Vehicular Urban Sensing: Dissemination and Retrieval

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Outline

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

Traditional Mobile Ad Hoc Network

- **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)

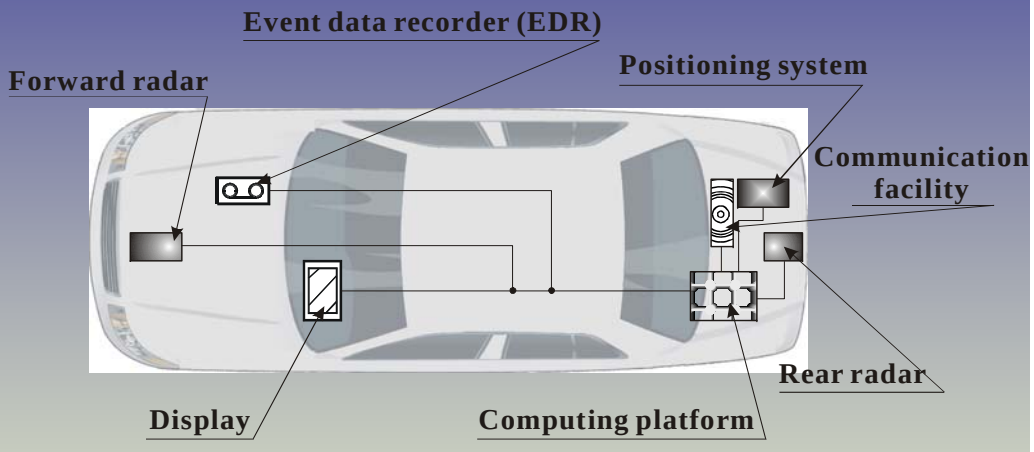
- **VANET => *Opportunistic* Ad Hoc Network**
  - Access to Internet readily available, but..
  - opportunistically “bypass it” with “ad hoc” if too costly or inadequate

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)
- Location Relevant Content Distr.
- Urban Sensing
- Advertising, Commerce, Games
- Etc

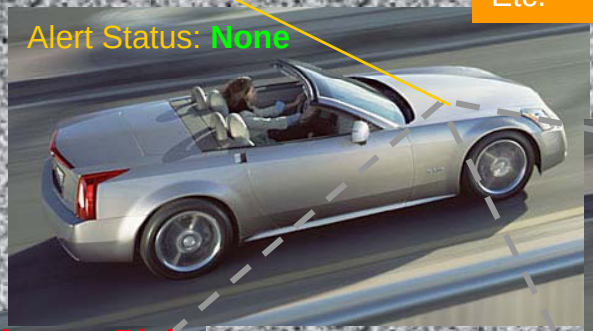
V2V Applications

- **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/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.

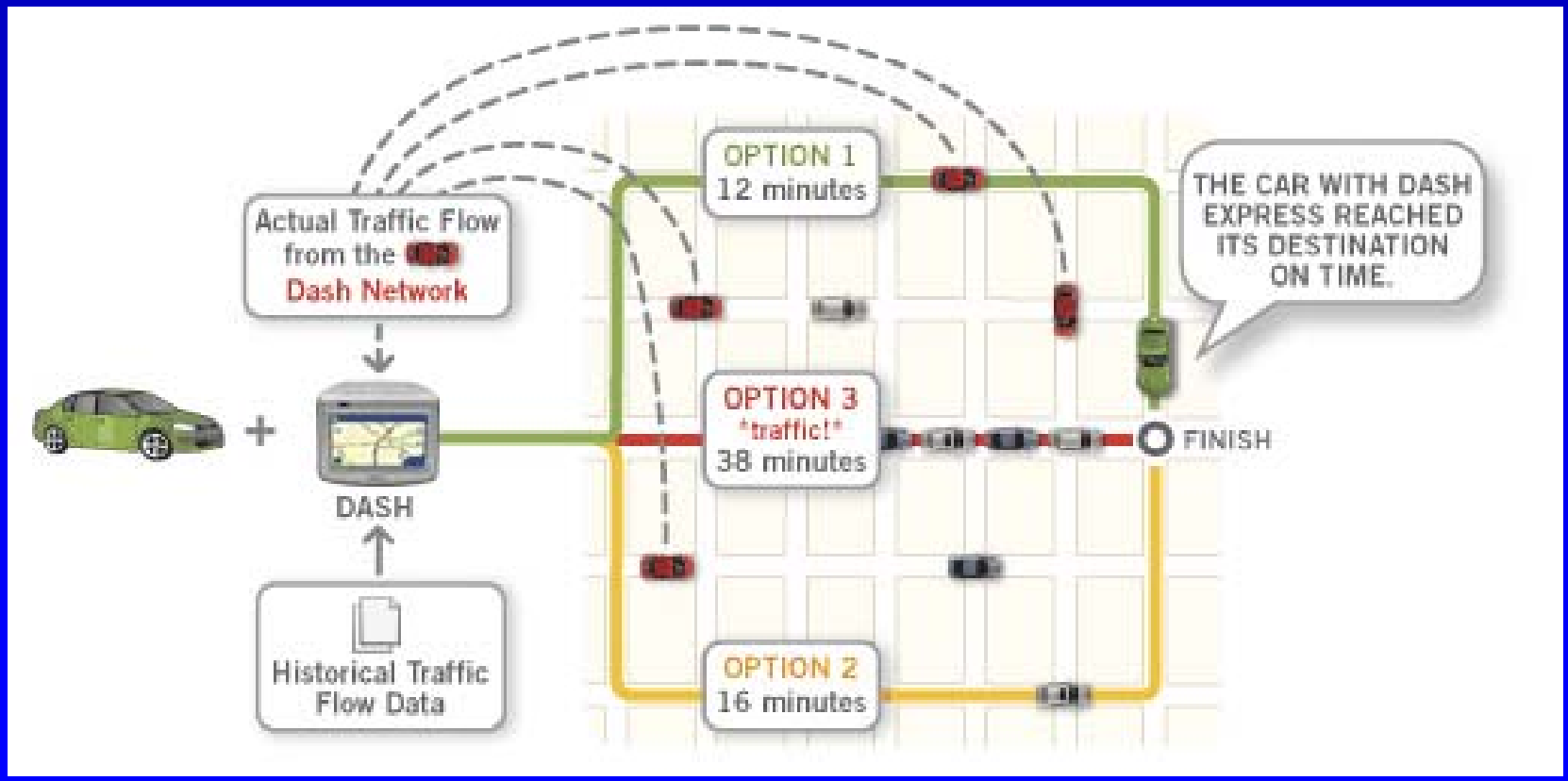


Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 75 mph
Acceleration: **+ 10m/sec^2**
Coefficient of friction: .65
Driver Attention: **Yes**
Etc.

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

V2V Applications (cont)

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



Intelligent Transport Systems

intelligent lane reservations

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..

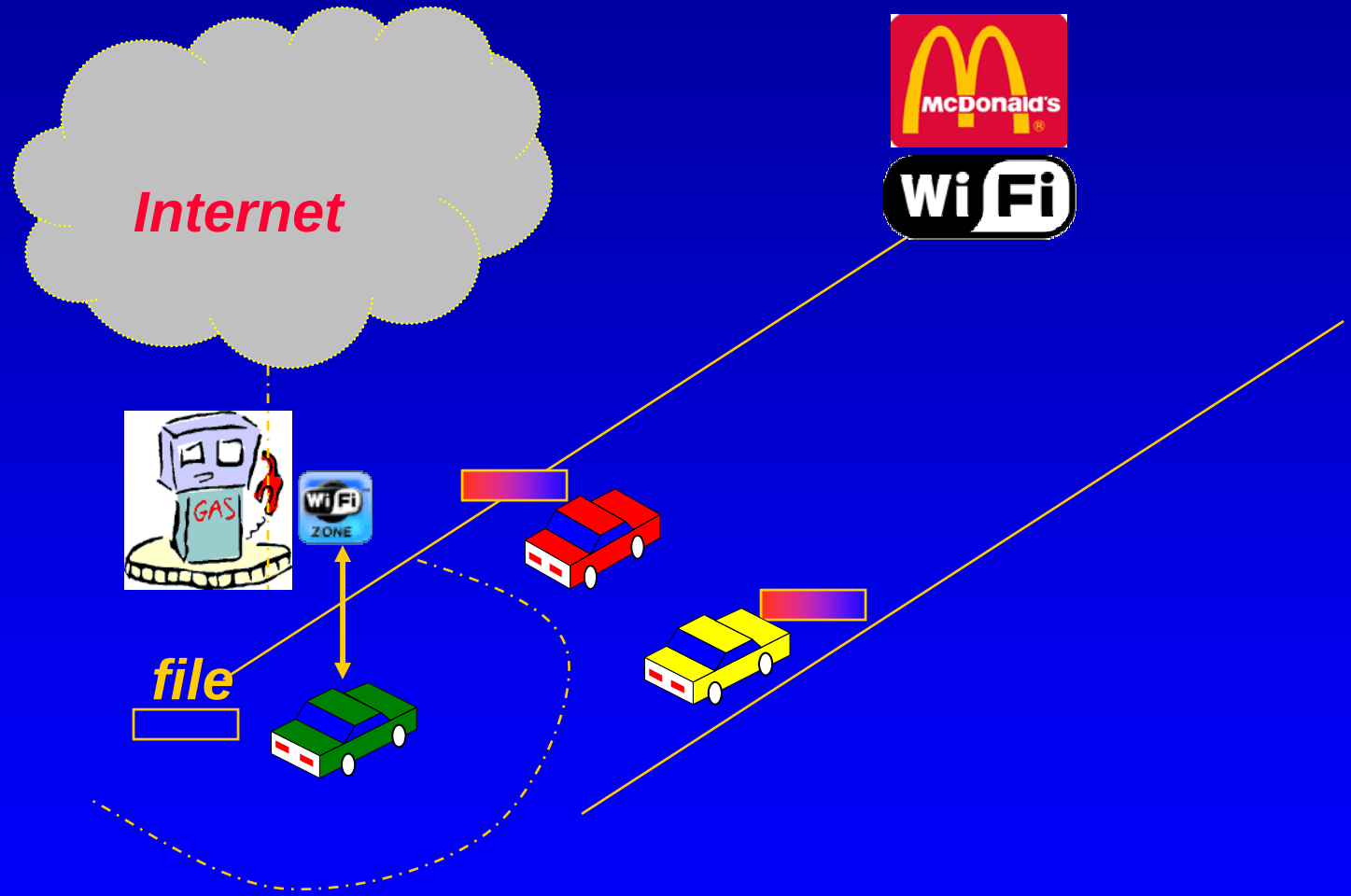
Commerce (Flea Net):

- 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

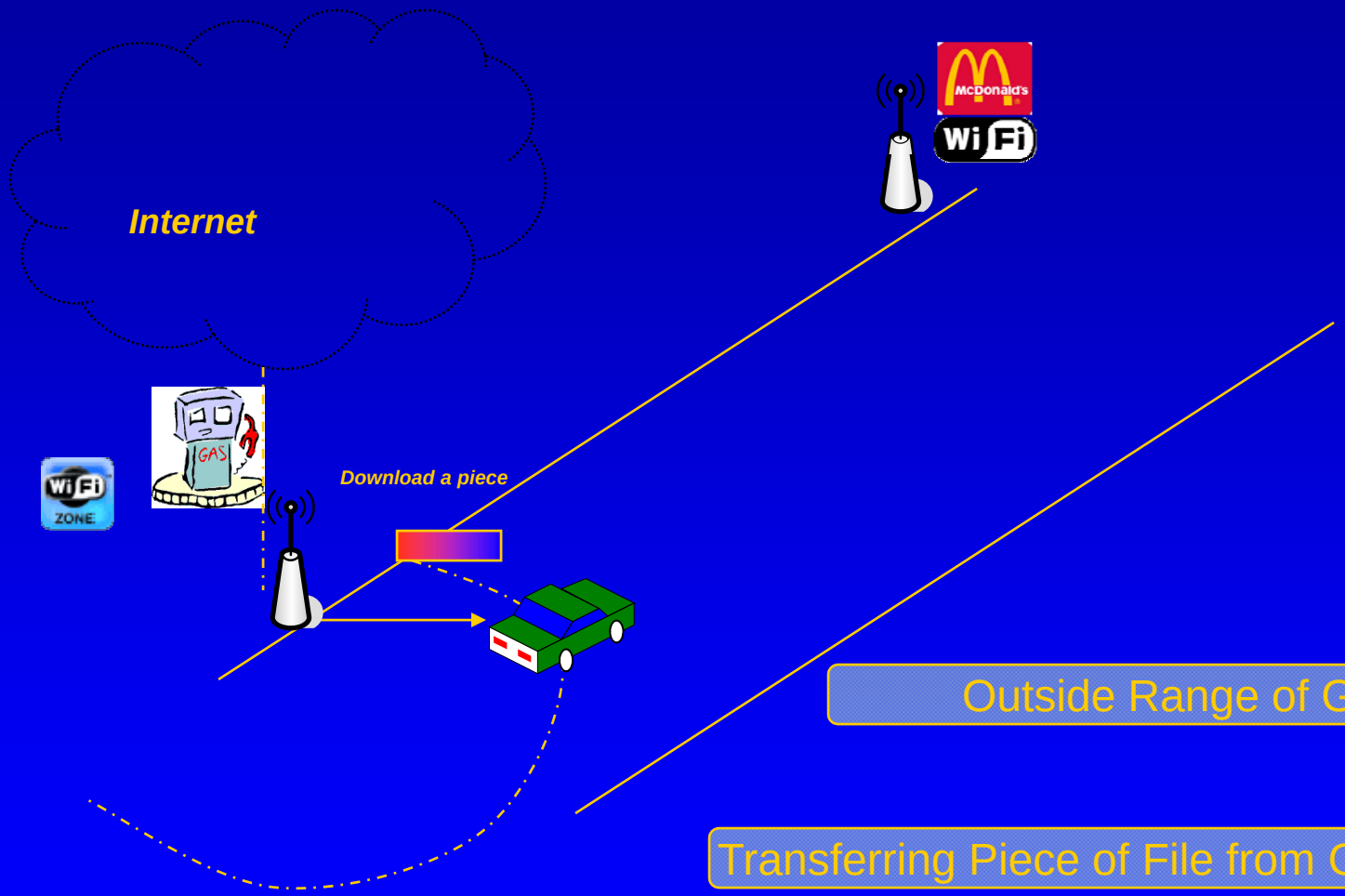
Downloading from GPRS/3G too slow and quite expensive

3G broadcast services (MBMS, MediaFLO) only for TV

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

Solution: Co-operative P2P Downloading via Car-Torrent

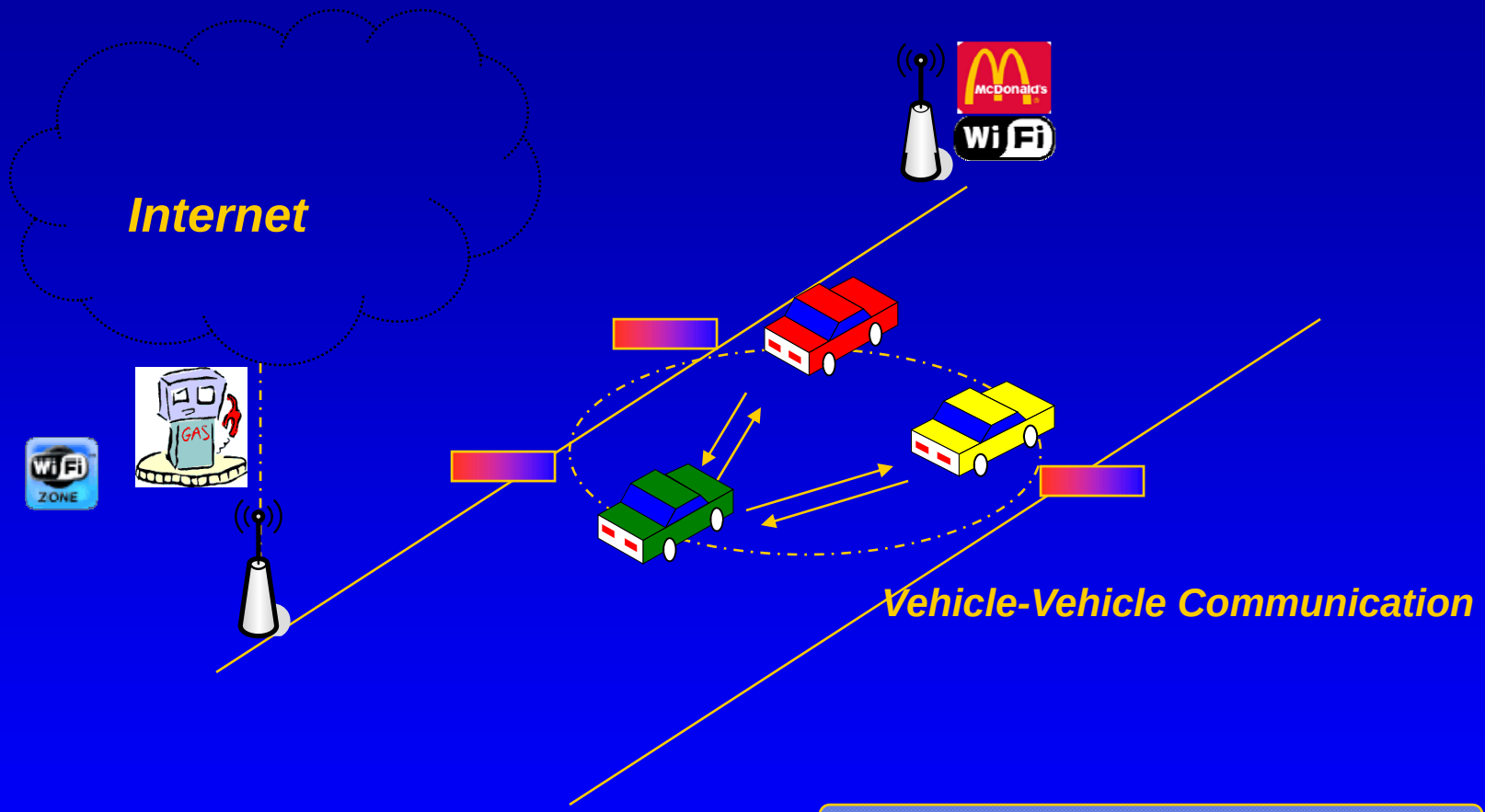
CarTorrent: Basic Idea



Outside Range of Gateway

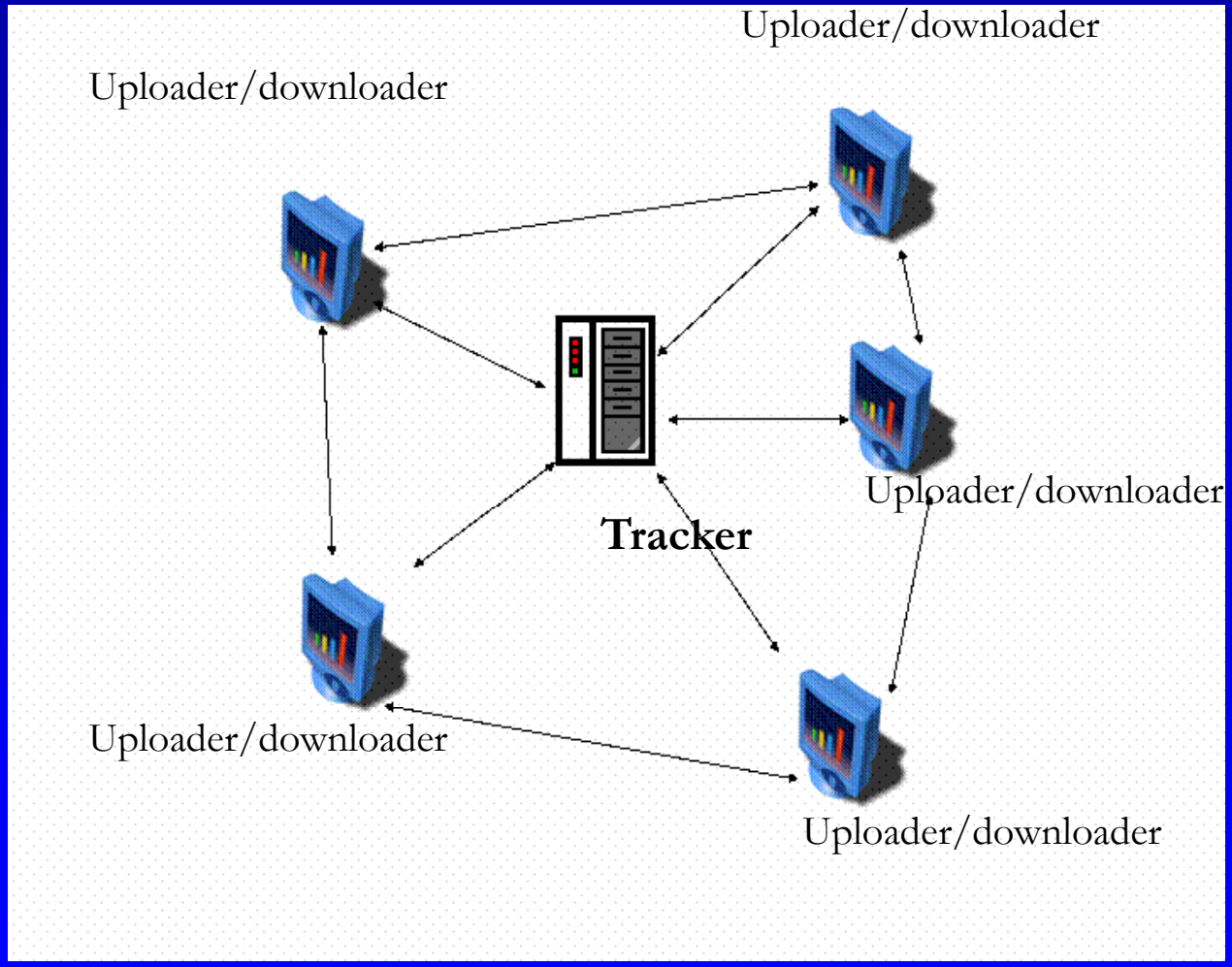
Transferring Piece of File from Gateway

Co-operative Download: Car Torrent

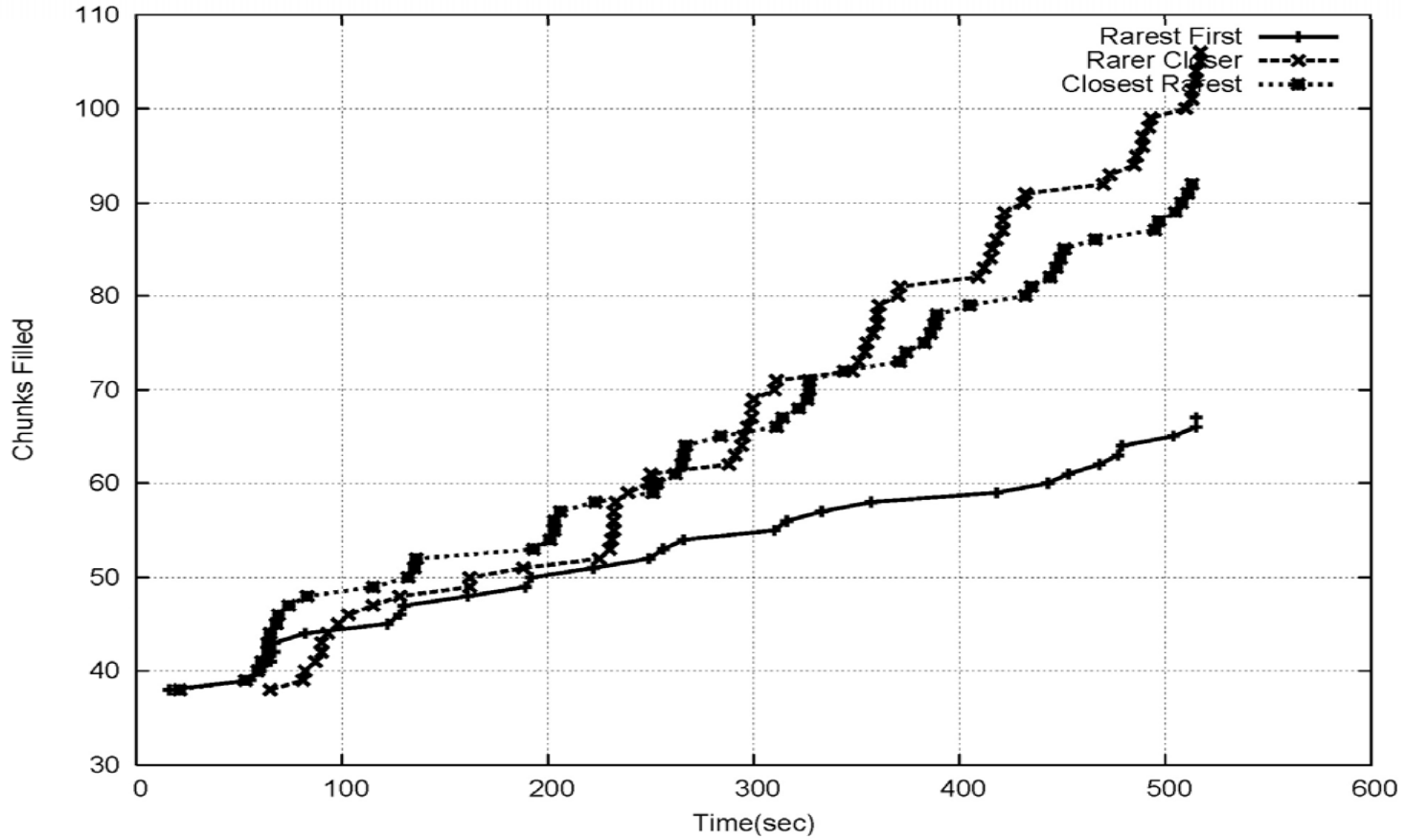


Exchanging Pieces of File Later

Car Torrent inspired by BitTorrent: Internet P2P file downloading



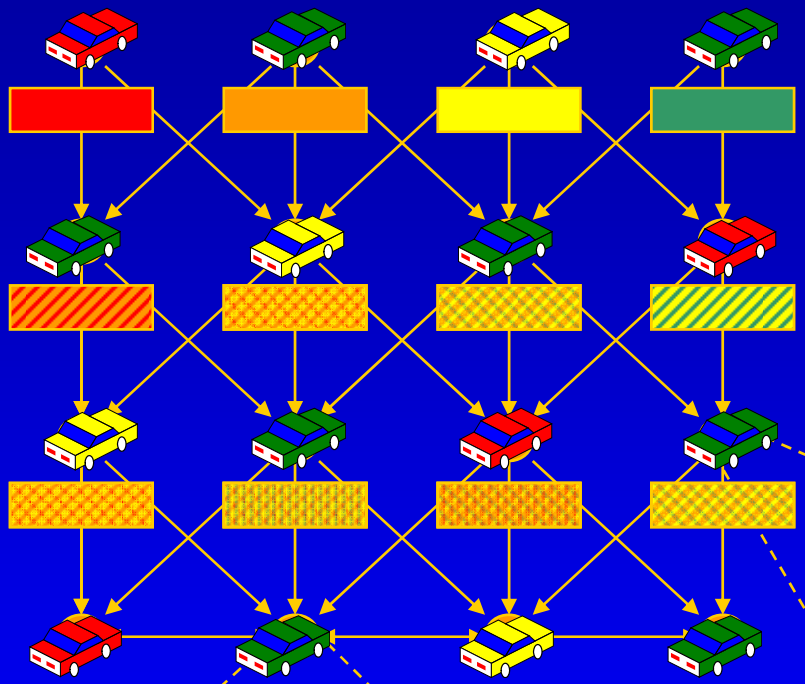
Selection Strategy Critical



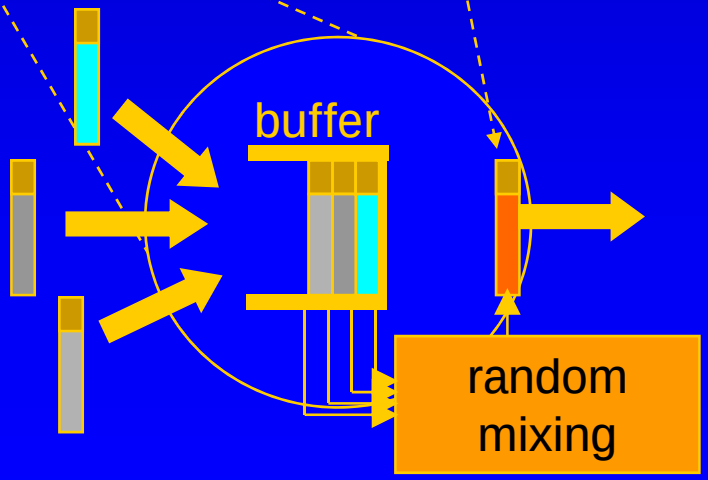
CarTorrent with Network Coding

- 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!

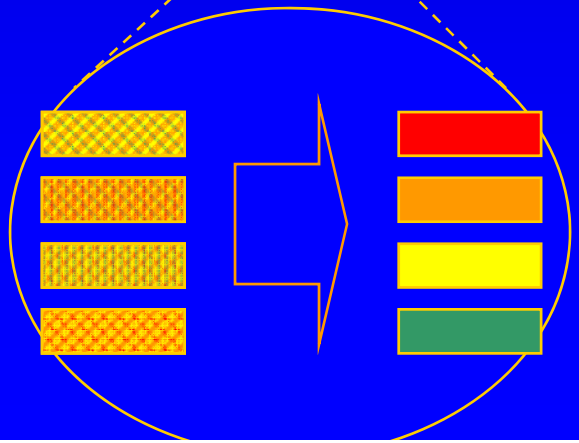
Network Coding



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)



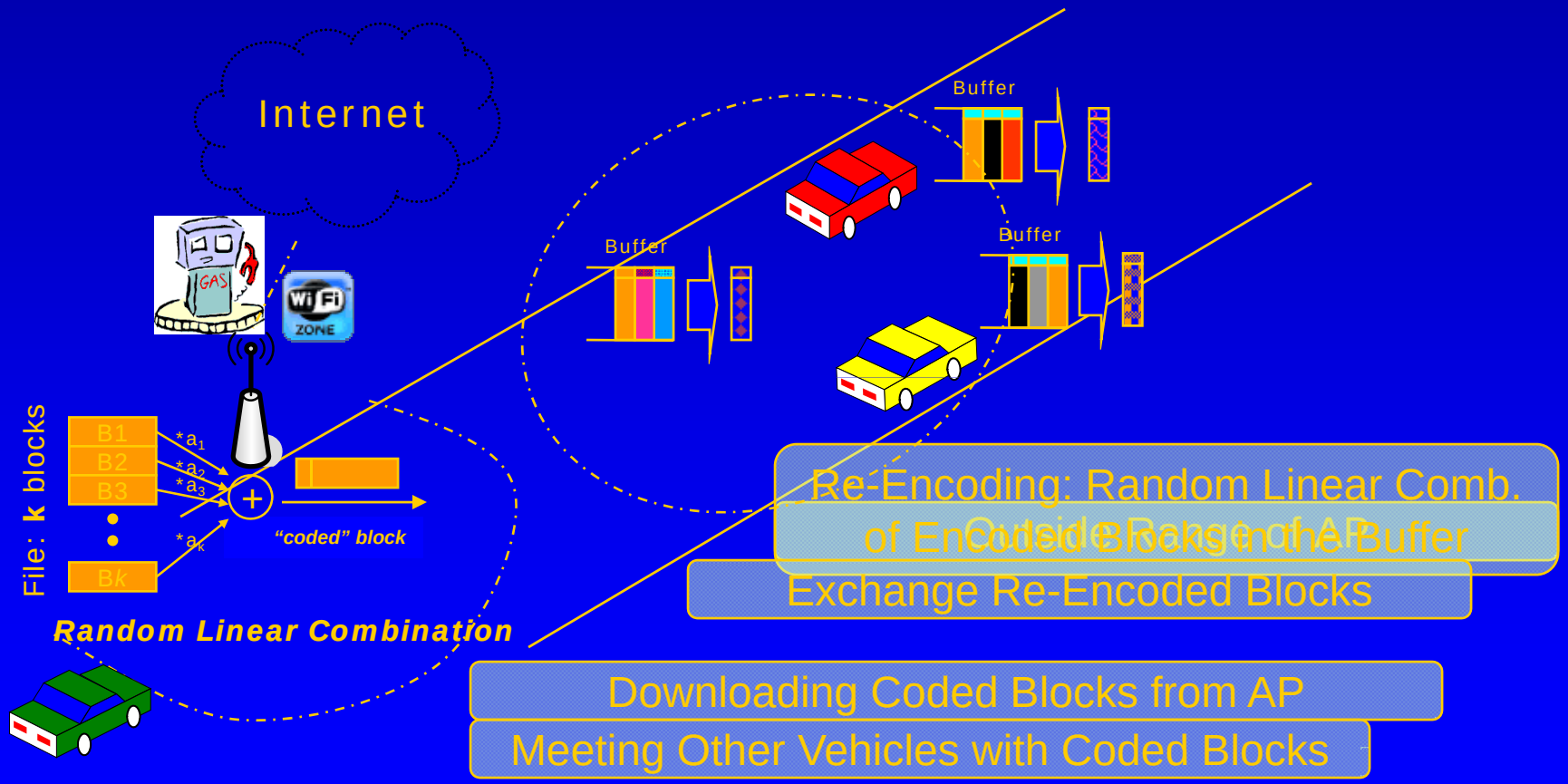
Intermediate nodes



Receiver recovers original by matrix inversion

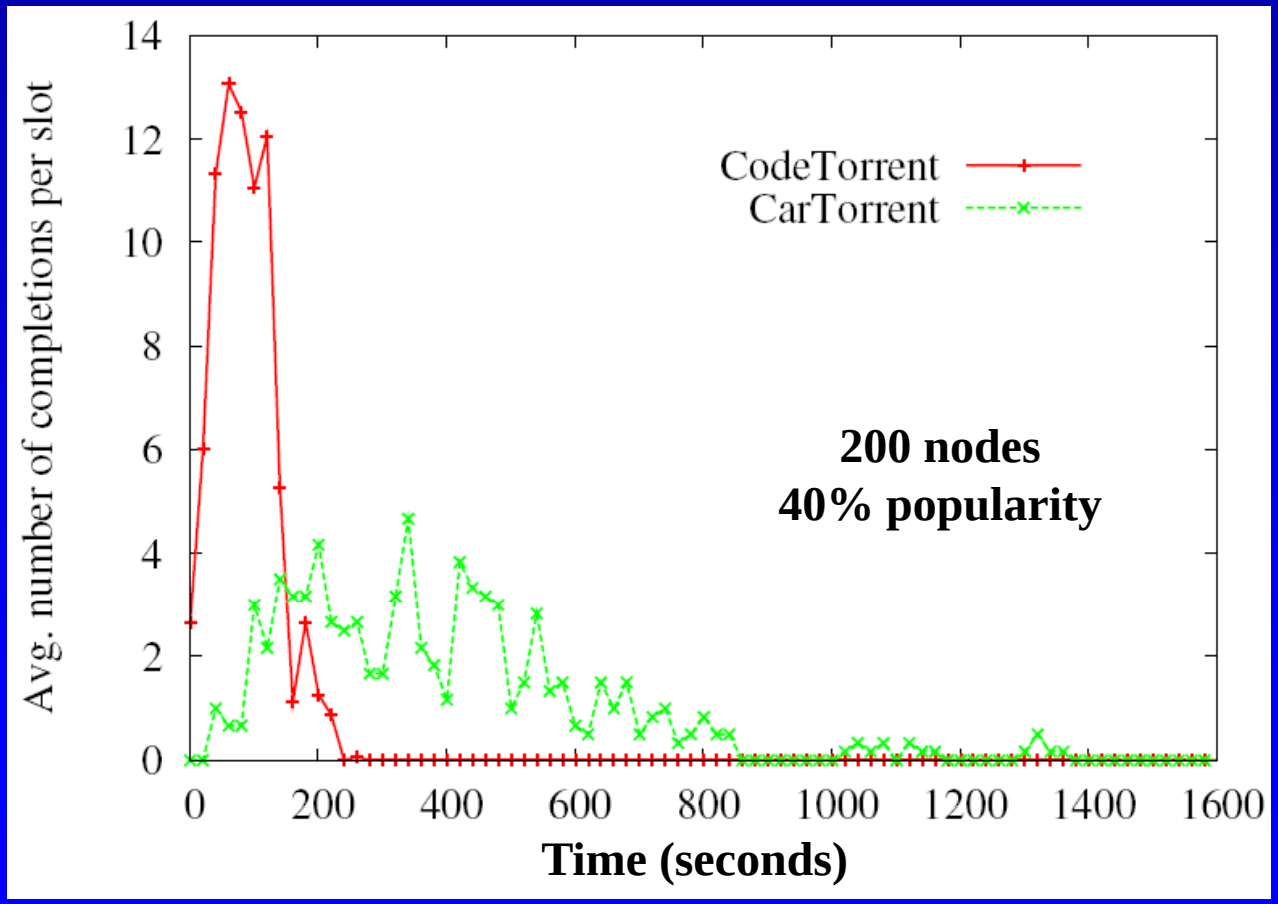
CodeTorrent

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



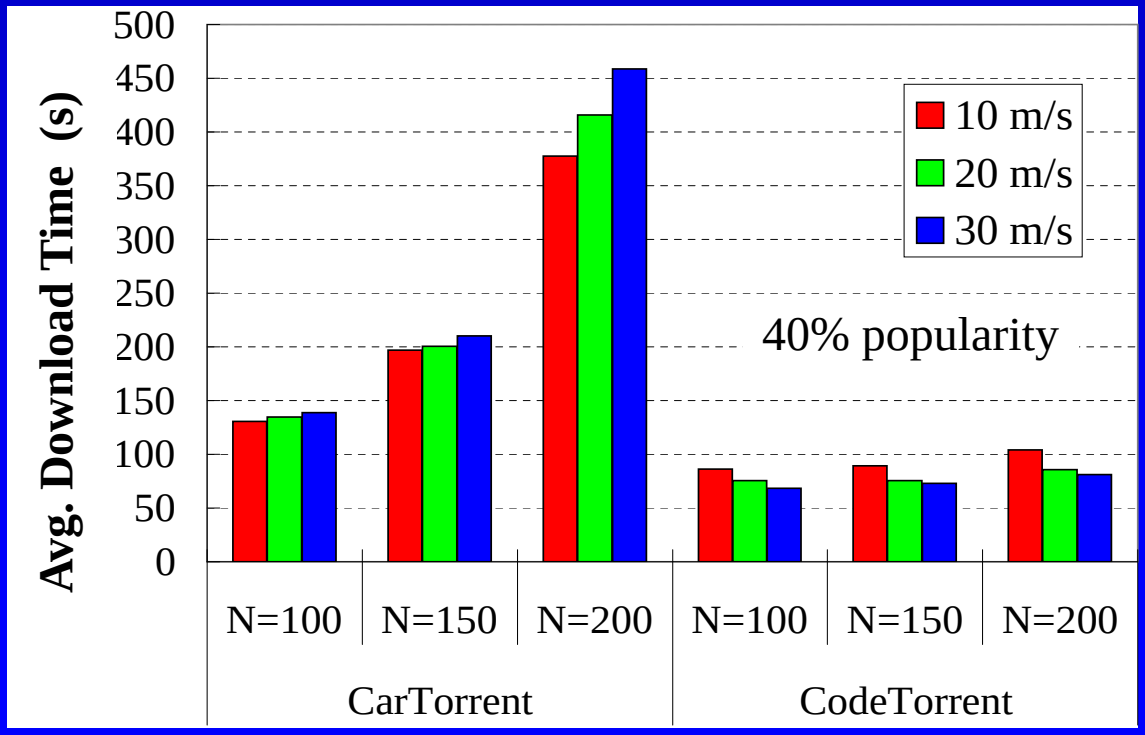
Simulation Results

- **Completion time density**

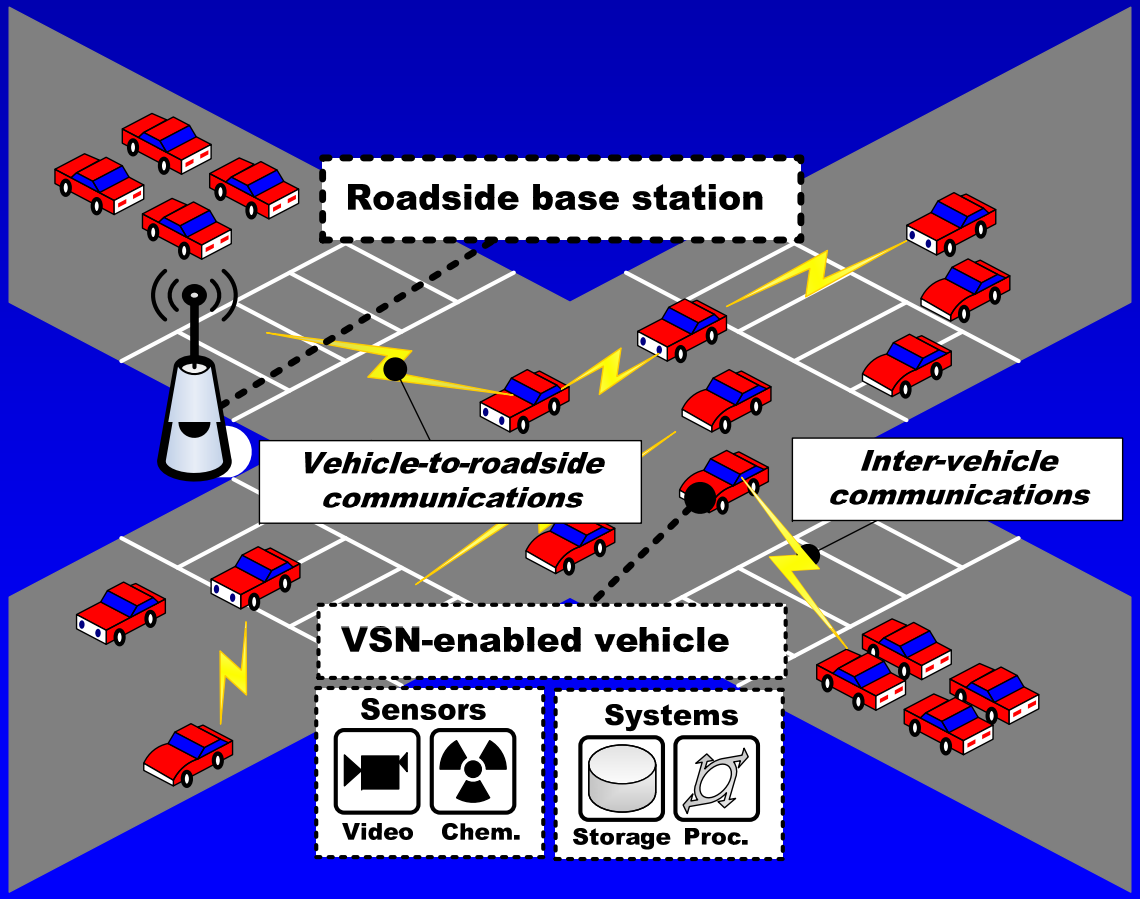


Simulation Results

- **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

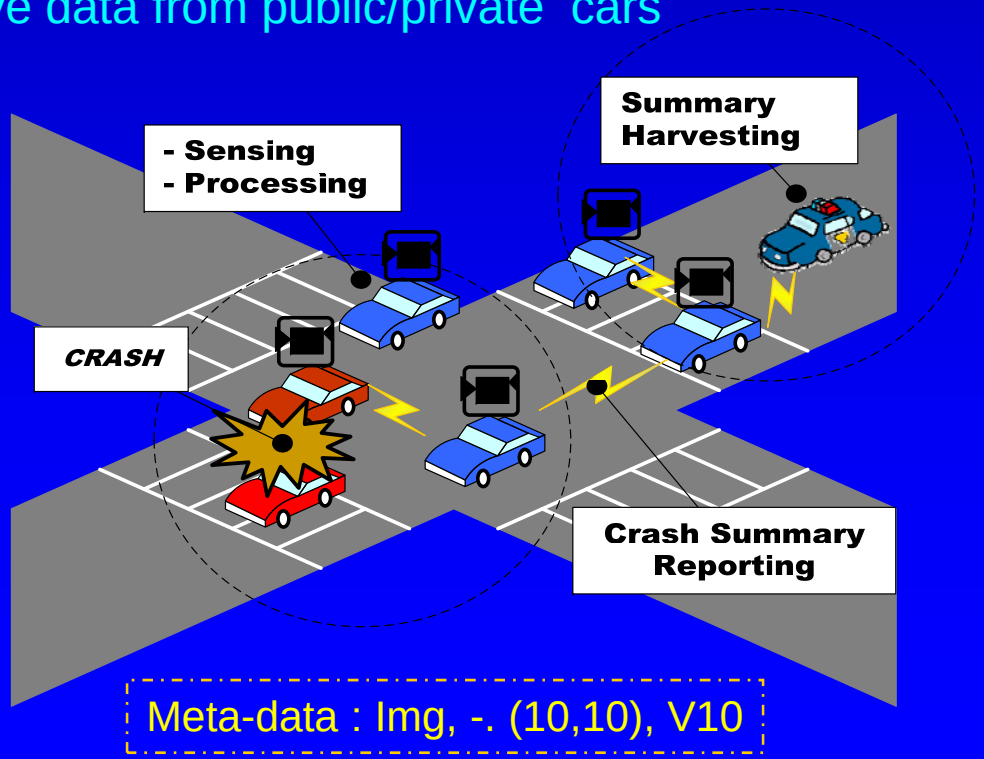


Vehicular Sensor Applications

- **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 (Dash Express; 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 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*

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**

MobEyes (UCLA)

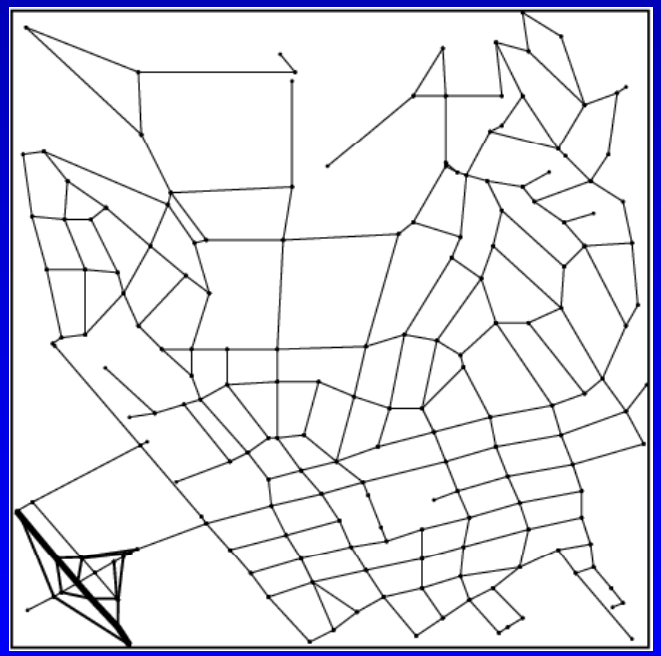
- **“Epidemic diffusion” :**
  - *Mobile nodes* periodically broadcast *meta-data* of events to their neighbors
  - A *mobile agent* (the police) queries nodes and harvests events
  - Data dropped when stale and/or geographically irrelevant

MobEyes: Mobility-assisted 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)**

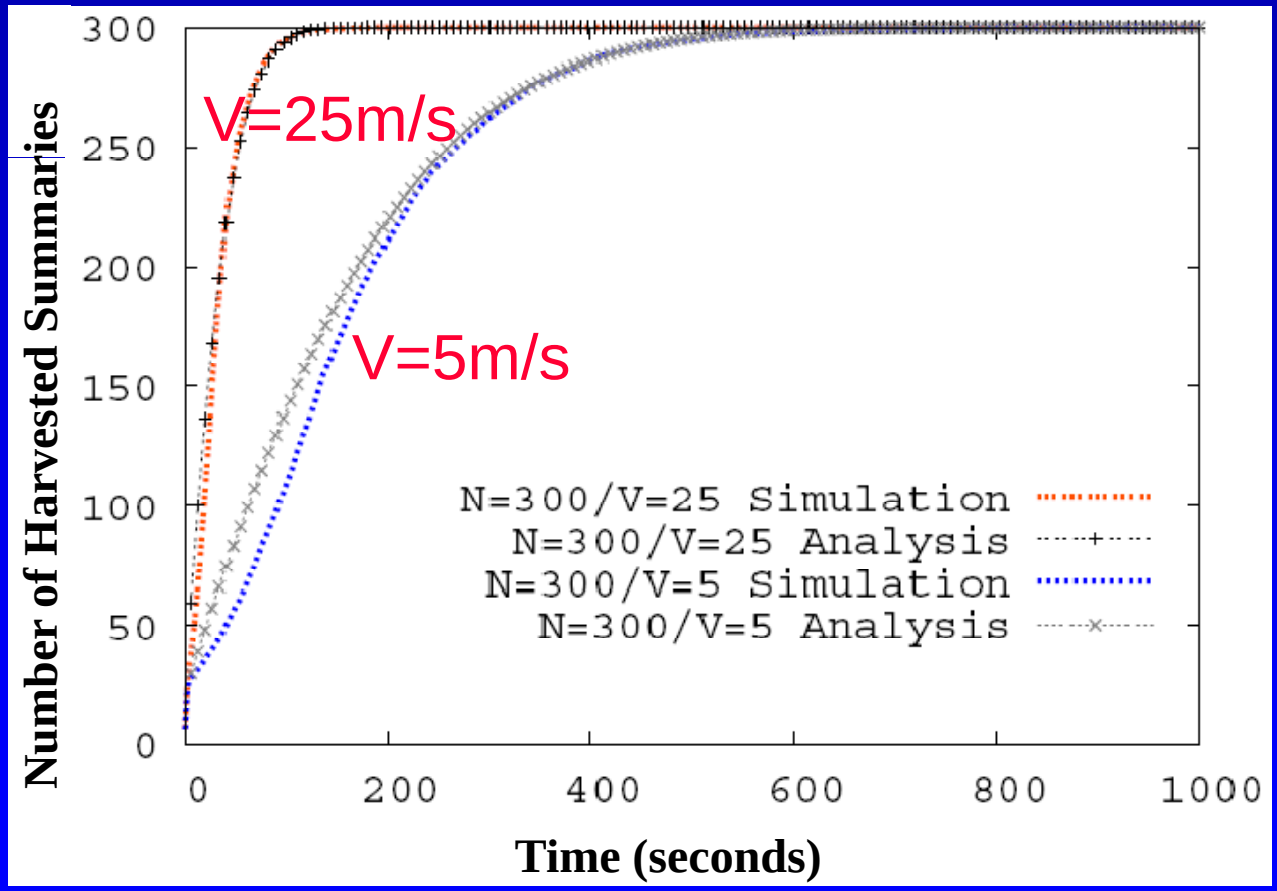
Simulation Experiment

- **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



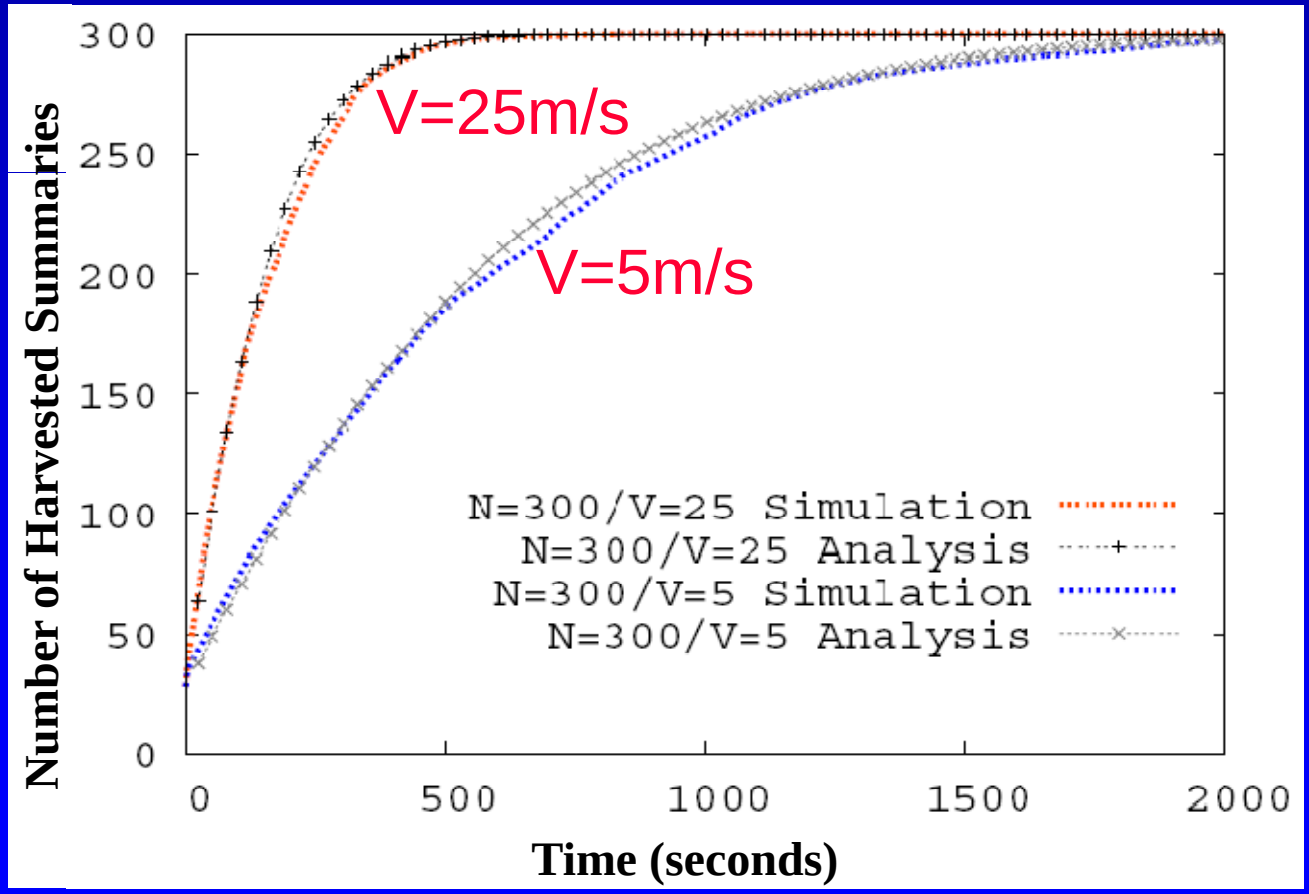
Meta-data harvesting delay with RWP

- Higher mobility decreases harvesting delay



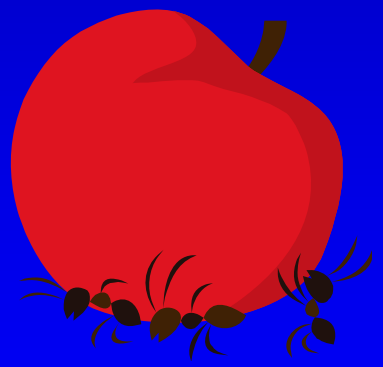
Harvesting Results with “Real Track”

- Restricted mobility results in larger delay



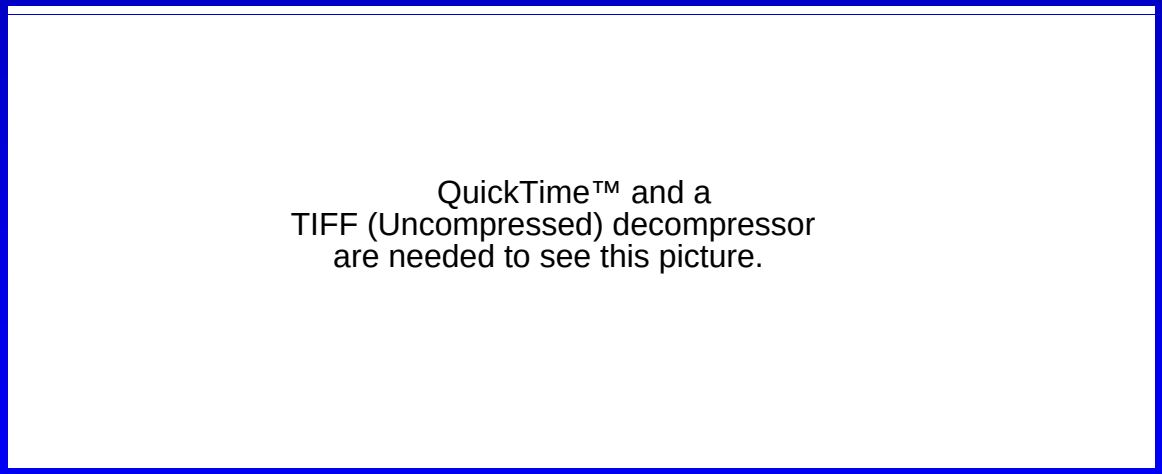
Multi-agent Harvesting

- **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

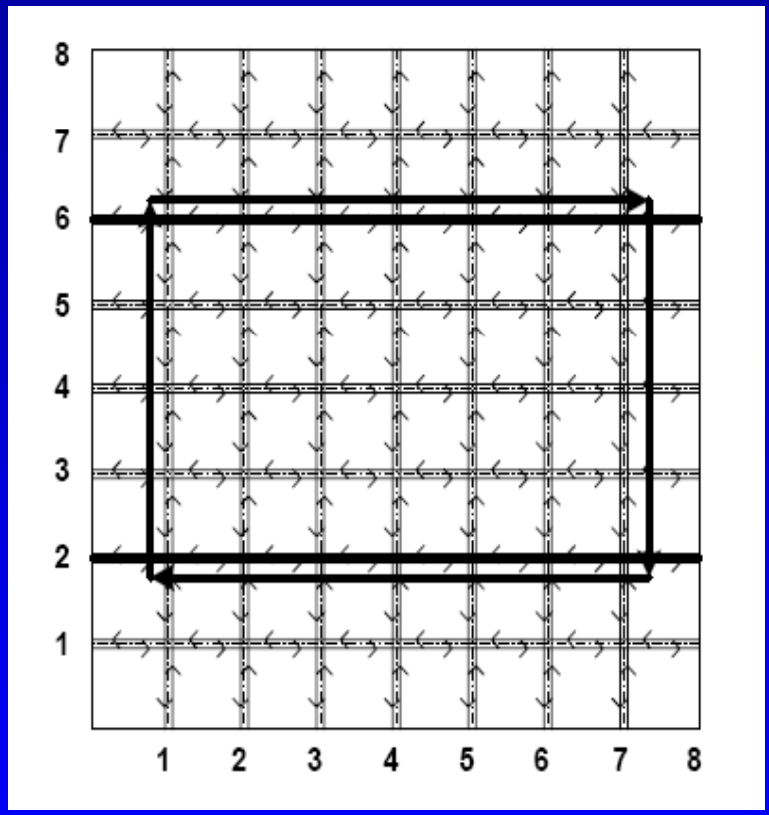
- **Data-taxis**
  - Similar to the chemotactic behavior of E-coli bacteria
    - Modes of locomotion: tumble, swim, search
    - Strategy: greedy approach with random search
  - Three modes of agent operation



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

Evaluation Framework

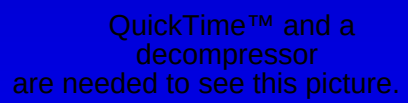
- **Simulation setup**
  - Manhattan mobility model
  - Streets 2 and 6 with valuable information
  - Up to 4 agents
- **Candidate algorithms**
  - RWF (Random Walk Foraging)
  - BRWF (Biased RWF)
  - PPF (Preset Pattern Foraging)
  - DTF (Data-taxis Foraging)



7x7 Manhattan grid

Performance Results

Aggregate number of harvested data



Vehicular Security requirements

Sender authentication

Verification of data consistency

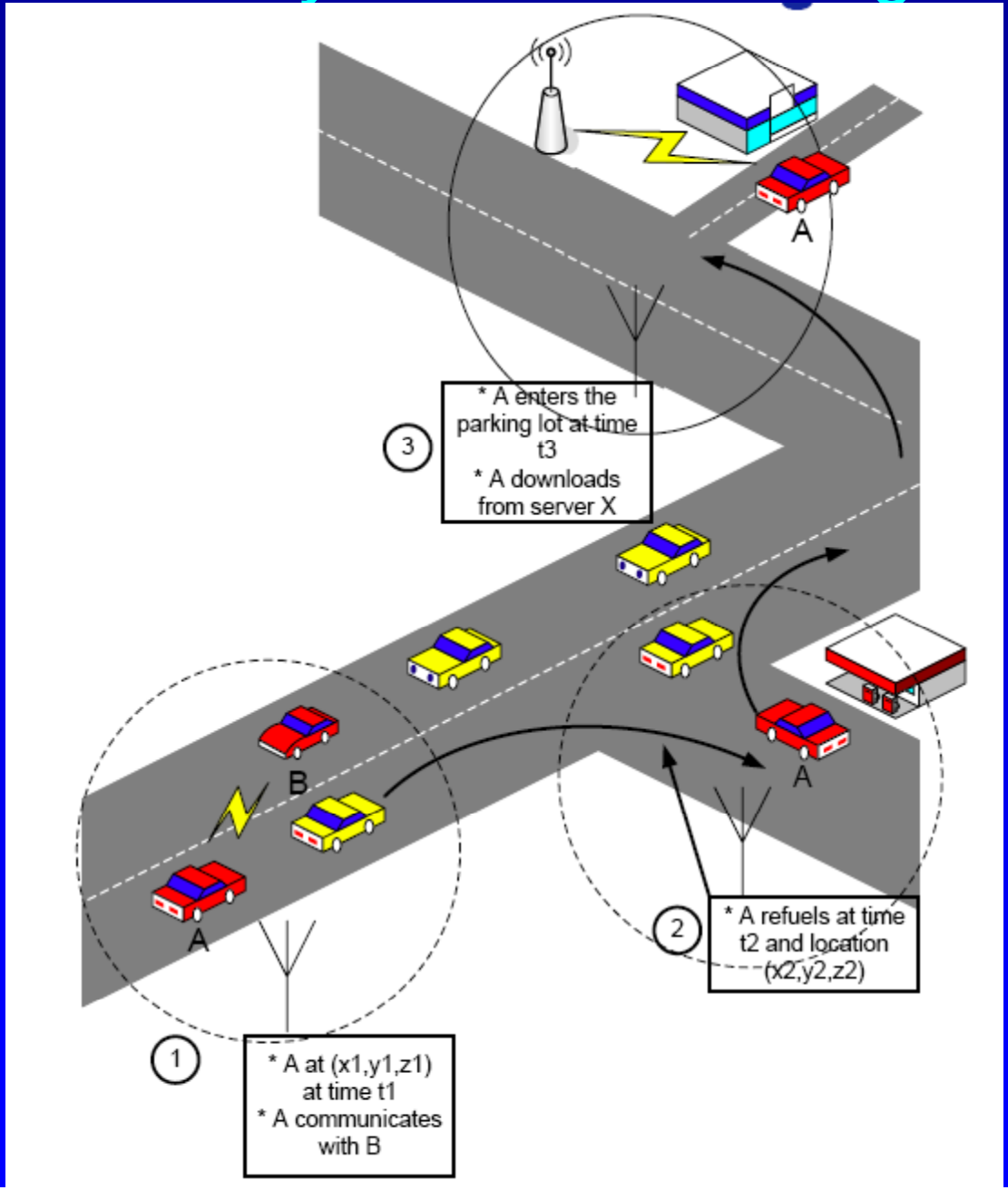
Protection from Denial of Service

Non-repudiation

Privacy

Challenge: Real-time constraint

Privacy Attack: Tracking



New security requirements for dissemination

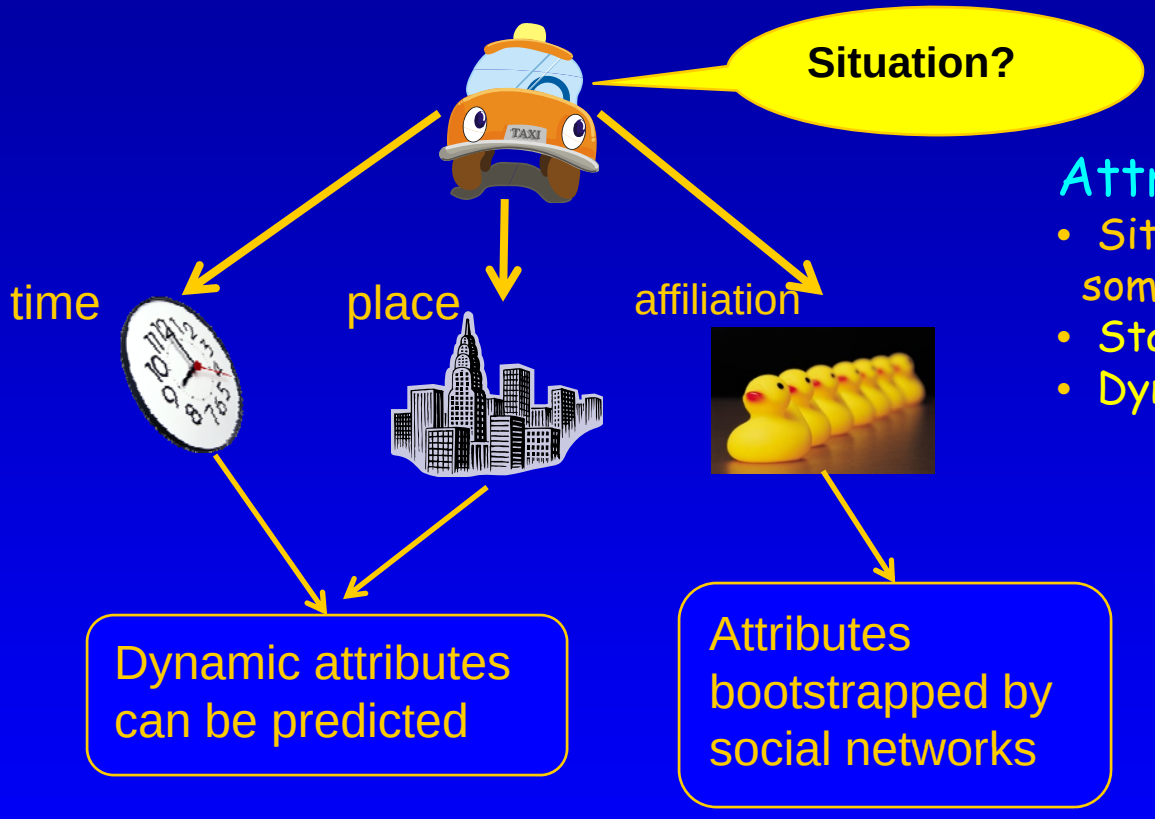
Selective, private dissemination:

- **Example #1: A driver wants to alert all taxicabs of company A on 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 private 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



Attribute based Trust

- Situation elements are encoded into some attributes
- Static attributes (affiliation)
- Dynamic attributes (time and place)

Social Trust

- Bootstrap initial trust
- Transitive trust relations

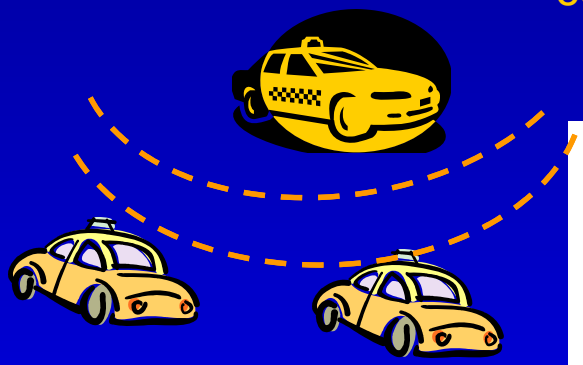
Proactive Trust

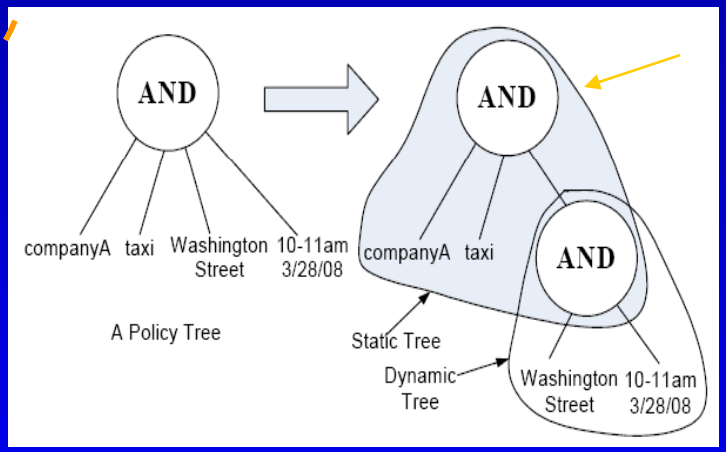
- predict dyn attributes based on mobility and location service
- establish trust in advance

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)

plaintext → Extended ABE Module → Ciphertext

Extended ABE Module → Signature

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).

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).

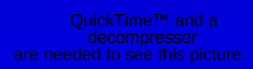
Allow:

- **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

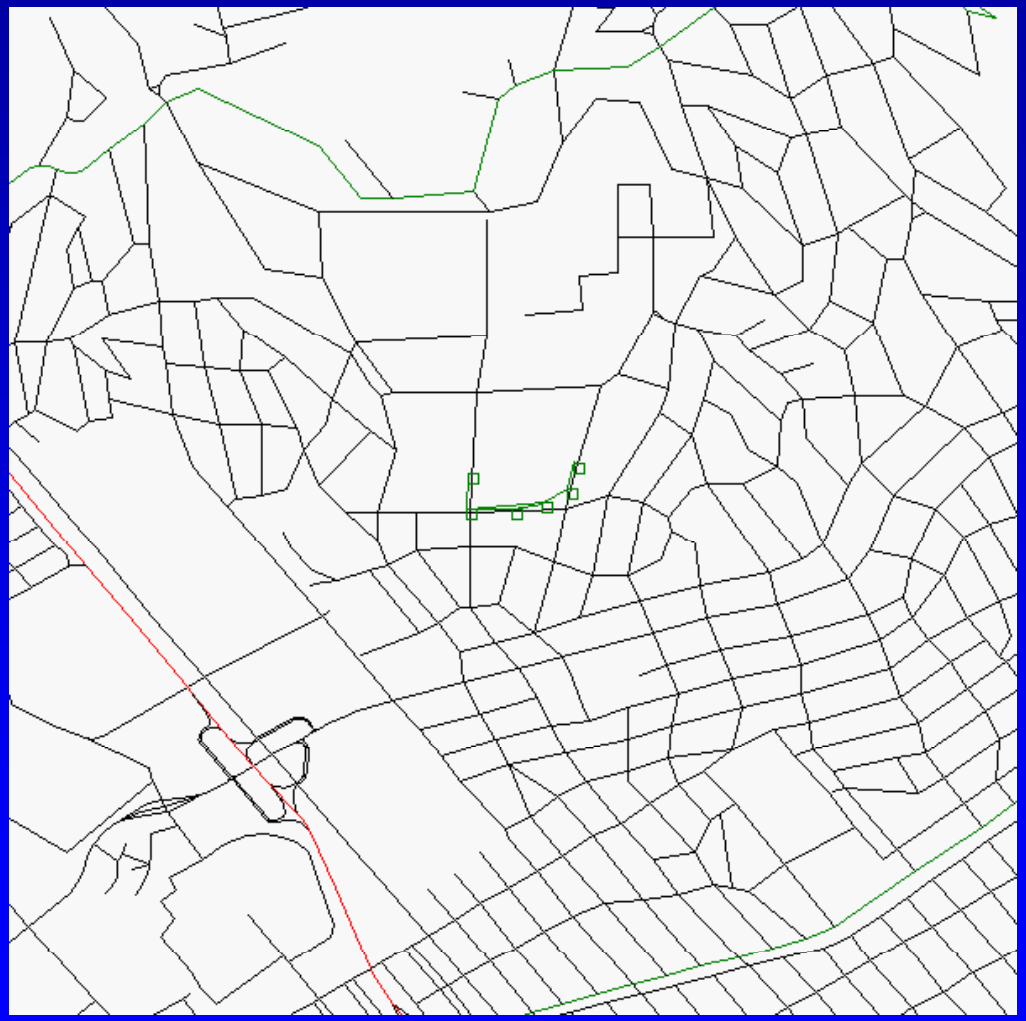
Campus Initial Coverage Using MobiMesh




LINKSYS
Wireless N

“Instrumenting” the vehicle

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 higways
- **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!