Peer to Peer Urban Sensing from Mobile Platforms

ISWCS 2007
Trondheim, October 2007

Mario Gerla
Computer Science Dept, UCLA
www.cs.ucla.edu

Outline

- **Why vehicle communications?**
- **Vehicles and “opportunistic” ad hoc networking**
- **Vehicular applications**
  - Content download/share (Car Torrent)
  - Urban sensing
    - CARTEL (MIT)
    - Mobeyes (UCLA)
  - Bio inspired “harvesting”
- **The UCLA CAMPUS Testbed**

Why Vehicle Communications?

- **Safe navigation:**
  - Forward Collision Warning,
  - Blind Spot Warning,
  - Intersection Collision Warning…….
  - Advisories to other vehicles
    - “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.

Vehicle Comms(cont)

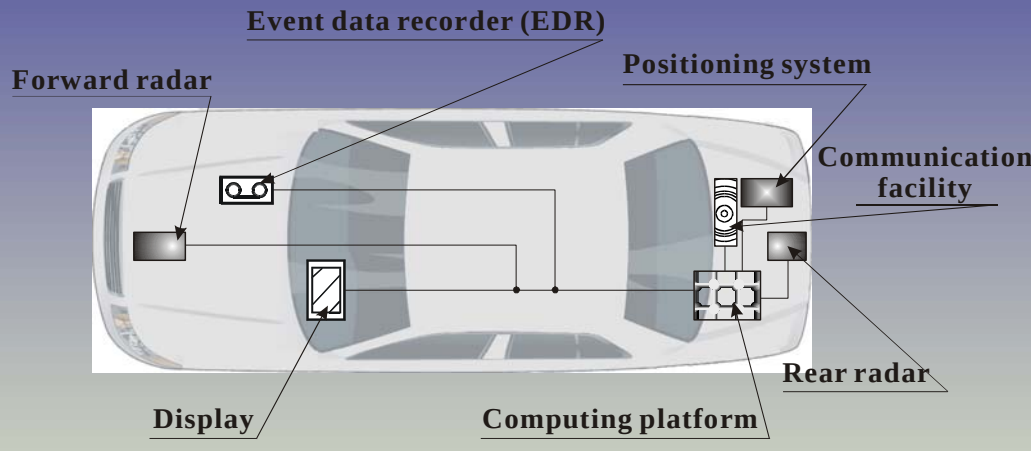
- **Content delivery/sharing:**
  - Music, news, video, IPTV, etc
  - Location relevant multimedia files
  - Local ads, tourist information, etc
  - Passenger to passenger internet games

Vehicle Comms (cont)

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

The Enabling Standard: DSRC / IEEE 802.11p

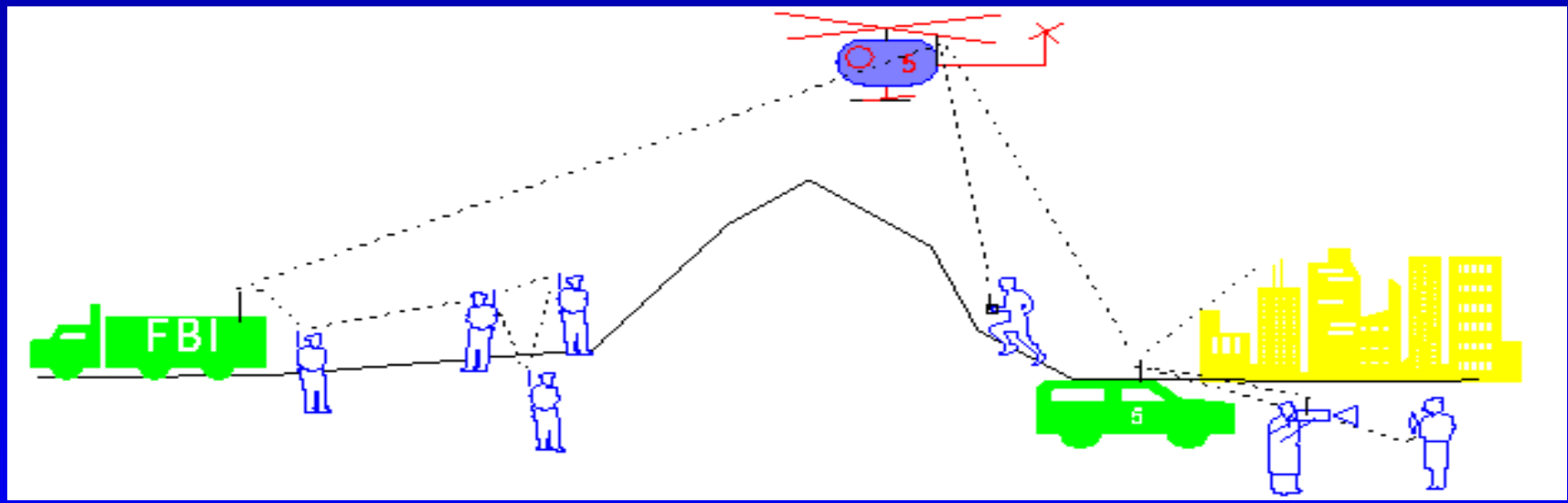
- Car-Car communications at 5.9Ghz
- Derived from 802.11a
- three types of channels: Vehicle-Vehicle *service*, a Vehicle-Gateway *service* and a *control broadcast* channel .
- Ad hoc mode; and infrastructure mode
- 802.11p: IEEE Task Group for Car-Car communications



Traditional Ad Hoc Networks

- Instantly deployable, re-configurable (No fixed infrastructure)
- Created to satisfy a “temporary” need
- Portable (eg sensors), mobile (eg, cars)
- Multi-hopping (to save power, overcome obstacles, etc.)

Wireless Ad Hoc Net



Traditional Ad Hoc Networks

- Instantly deployable, re-configurable (No fixed infrastructure)
- Created to satisfy a “temporary” need
- Portable (eg sensors), mobile (eg, cars)
- Multi-hopping (to save power, overcome obstacles, etc.)

Examples: military, civilian disaster recovery

Traditional Ad Hoc Networks

- Instantly deployable, re-configurable (No fixed infrastructure)
- Created to satisfy a “temporary” need
- Portable (eg sensors), mobile (eg, cars)
- Multi-hopping (to save power, overcome obstacles, etc.)

Examples: military, civilian disaster recovery

Common theme: NO INFRASTRUCTURE!

New Paradigm : "Opportunistic" ad hoc nets

- Recreational, commercial, education:
  - Vehicle networks
  - Group of friends sharing 3G via Bluetooth
  - Network games, etc
- Access to Internet:
  - available, but;
  - "bypass it" with "ad hoc" if too costly or inadequate

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.

The rest of my talk

Applications:

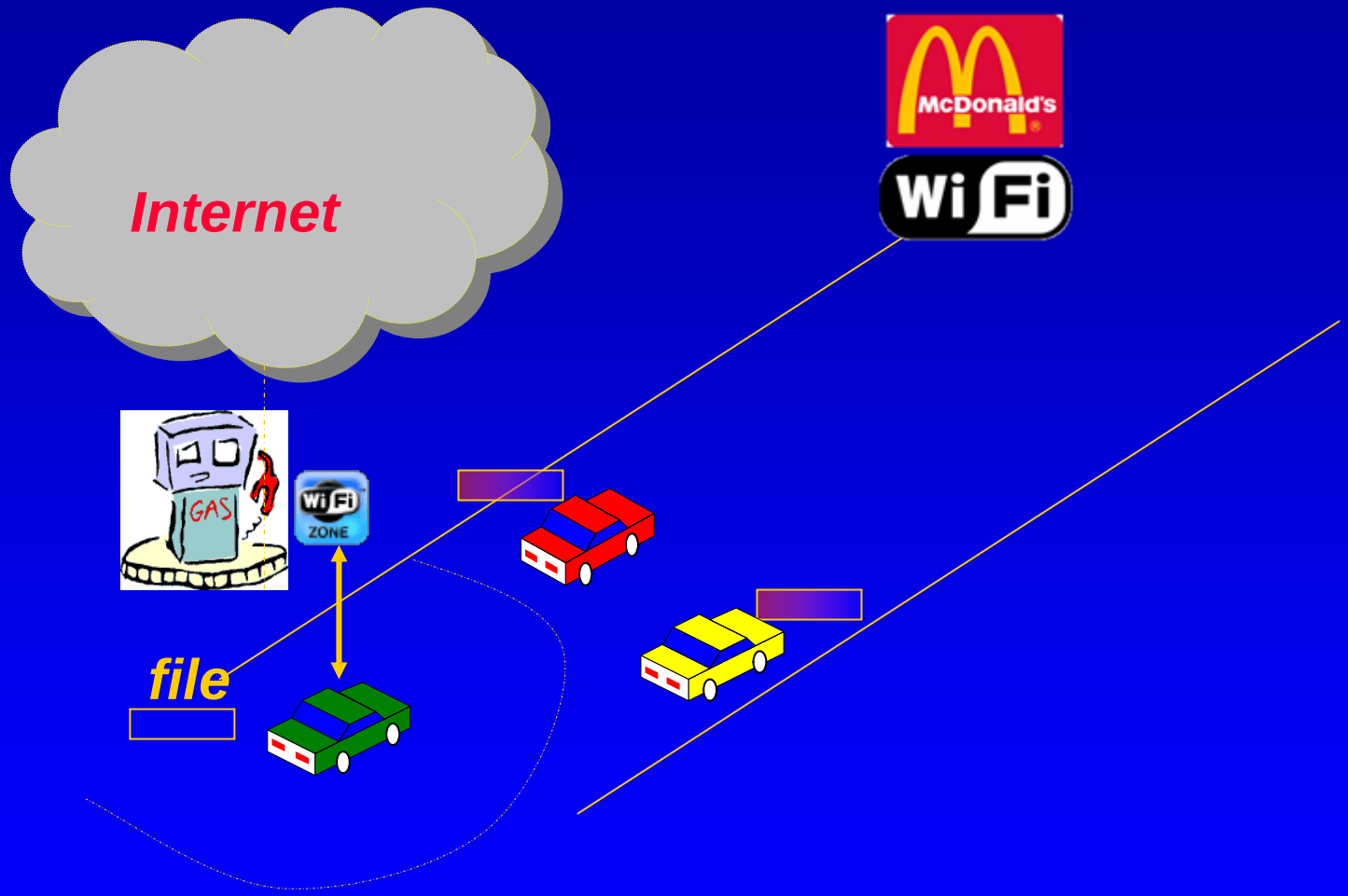
- **Content sharing:** Car Torrent
- **Sensor platforms:**
  - Cartel
  - MobEyes

The C-VeT testbed at UCLA

CarTorrent : Opportunistic Ad Hoc networking to download large 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

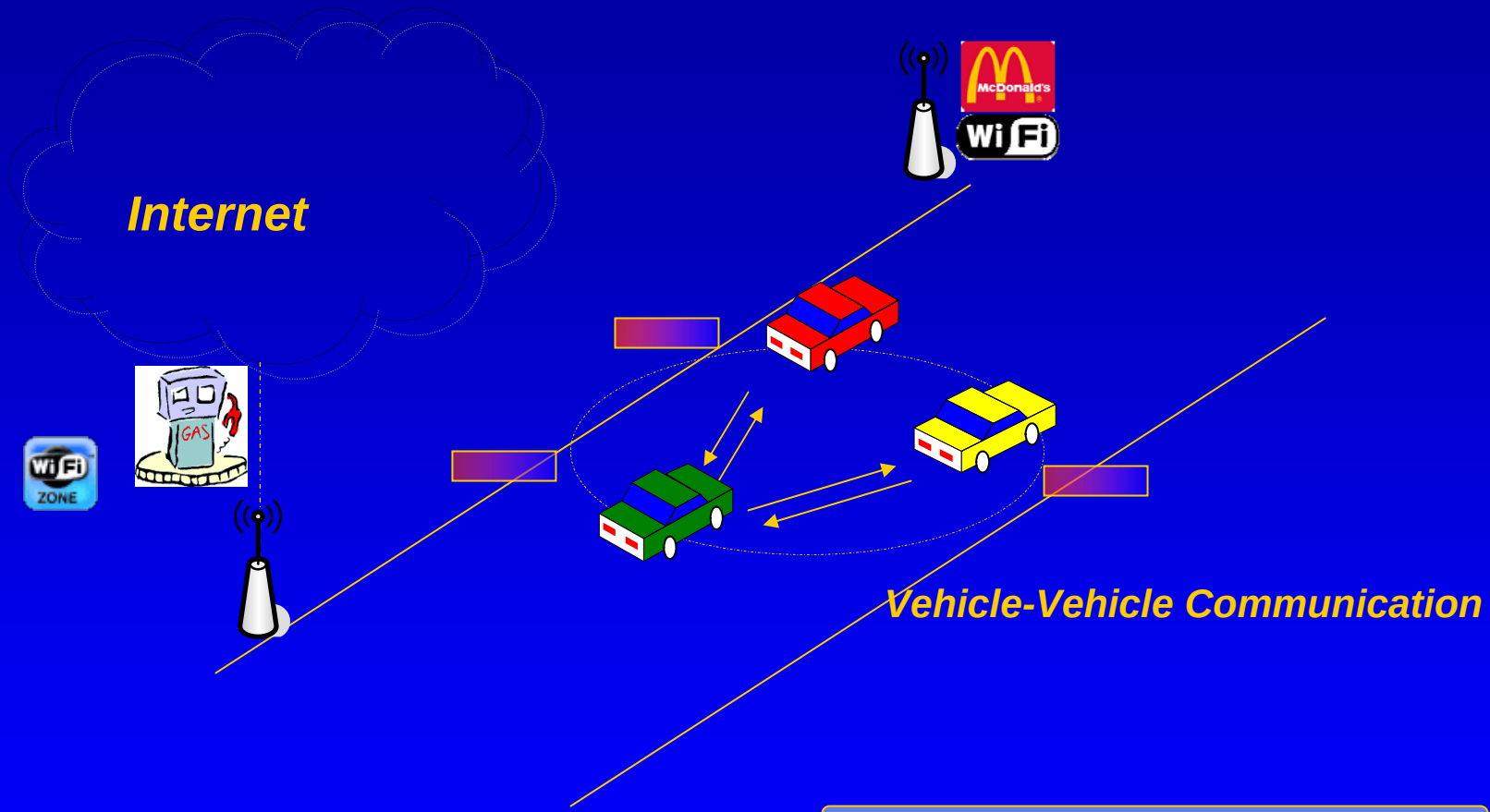
Downloading from GPRS/3G too slow and quite expensive

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

Solution: Co-operative P2P Downloading via Car-Torrent

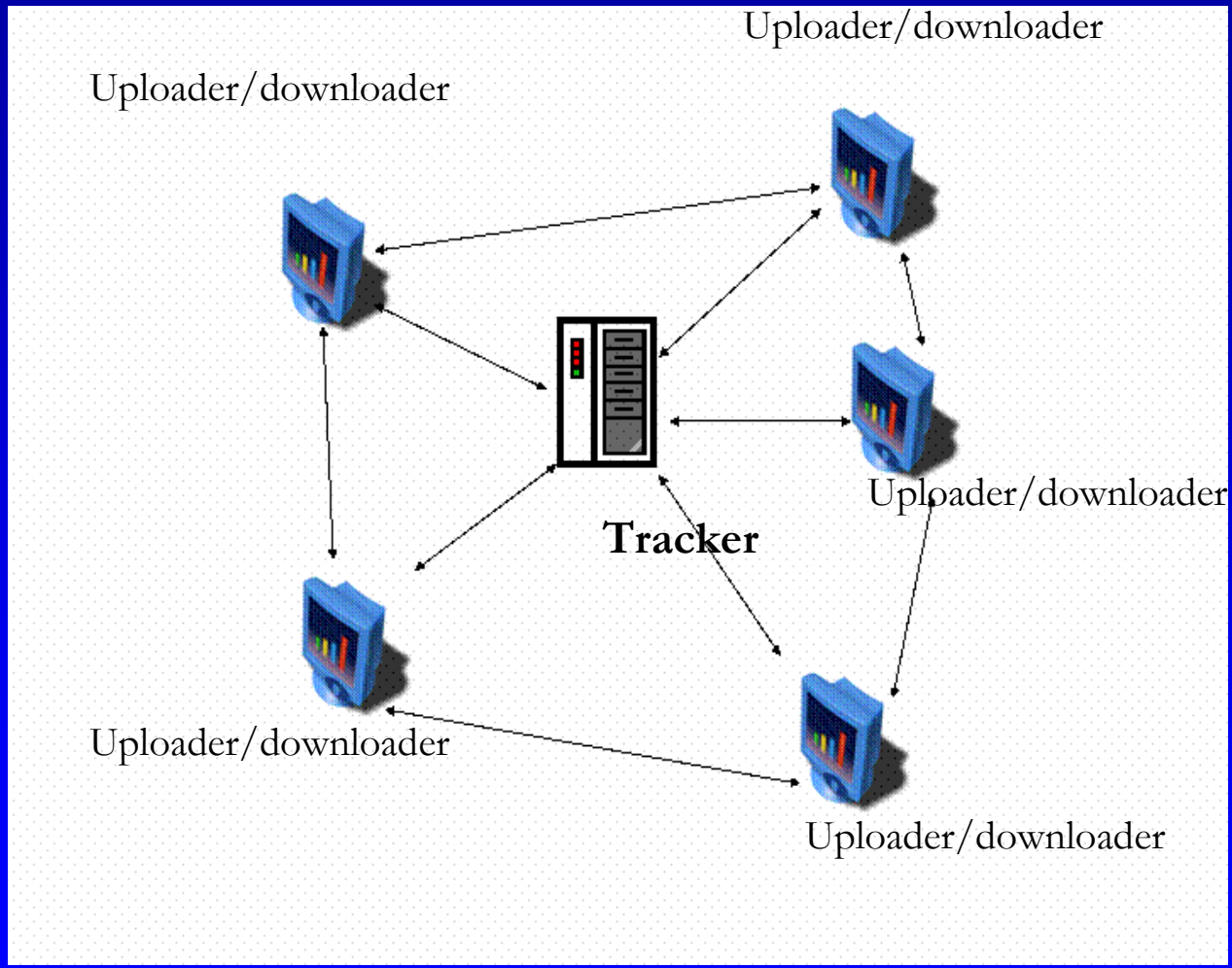
CarTorrent: Basic Idea

Co-operative Download: Car Torrent

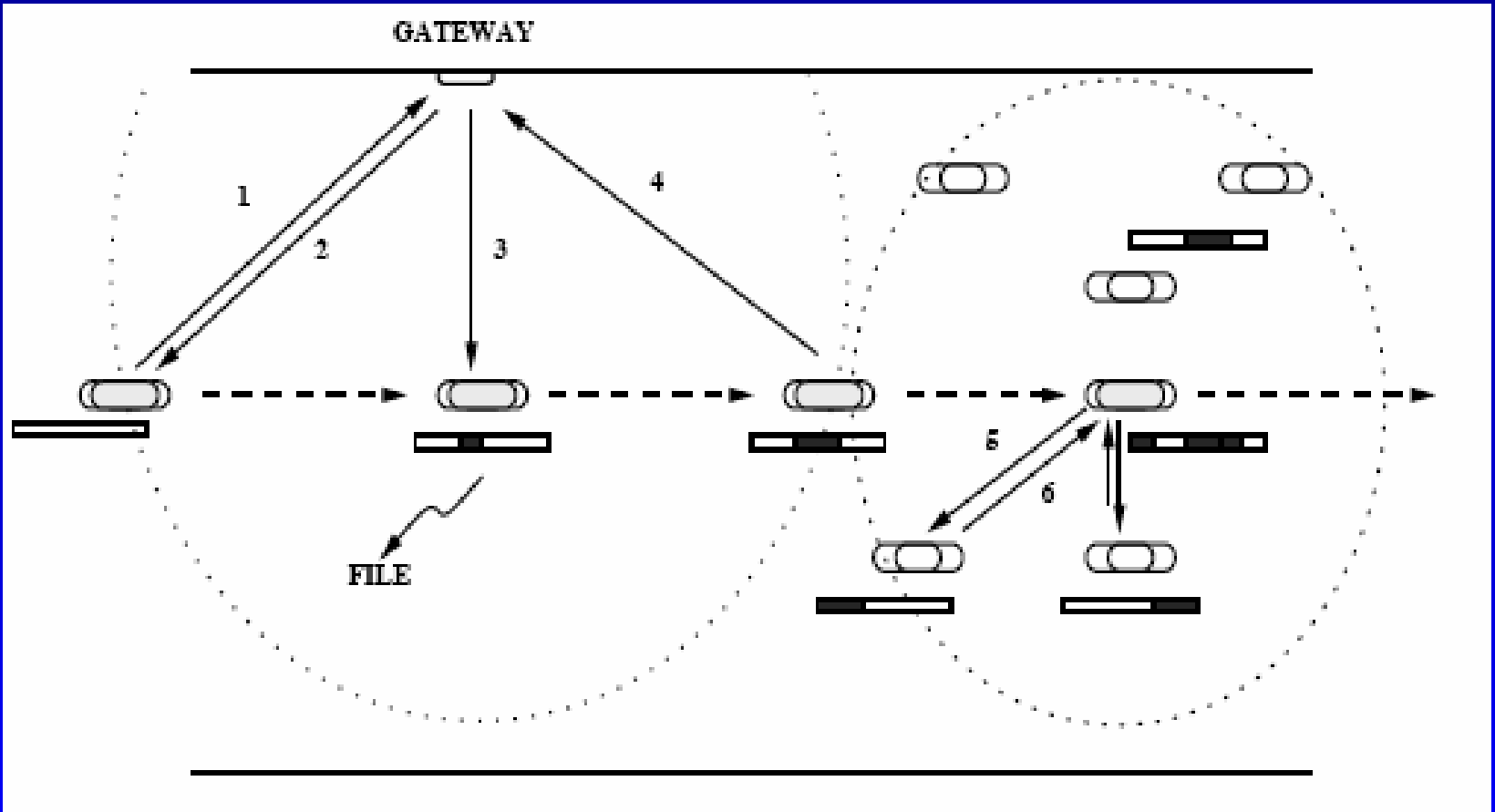


Exchanging Pieces of File Later

Car Torrent inspired by BitTorrent: Internet P2P file downloading



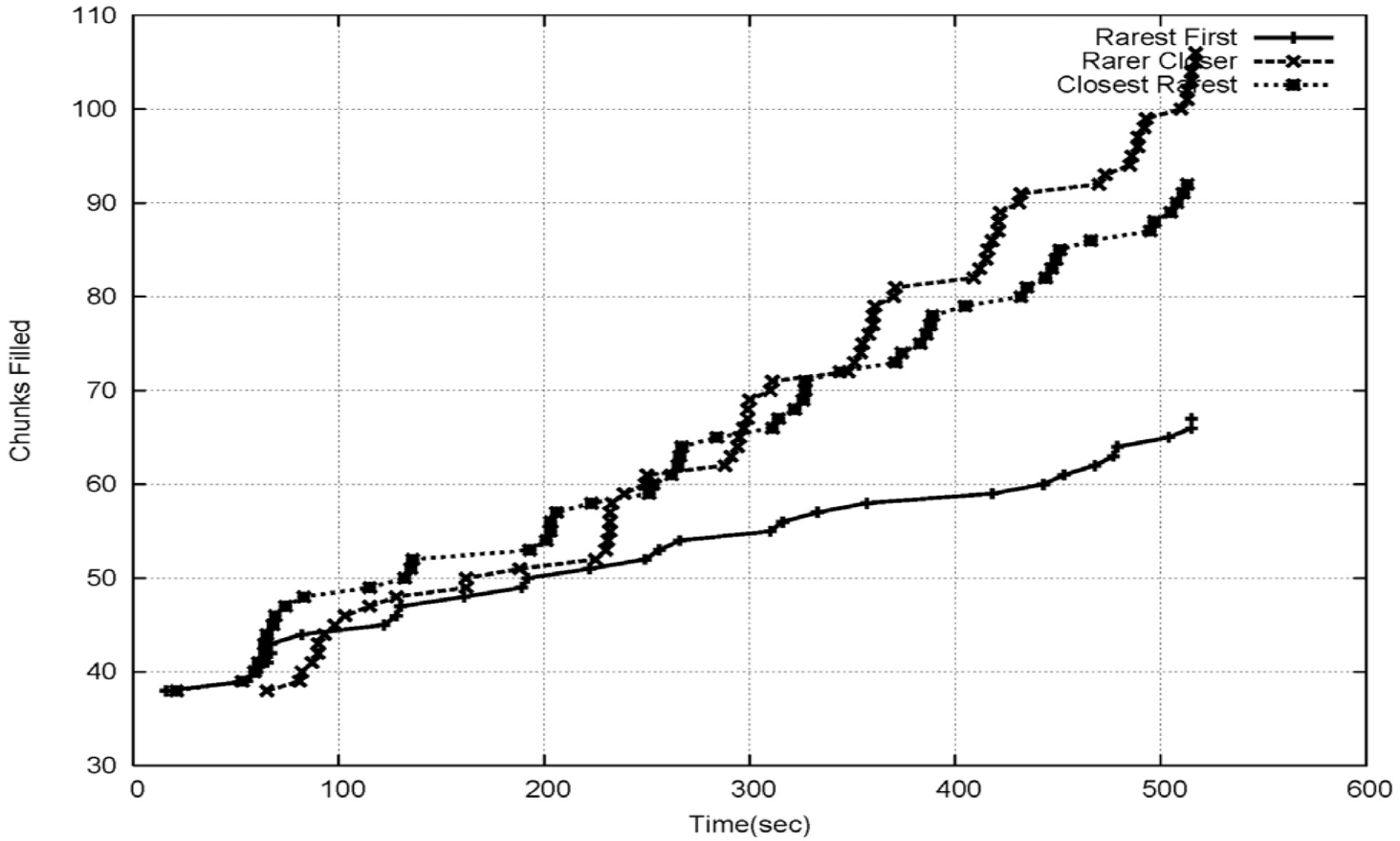
CarTorrent: *Gossip* to discover peers



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

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

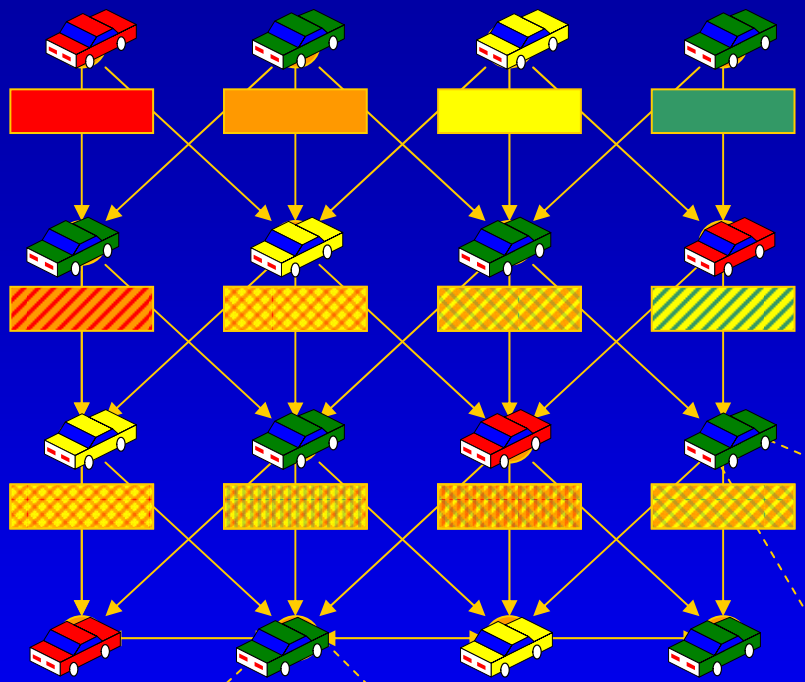
Selection Strategy Critical



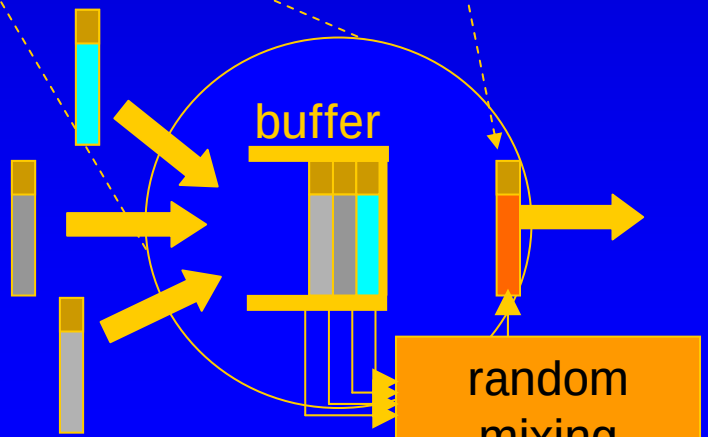
CarTorrent with Network Coding

- 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!

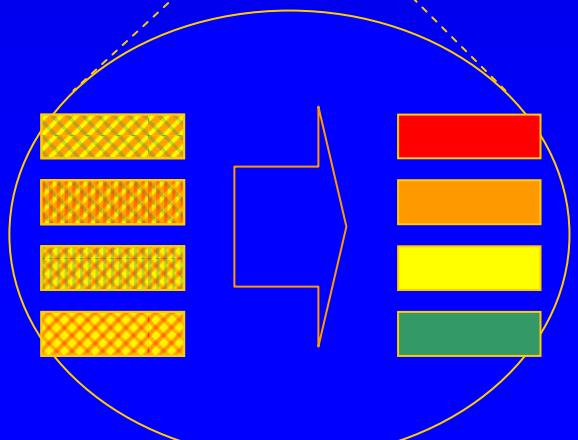
Network Coding



e = [e_1 e_2 e_3 e_4] encoding vector tells how packet was mixed (e.g. coded packet **p** = $\sum e_i \boldsymbol{x}_i$ where $\boldsymbol{x}_i$ is original packet)



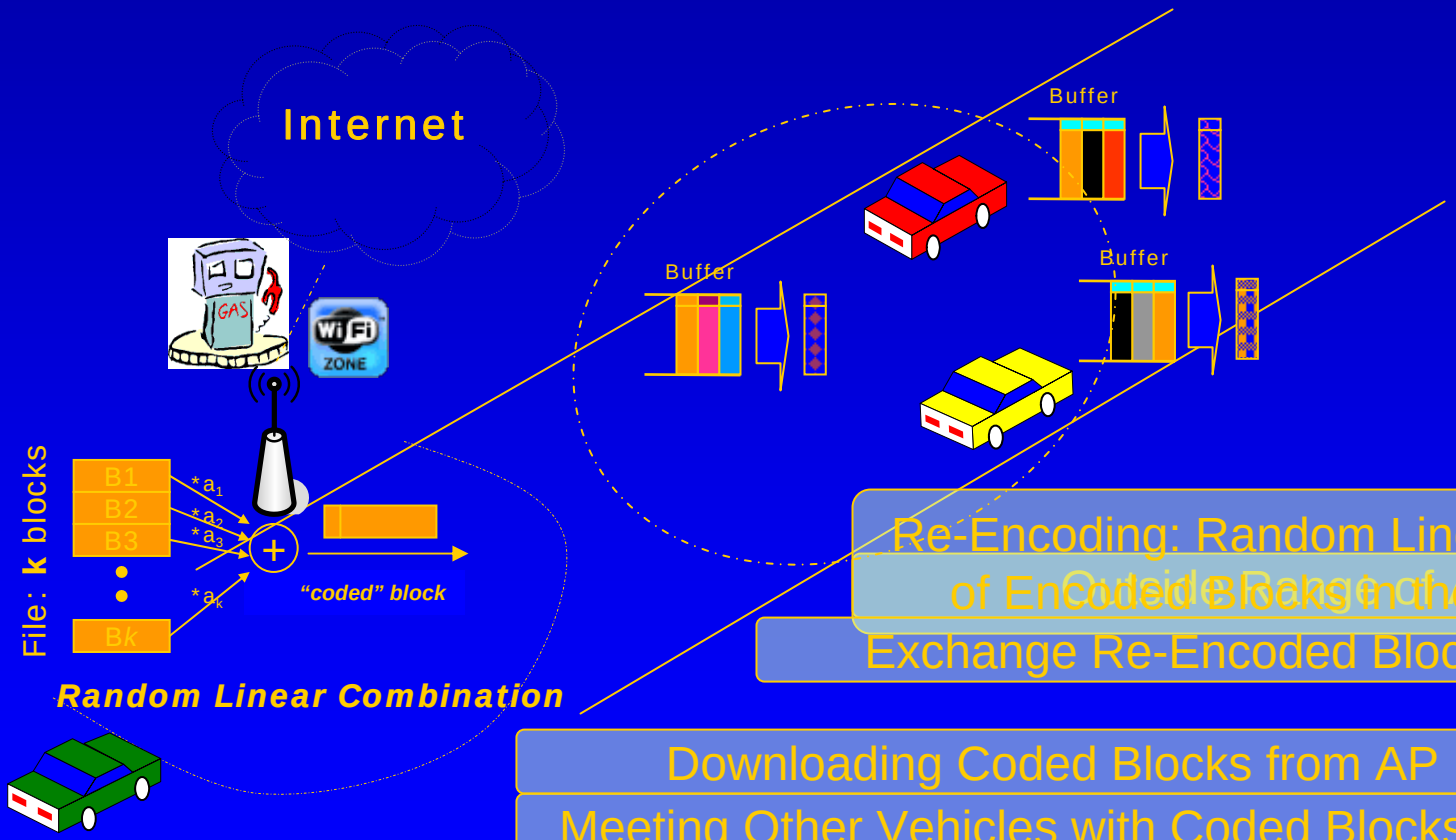
Intermediate nodes



Receiver recovers original by matrix inversion

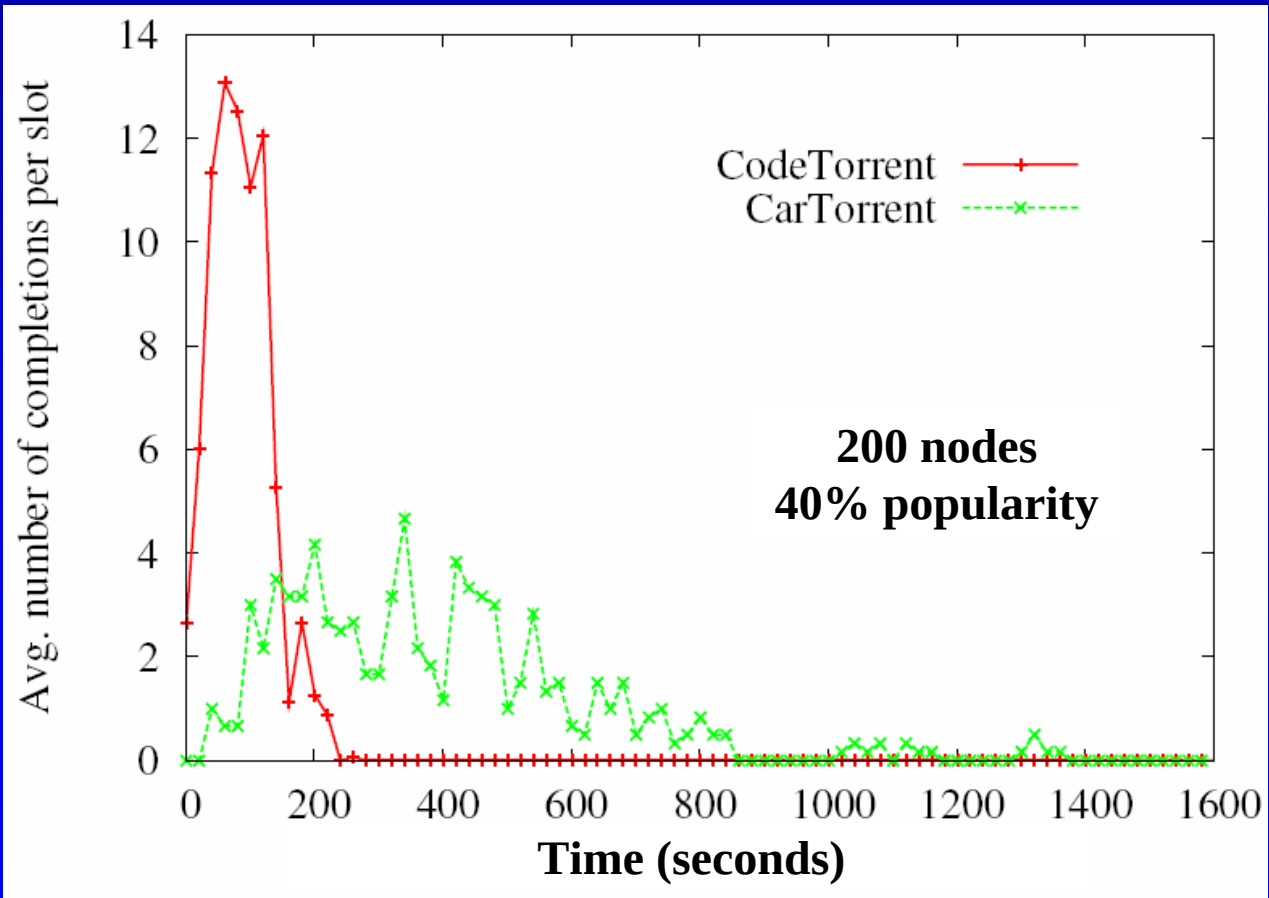
CodeTorrent: Basic Idea

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



Simulation Results

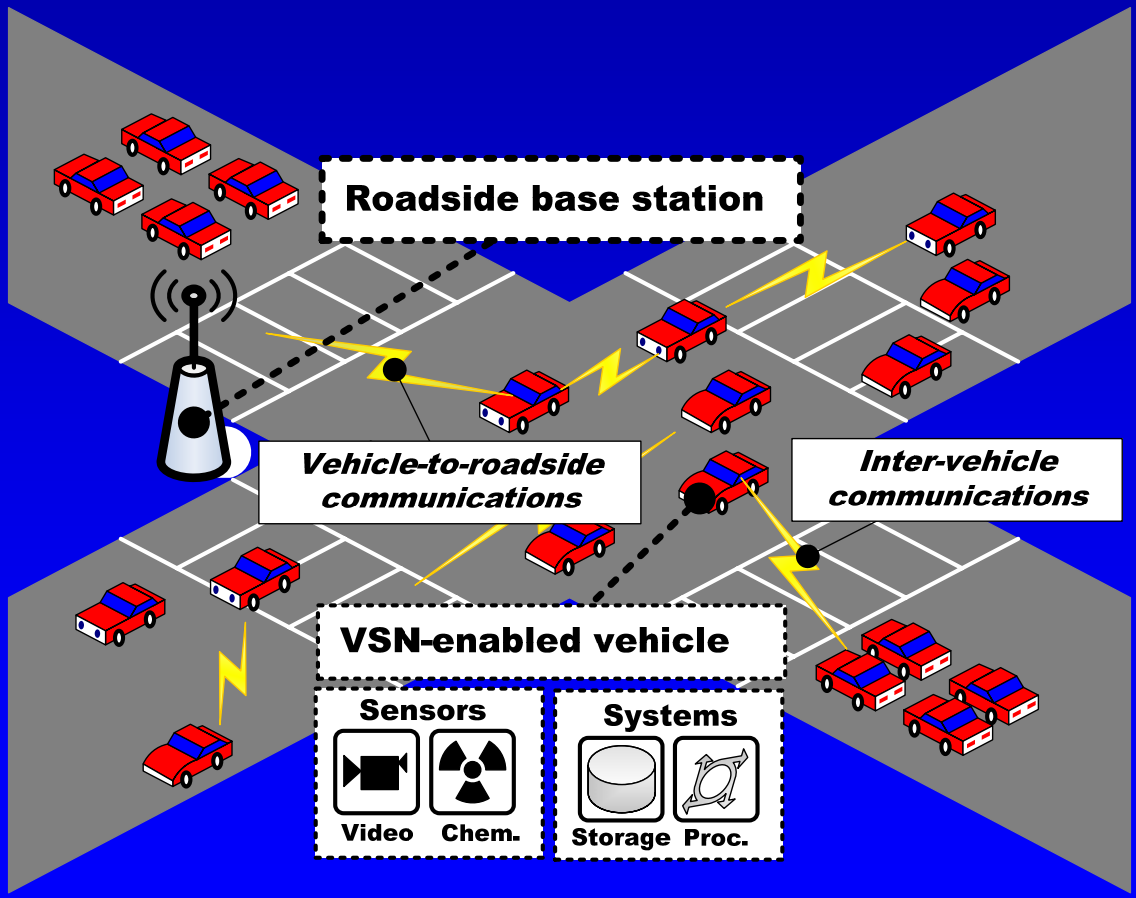
- **Completion time density**



Content sharing in the vehicle network

- **So far, we assumed that the content comes from the internet:**
  - Car Torrent
  - Ad Torrent - distributing local ads
  - IPTV
- **However, data and content is generated also on board of the vehicle:**
  - videocameras, GPS, on-board diagnostics, traffic, time, vibration, chemical, noise, etc
- **Vehicles as “mobile” sensor platforms**
- **Urban sensing**

Vehicular Sensor Network



Vehicular Sensor Applications

- **Environment**
  - Traffic congestion monitoring
  - Urban pollution monitoring
- **Civic and Homeland security**
  - Forensic accident or crime site investigations
  - Terrorist alerts

Accident Scenario: storage and retrieval

- Designated Cars (eg, busses, taxicabs, UPS, police agents, 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, Location, Vehicle ID)
  - **Post** it on some form of distributed index
- Police retrieve data from designated cars

How to store/retrieve the data?

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

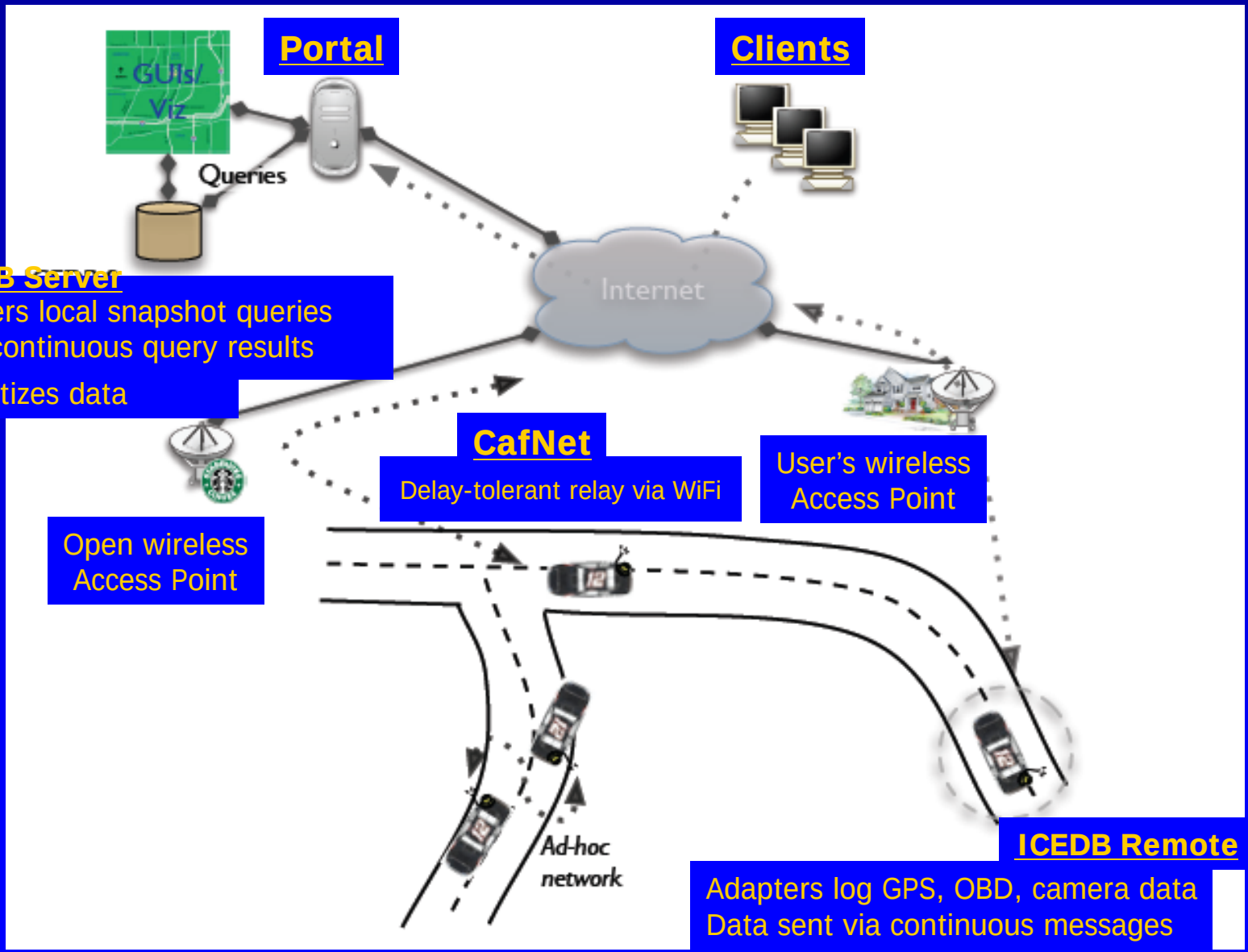
- **Distribute data to the entire vehicle net (flooding)**
- **Upload to nearest Access Point (Cartel project, MIT)**
- **Publish/subscribe model: publish to a mobile server (eg, an "elected"vehicle)**
- **Distributed Hash Tables (eg, Virtual Ring Routing)**
- **"Epidemic diffusion" (our proposed approach)**

CarTel: A Distributed Mobile Sensor Computing System*

Hari Barakrishnan
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 System Architecture



Intermittently connected DB (ICEDB)

- **ICEDB server**
  - Maintains a list of continuous queries submitted by applications
  - Queries are pushed to mobile nodes using CafNets
  - CafNet: Carry-and-Forward Network - a node “carries” the data until it can be forwarded
  - Results from ICEDB clients are stored in the portal
- **ICEDB client**
  - Process the sensed data and return the query results using CafNet
  - Prioritize the result streams in the order of importance

CarTel Case Studies

- **Road traffic analysis**
  - Commute time analysis
  - Traffic hot spot heuristics
- **Wide-area Wi-Fi measurements**
- **Automotive diagnostics via OBD-II**

New York Times Oct 17, 2007

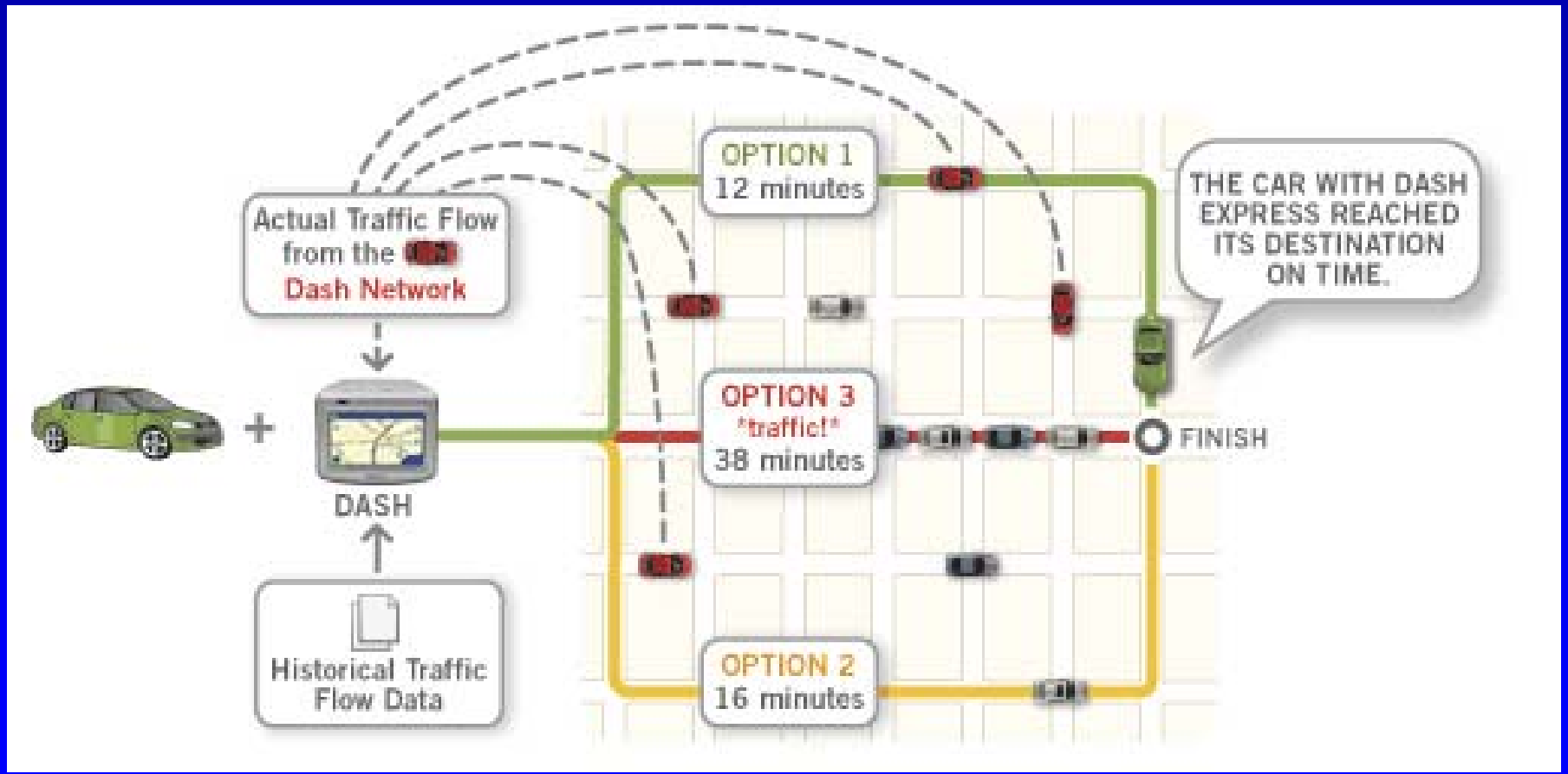
“Dash Navigation System”

http://www.nytimes.com/2007/10/18/technology/circuits/18basics.html?ex=1193284800&en=c352cb7954eab25d&ei=5070&emc=eta1

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
  - Vehicle routing decision based on traffic flow statistics + real-time traffic information
- **Dash Express users pull real-time traffic information via GSM or WiFi**
- **Product will be released in Q1 2008**

Routing The Dash Way



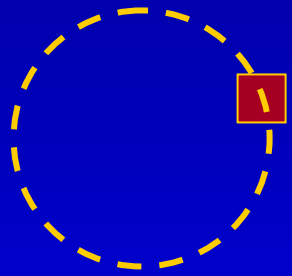
MobEyes
Comp Science Dept, UCLA

- **“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-assist Meta-data Diffusion/Harvesting

- **Mobeyes exploit "mobility" to disseminate meta-data!**
- ***Mobile nodes* are periodically broadcasting meta-data of events sensed data to their neighbors**
  - Data "owner" advertises **only** "his" own meta-data to his neighbors
  - Neighbors listen to advertisements and store them into their local storage
- **A *mobile* agent (the police) harvests a set of "missing" meta-data from mobile nodes by actively querying mobile nodes (via. Bloom filter)**

Mobility-assist Meta-data Diffusion/Harvesting



HREP

HREQ

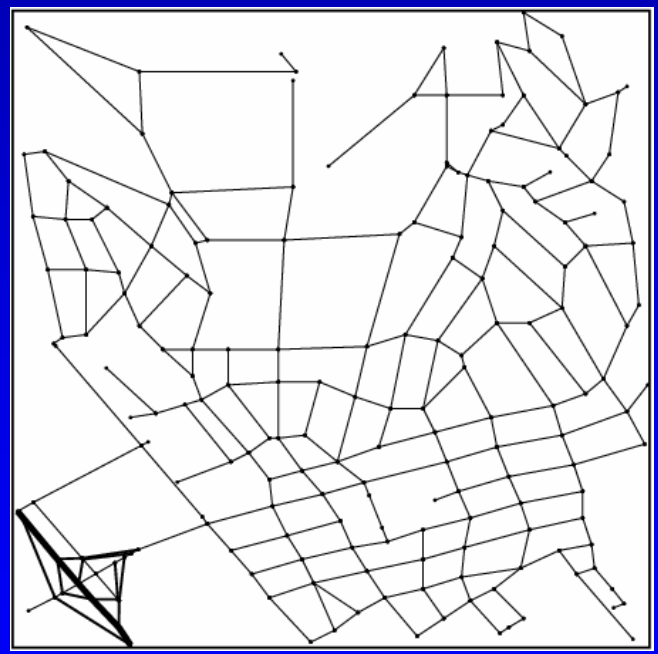
Agent harvests a set of *missing* meta-data from neighbors

Periodical meta-data broadcasting

+ Broadcasting meta-data to neighbors
+ Listen/store received meta-data

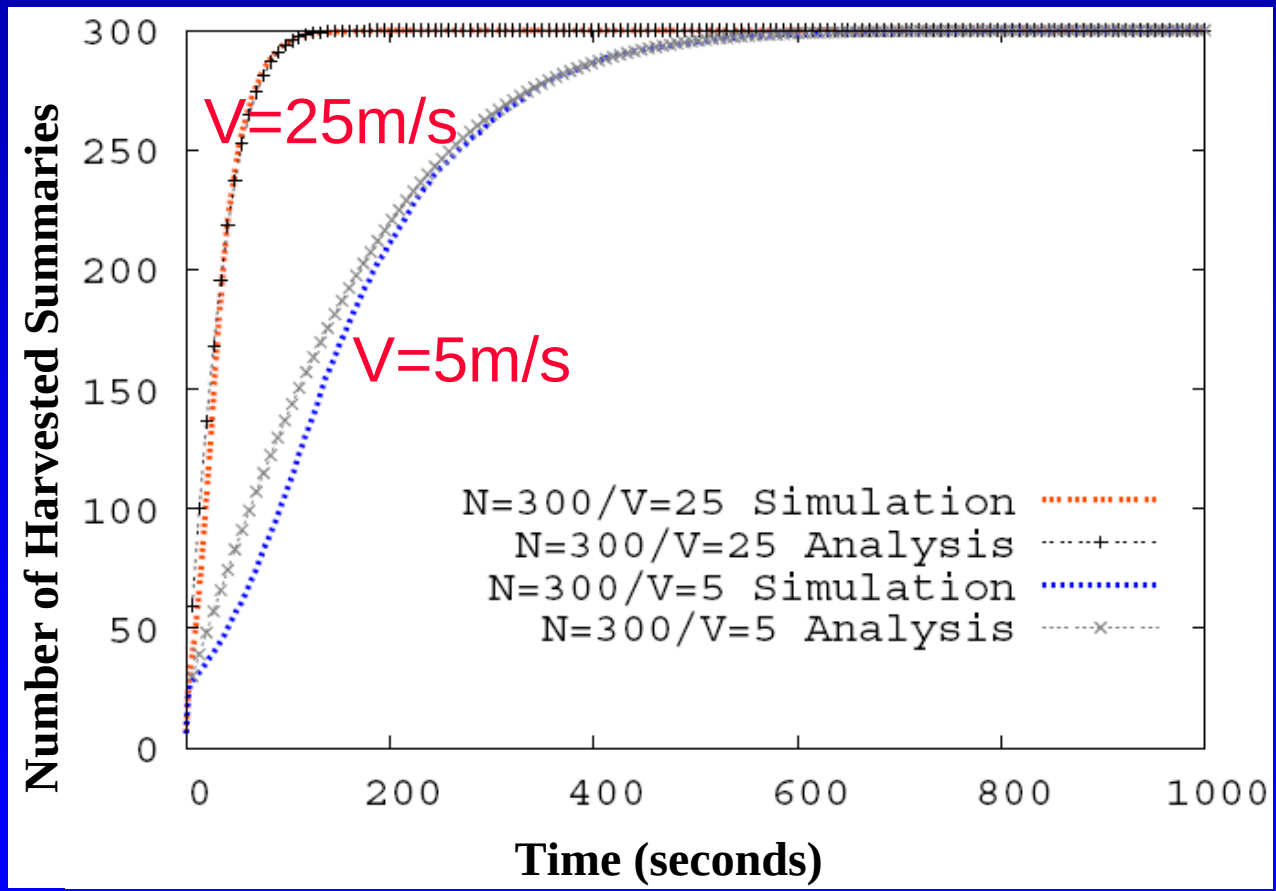
Simulation Experiment

- **Simulation Setup**
  - NS-2 simulator
  - 802.11: 11Mbps, 250m tx range
  - Average speed: 10 m/s
  - Mobility Models
    - Random waypoint (RWP)
    - Real-track model (RT) :
      - Group mobility model
      - merge and split at intersections
    - *Westwood* map



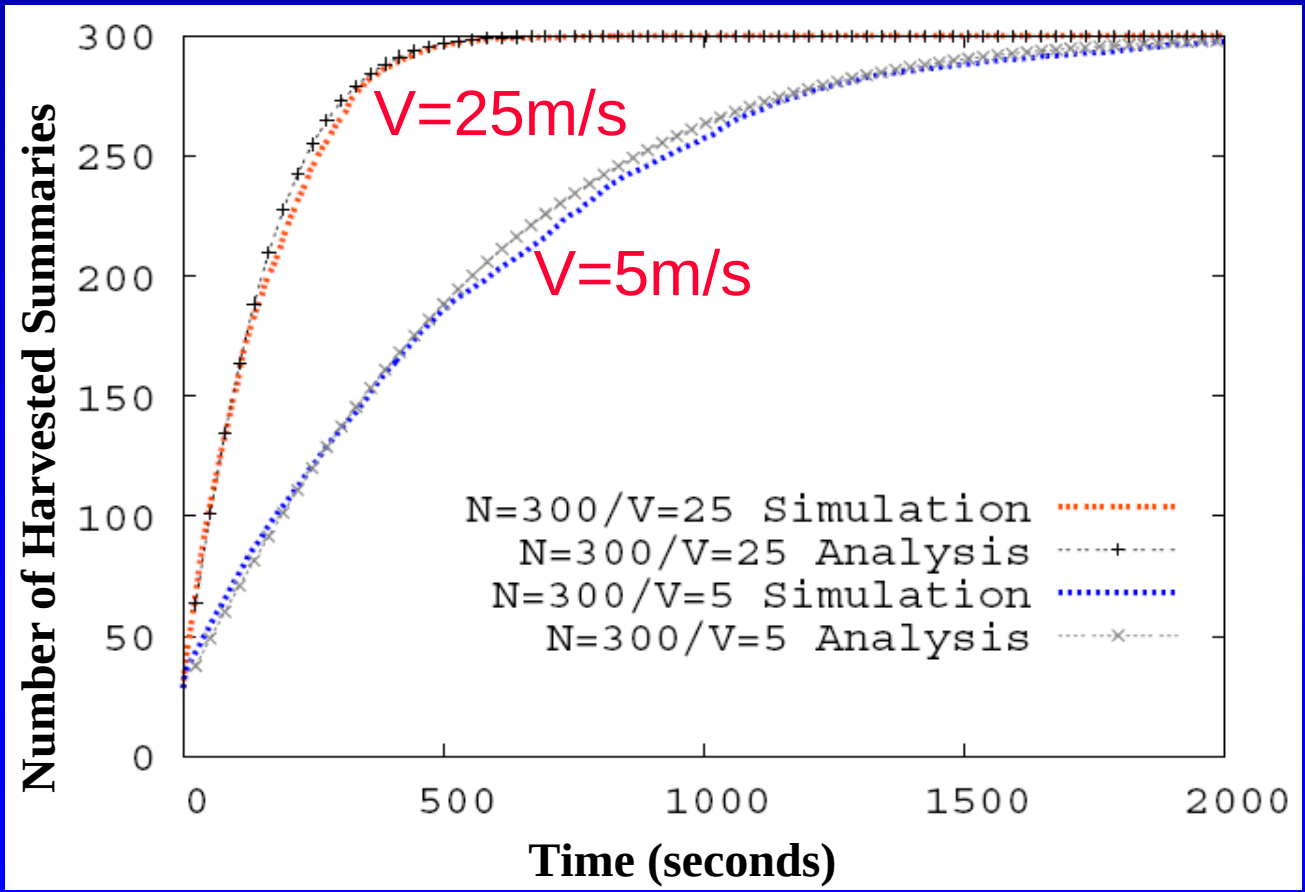
Meta-data harvesting delay with RWP

- Higher mobility decreases harvesting delay



Harvesting Results with “Real Track”

- Restricted mobility results in larger delay



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

Long Term Plan

- **We plan to install our node equipment in:**
  - 50 Campus operated vehicles (including shuttles and facility management trucks).
    - Exploit “on a schedule” and “random” campus fleet mobility patterns
  - 50 Commuting Vans
    - Measure freeway motion patterns (only tracking equipment installed in this fleet).
  - Hybrid cross campus connectivity using 10 WLAN Access Points .

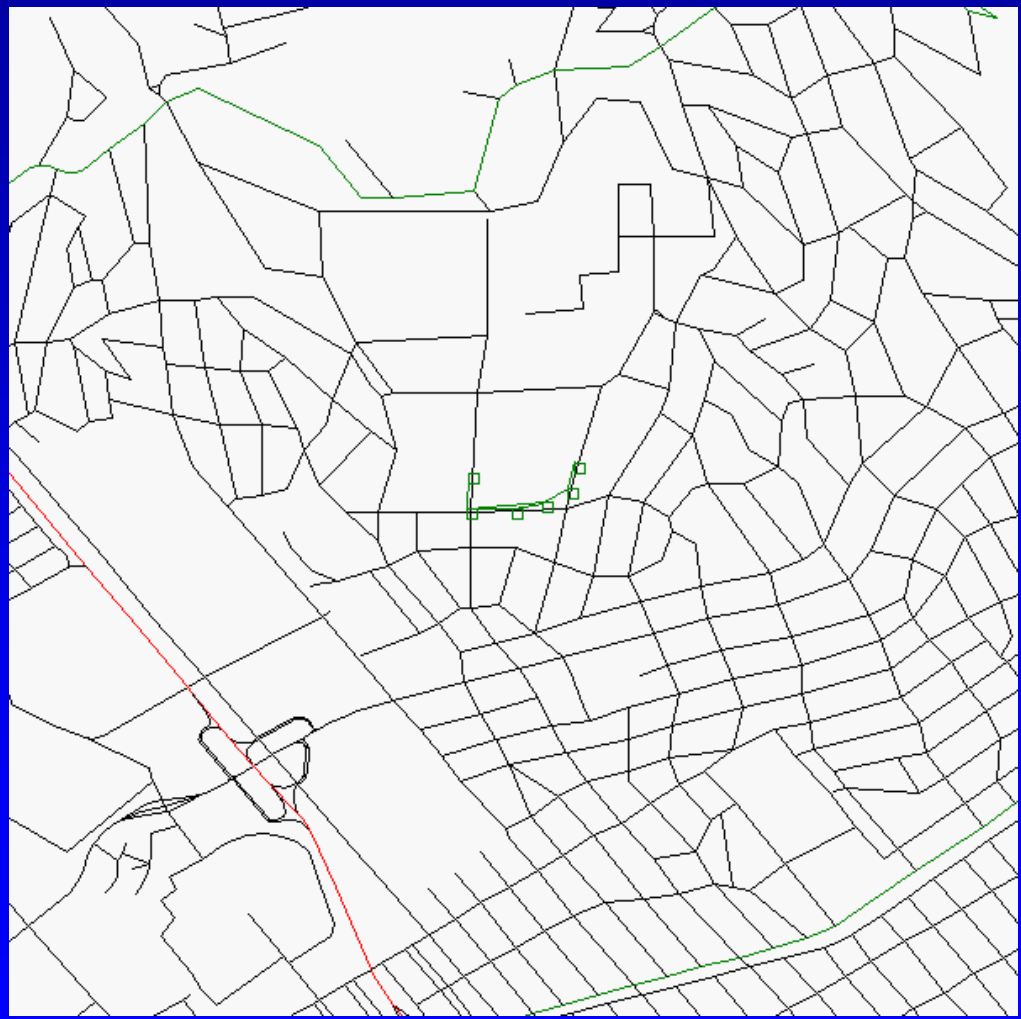

LINKSYS
Wireless N

The C2C testbed

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

- **V2V communications effective for content/entertainment:**
  - Car torrent, Code torrent, Ad Torrent
  - Car to Car Internet games
- **V2V are critical for urban surveillance:**
  - Pervasive, mobile sensing: MobEyes
  - Emergency Networking
  - Evacuation
- **Infrastructure support is critical**

Future Work

- **Still, lots of exciting work ahead :**
  - Routing models: geo-routing, hybrid routing
  - Transport models: epidemic, P2P
  - Searching massive mobile storage
  - Security, privacy, incentives
- **The need for a testbed:**
  - Realistic assessment of radio, mobility characteristics
  - Account for user behavior
  - Interaction with (and support of) the Infrastructure

The End

Thank You