/retrieve the Metadata?

To store data (and maintain an index to it) several options:

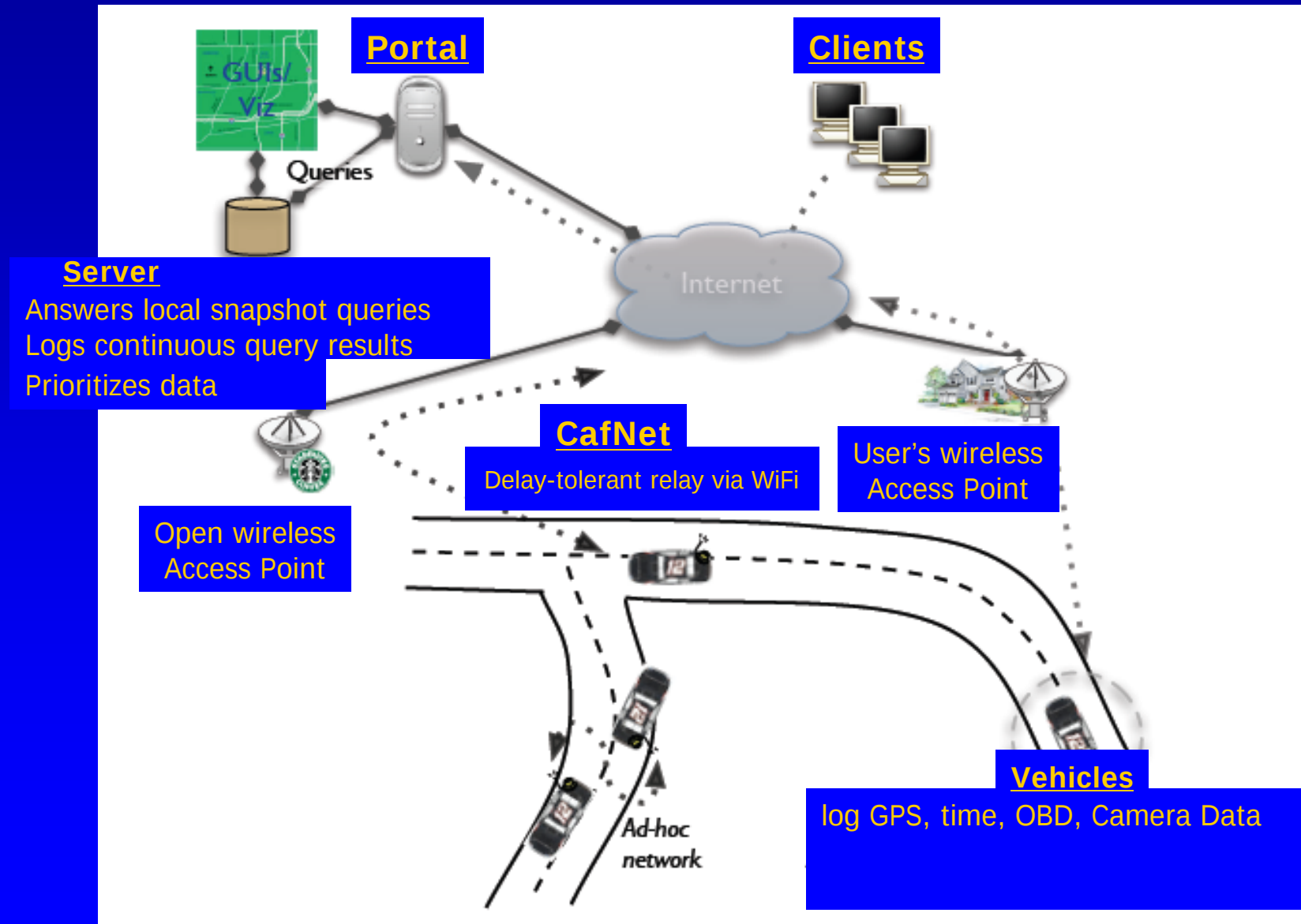
- Upload to nearest Access Point (Cartel project, MIT)
- “Flood” data to all vehicles (eg, bomb threat)
- Publish/subscribe model: publish to a mobile server (eg, an “elected” vehicle)
- Distributed Hash Tables (eg, Virtual Ring Routing - Sigcomm 06)
- “Epidemic diffusion” -> our proposed approach

CarTel: A Distributed Mobile Sensor Computing System*

Hari Balakrishnan
Comp Science Dept, MIT

* Bret Hull, Vladimir Bychkovsky, Yang Zhang, Kevin Chen, Michel Goraczko, Allen Miu, Eugene Shih, Hari Balakrishnan and Samuel Madden, "CarTel: A Distributed Mobile Sensor Computing System," *SenSys'06*

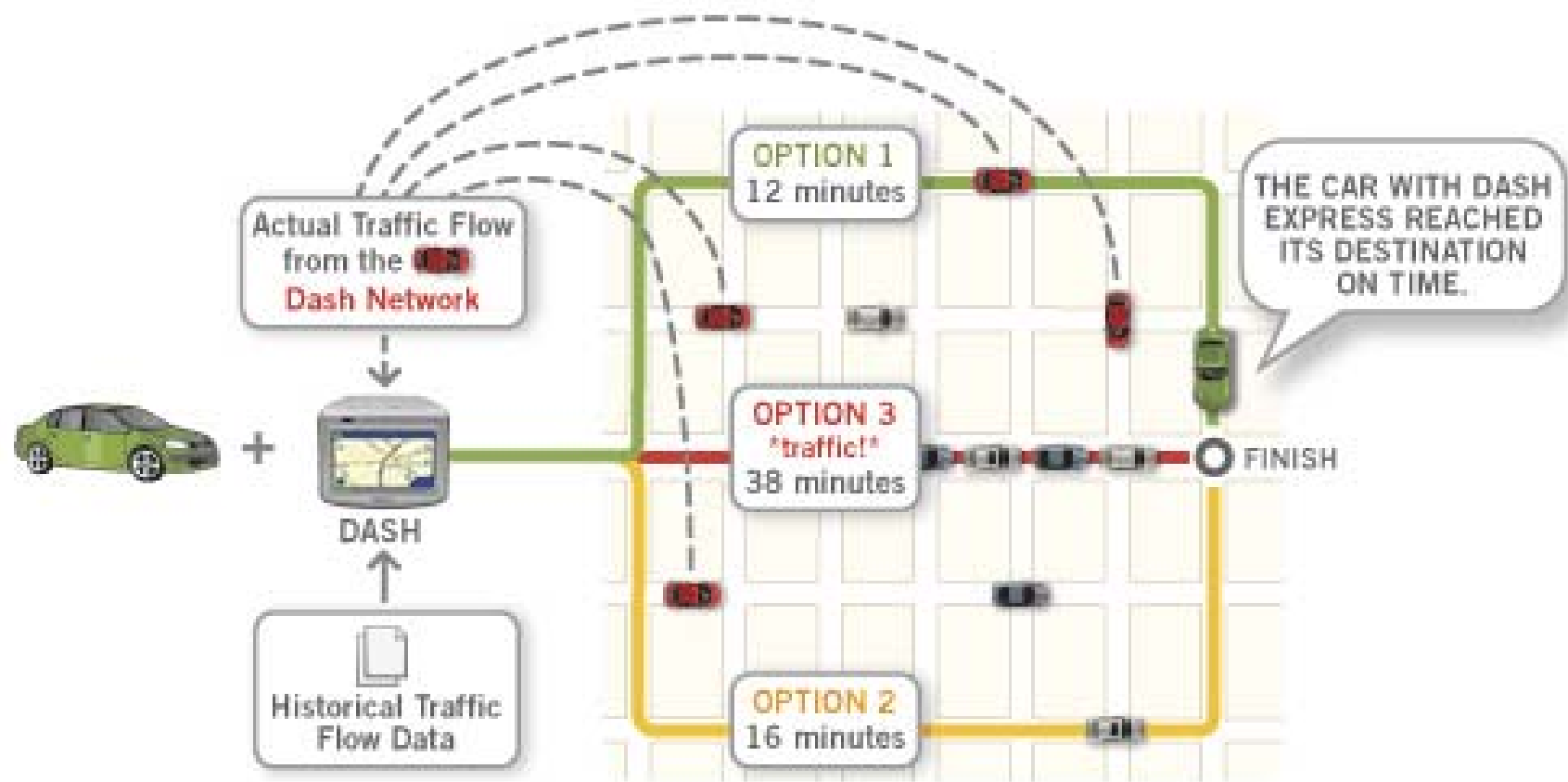
CarTel: H. Barakrishnan (MIT)



Dash Express Navigation System

- **Network connectivity in Dash Express**
 - Cellular (GSM) and open WiFi to provide Internet connectivity
- **Dash Express node as a sensor reports the traffic information to Internet portal**
 - Real-time traffic information gathering
 - Gathered traffic information is used for traffic flow analysis
 - Routing recommendations based on traffic flow statistics + real-time traffic information
- **Dash Express users pull real-time traffic information via GSM or WiFi**
- **Product released in Q1 2008**

Dash Express - “cooperative” navigator: clients upload trip times



MobEyes (UCLA)

- “Epidemic diffusion” :
 - *Mobile nodes* periodically broadcast *meta-data* of events to their neighbors
 - *A mobile agent* (the police) queries nodes and harvests events
 - Data dropped when stale and/or geographically irrelevant

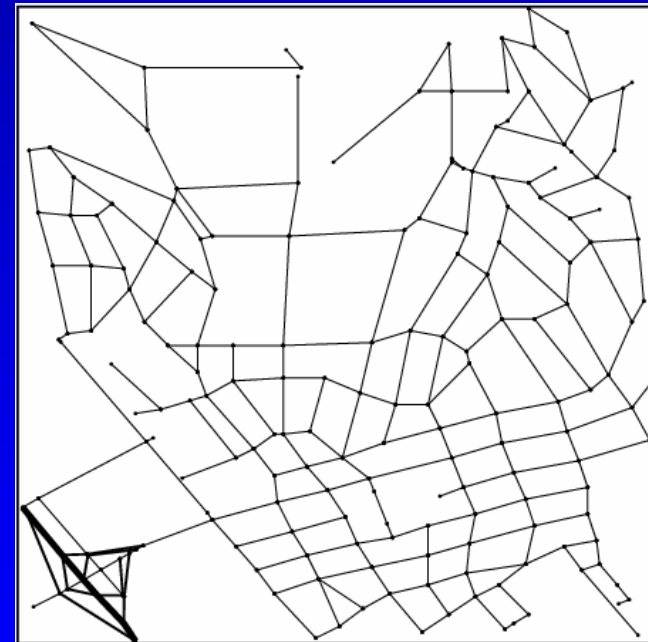
Mobility-assisted Meta-data Diffusion/Harvesting

- Mobeyes exploit “mobility” to disseminate meta-data!
- *Mobile nodes* periodically broadcast meta-data to their neighbors
 - Only “originator” advertises meta-data to neighbors
 - Neighbors store advertisements in their local memory
 - Drop stale data
- A *mobile agent* (the police) harvests meta-data from mobile nodes by actively querying them (with Bloom filter)

Simulation Experiment

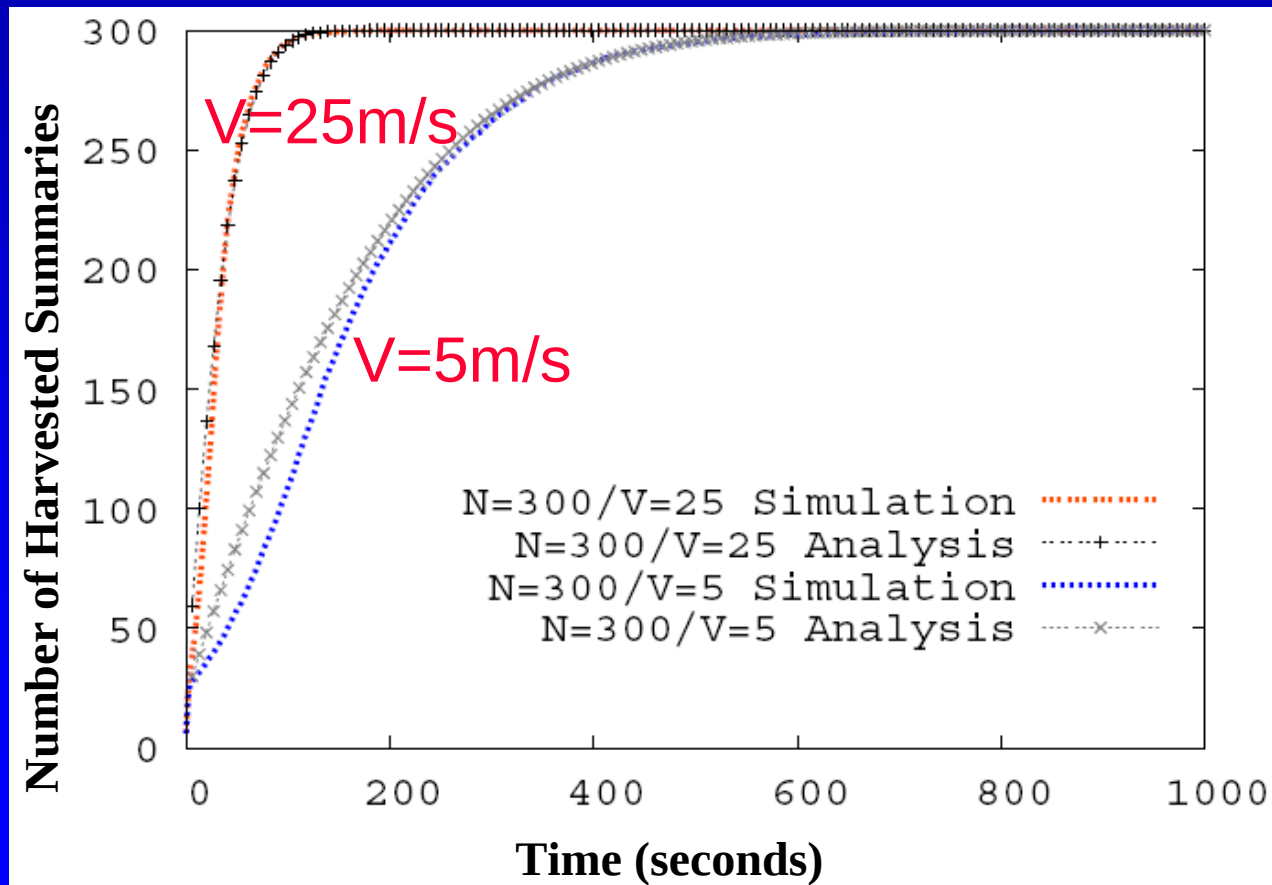
- **Simulation Setup**

- NS-2 simulator
- 802.11: 11Mbps, 250m tx range
- Average speed: 5 to 25 m/s
- Mobility Models
 - Random waypoint (RWP)
 - Real-track model (RT) :
 - Group mobility model
 - merge and split at intersections
 - *Westwood* map



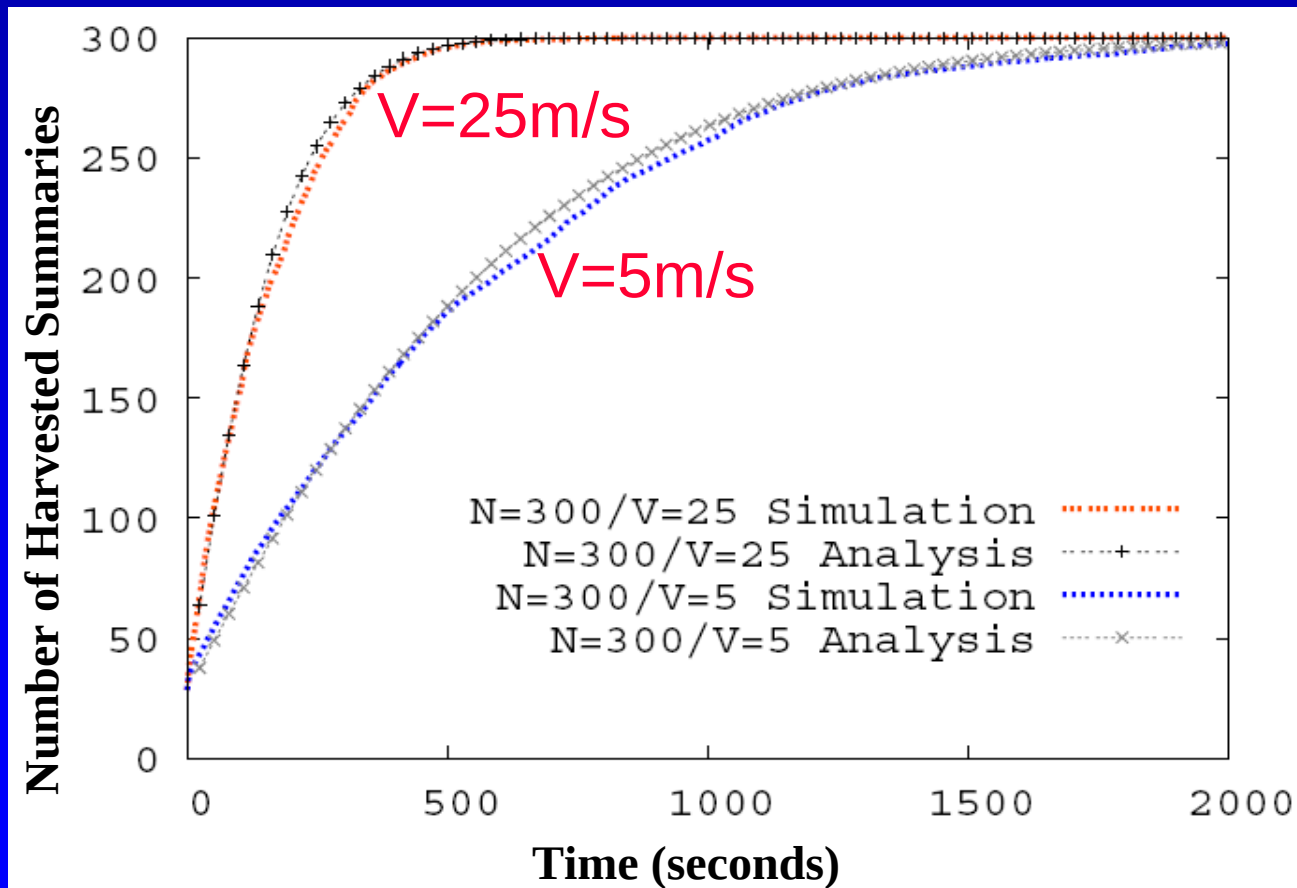
Meta-data harvesting delay with RWP

- Higher mobility decreases harvesting delay



Harvesting Results with “Real Track”

- Restricted mobility results in larger delay



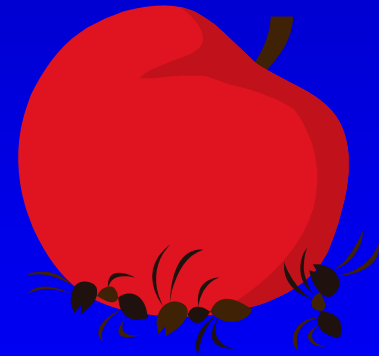
Multi-agent Harvesting

- **Challenges**

- Scale of operation: harvested region may include several city blocks
- Location and nature of the critical information not known a priori
- *Multi-agent harvesting*

- **Bio Inspired Approach**

- “Social” animals solve a similar problem – *foraging* to find reliable food sources



Bio Inspired Algorithm Design

- **Data-taxis**

- Similar to the chemotactic behavior of E-coli bacteria
 - Modes of locomotion: tumble, swim, search
 - Strategy: greedy approach with random search
- Three modes of agent operation

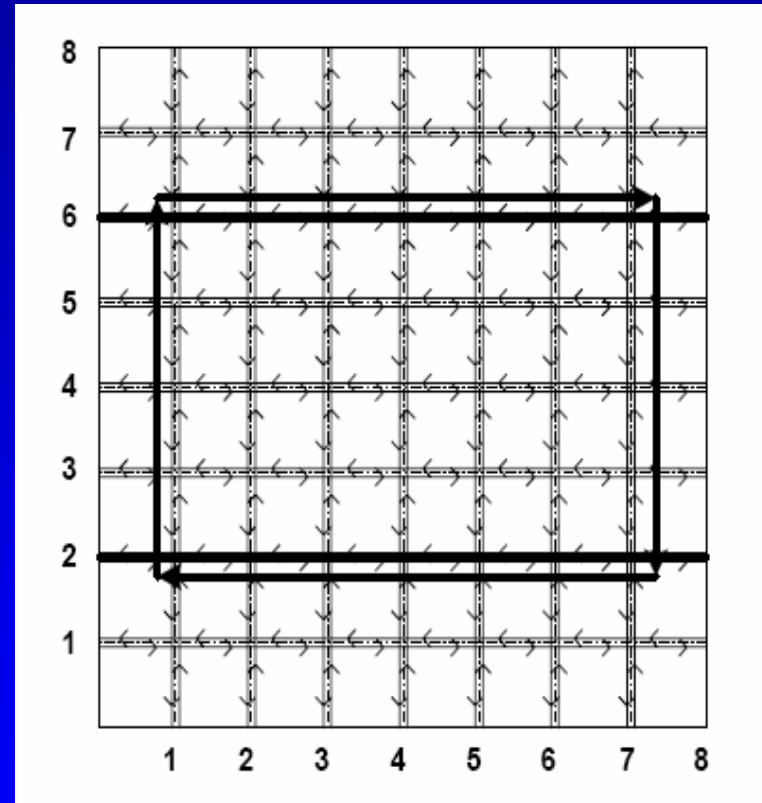
QuickTime? and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

- **Collision avoidance**

- Avoids collecting the same data by different agents
- Pheromone trail
- Move in a direction to minimize collision (Levy jump)

Evaluation Framework

- **Simulation setup**
 - Manhattan mobility model
 - Streets 2 and 6 with valuable information
 - Up to 4 agents
- **Candidate algorithms**
 - RWF (Random Walk Foraging)
 - BRWF (Biased RWF)
 - PPF (Preset Pattern Foraging)
 - DTF (Data-taxis Foraging)



7x7 Manhattan grid

Performance Results

Aggregate number of harvested data

QuickTime?and a
decompressor
are needed to see this picture.

Vehicular Security requirements

Sender authentication

Verification of data consistency

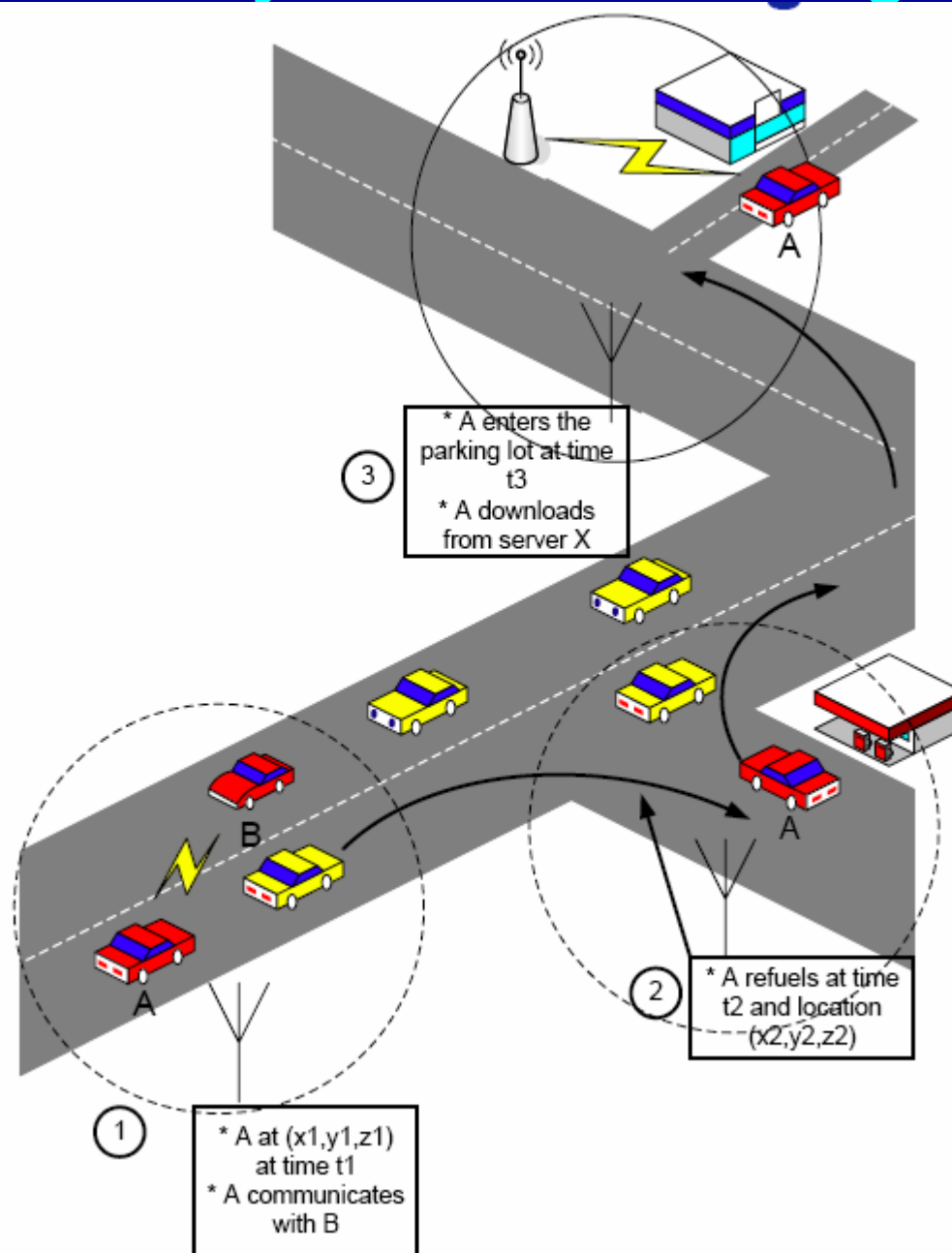
Protection from Denial of Service

Non-repudiation

Privacy

Challenge: Real-time constraint

Privacy Attack: Tracking



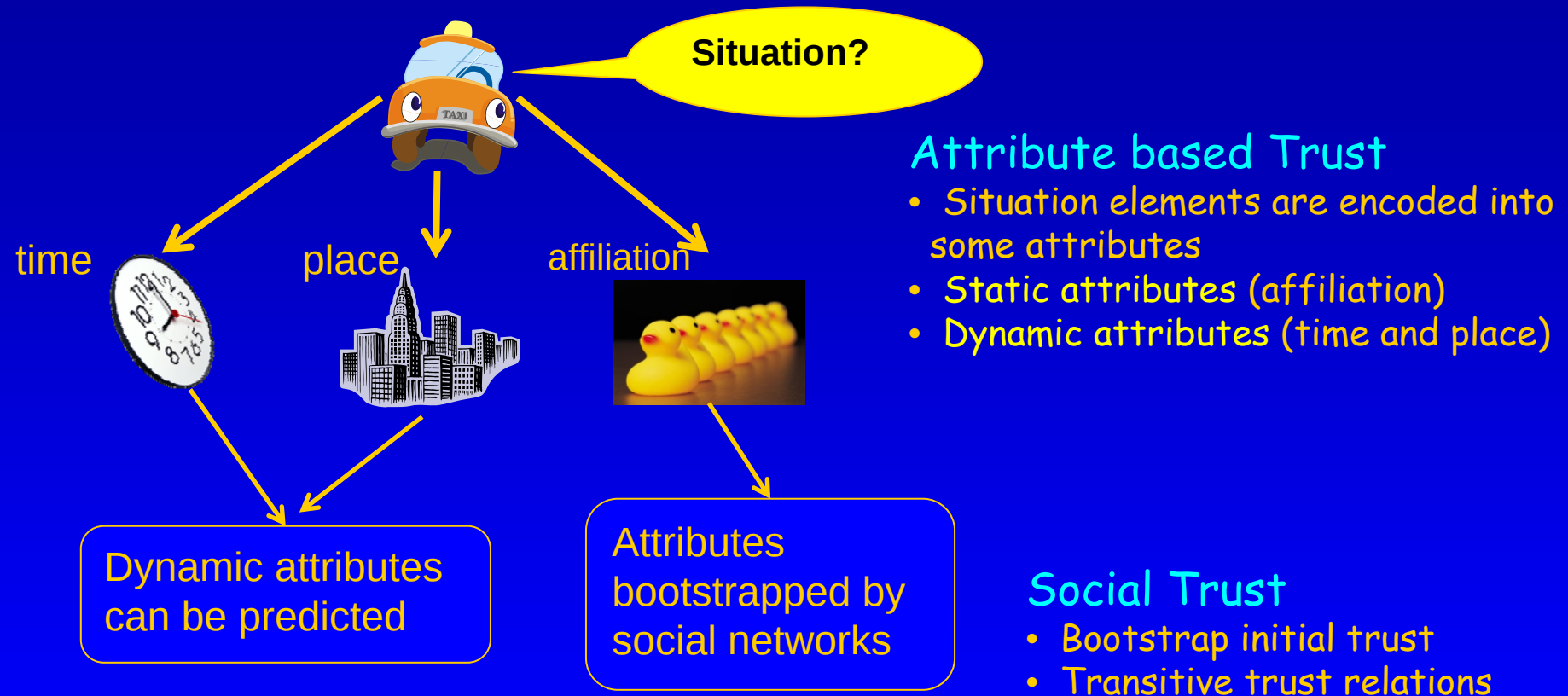
New security requirements for dissemination

Selective, private *Situation Aware* dissemination:

- **Example 1:** A driver wants to alert all taxicabs of company A that will be *near Washington Street between 10-11pm* that convention attendees need rides
- **Example 2:** A Police Agent has detected a **dangerous radiation leak**:
 - He wants to warn the cars *in the radiation area ONLY*
 - He wants to notify all the paramedics and firemen *in a larger surrounding area*.

Situation Aware Trust (SAT)

critical for “selective” dissemination



Proactive Trust

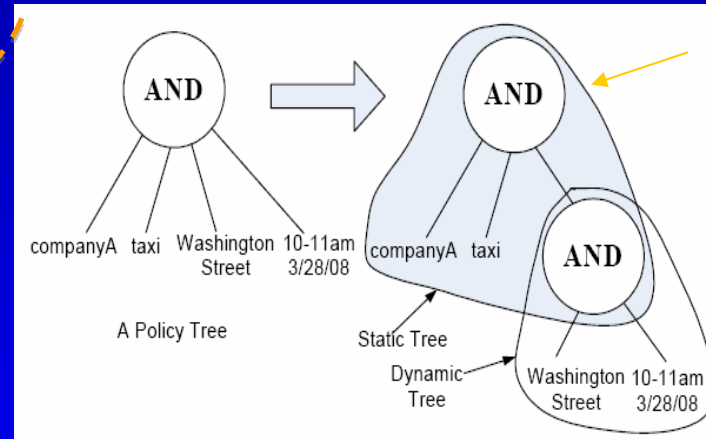
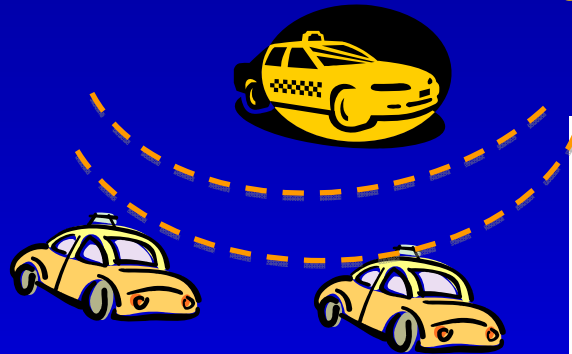
- predict dyn attributes based on mobility and location service
- establish trust in advance

An attribute based situation example:

Yellow Cab **AND** Taxi **AND** Washington Street **AND** 10-11pm 8/22/08

Security: attributes and policy group

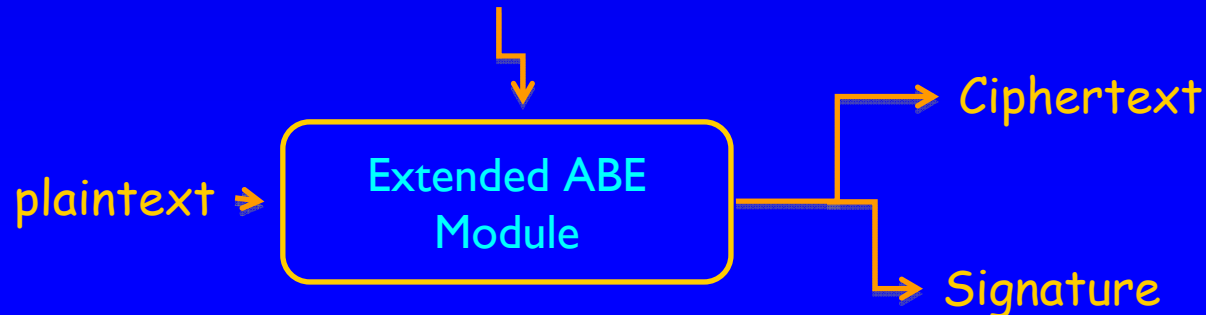
A driver wants to alert all taxicabs of company A on Washington Street between 10-11pm that convention attendees need rides



Central Key Master

Extension of Attribute based Encryption (ABE) scheme [IEEE S&P 07] to incorporate dynamic access tree

Attribute (companyA AND taxi AND Washington St. AND 10-11am)



Receivers who satisfy those encoded attributes (have the corresponding private key) can decrypt the message

C-VeT

Campus - Vehicular Testbed

E. Giordano, A. Ghosh,

G. Marfia, S. Ho, J.S. Park, PhD

System Design: Giovanni Pau, PhD

Advisor: Mario Gerla, PhD

The Plan

- **We plan to install our node equipment in:**
 - 30 Campus operated vehicles (including shuttles and facility management trucks).
 - Exploit “on a schedule” and “random” campus fleet mobility patterns
 - 30 Commuting Vans: Measure urban pollution, traffic congestion etc
 - 12 Private Vehicles: controlled motion experiments
 - Cross campus connectivity using 10 node Mesh (Poli Milano).



Campus Initial Coverage Using MobiMesh

QuickTime?and a
decompressor
are needed to see this picture.



“Instrumenting” the vehicle



C-VeT Goals

Provide:

- **A shared virtualized environment to test new protocols and applications**
- **Full Virtualization**
 - MadWiFi Virtualization (with on demand exclusive use)
 - Multiple OS support (Linux, Windows).

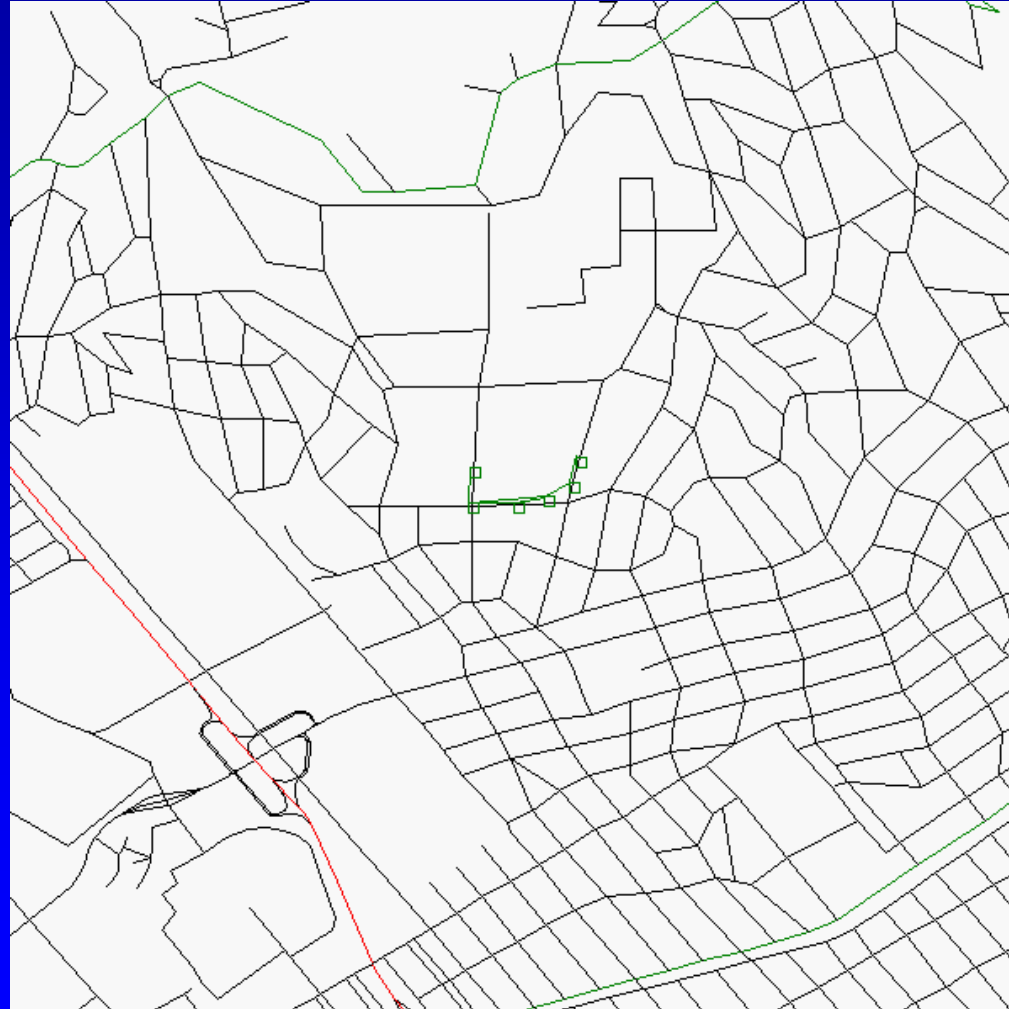
Allow:

- **Collection of mobility traces and network statistics**
- **Provide a platform for Urban Sensing, Geo routing etc**
- **Deployment of innovative V2V/V2I applications**

Preliminary Experiments

- **Equipment:**
 - 6 Cars roaming the UCLA Campus
 - 802.11g radios
 - Routing protocol: OLSR
 - 1 EVDO interface in the Lead Car
 - 1 Remote Monitor connected to the Lead Car through EVDO and Internet
- **Experiments:**
 - Connectivity map computed by OLSR
 - Azureus P2P application

Campus Demo: connectivity via OLSR



Conclusions

New VANET research opportunities:

- **Mobility models:**
 - Collection, measurements
 - Interaction between motion and network models
- **Routing:**
 - Geo routing, Delay tolerant routing, Network Coding,
- **New Applications:**
 - Content, mobile sensing, harvesting
 - Urban surveillance; pollution monitoring
 - Intelligent highways
- **Security:**
 - Private dissemination
 - Situation Aware Trust

The Future

- **Still, lots of exciting research ahead**
- **And, need a testbed to validate it!**
 - Realistic assessment of radio, mobility characteristics
 - Account for user behavior
 - Interaction with (and support of) the Infrastructure
 - Scalability to thousands of vehicles using hybrid simulation
- **We are building one at UCLA - come and share!**

Thank You!