Vehicular Grid Communications: the role of the Internet Infrastructure

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Outline

- Emerging urban vehicle applications
- Routing in a highly mobile urban environment
  - A case for geo-routing
  - Geo Location Service
- Extending Geo routing to the infrastructure
- To use or not to use the infrastructure?
  - load balance
- Conclusions

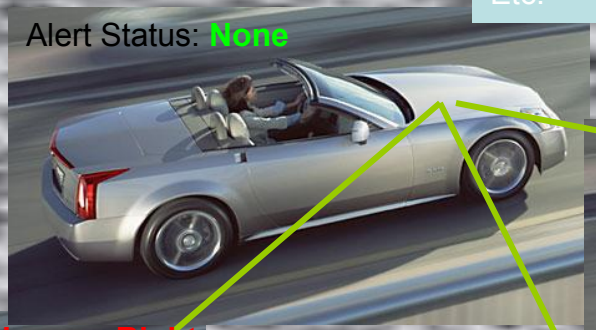
Urban Vehicle Grid Applications

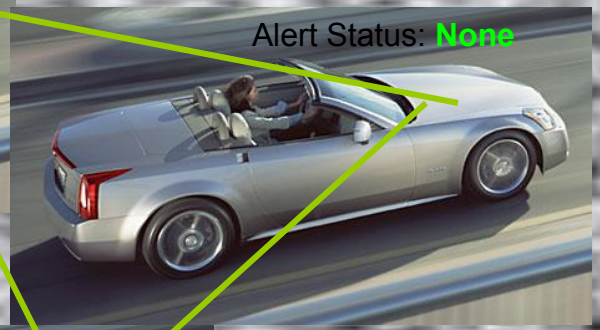
- Safe navigation
- Content distribution (video, ads)
- Vehicle as mobile sensor platform

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.

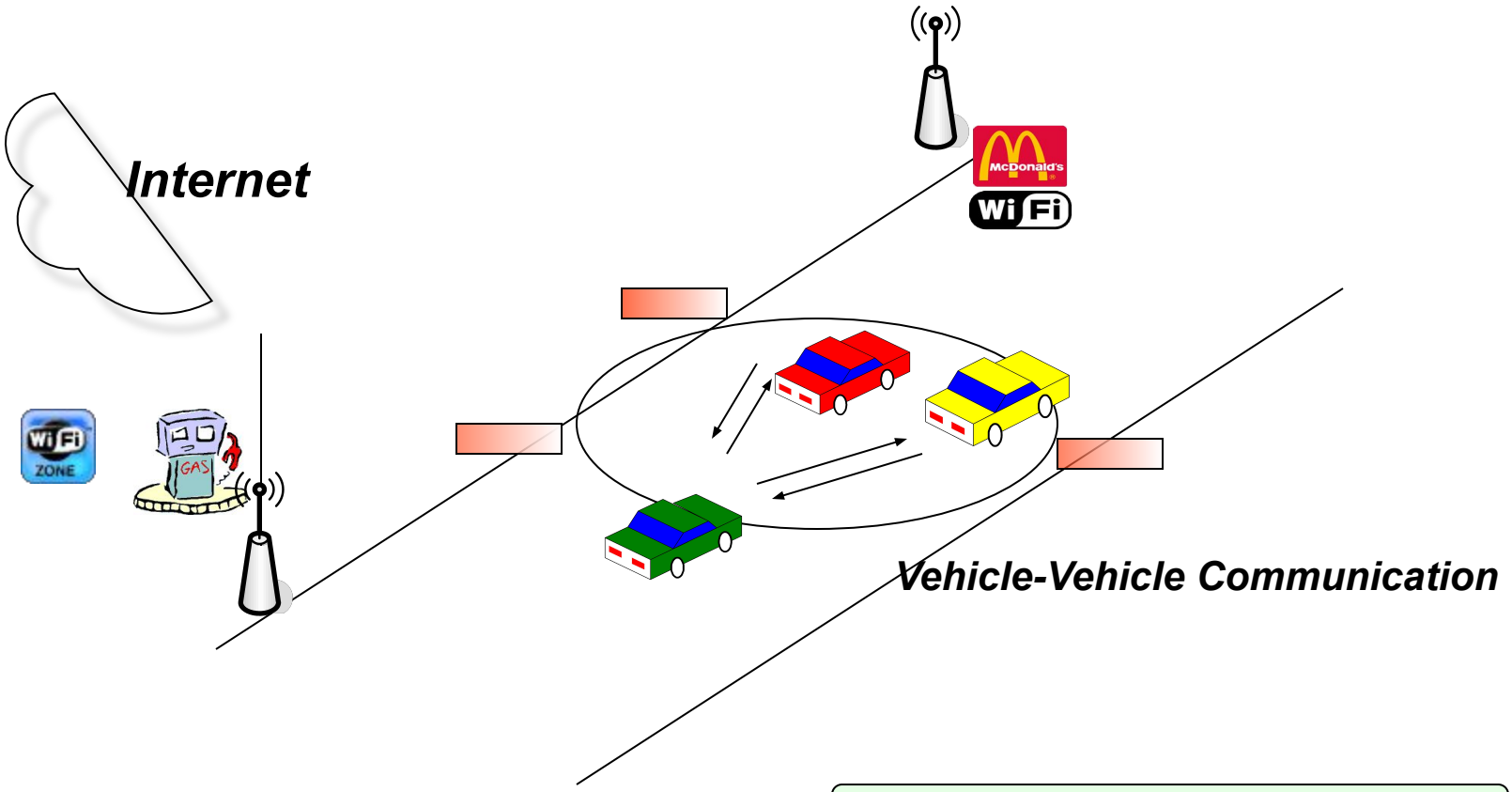




Vehicle type: Cadillac XLR
Curb weight: 3,547 lbs
Speed: 45 mph
Acceleration: **- 20m/sec^2**
Coefficient of friction: .65
Driver Attention: **No**
Etc.

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

Co-operative Download: Car Torrent

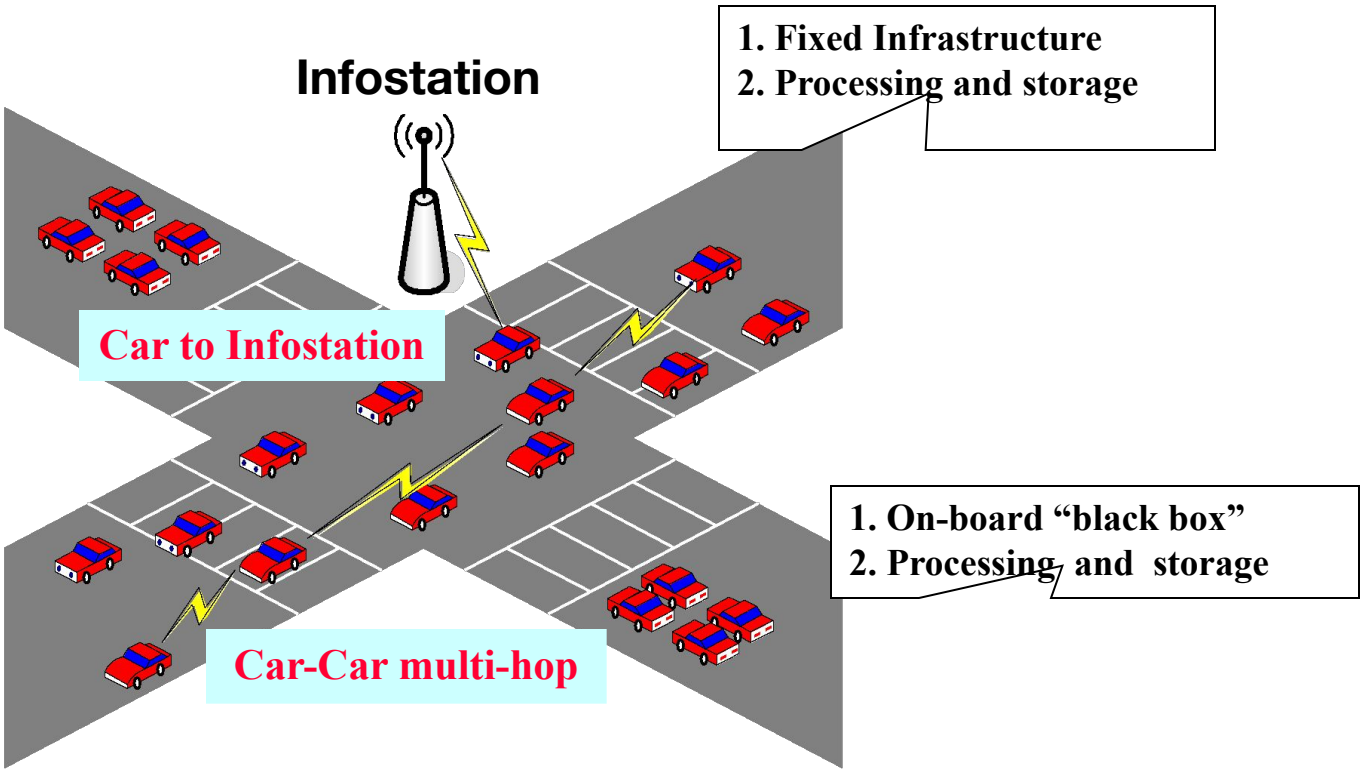


Exchanging Pieces of File Later

Digital Billboard: Ad Torrent

- Every Access Point (AP) disseminates Ads that are relevant to the proximity of the AP
- Passing cars pick up the Ads
- What is an Ad?
  - simple text message
  - trailer of nearby movies,
  - virtual tour of hotels etc
- Business owners in the vicinity subscribe to this digital billboard service for a fee.

Vehicular Sensor Network (VSN)

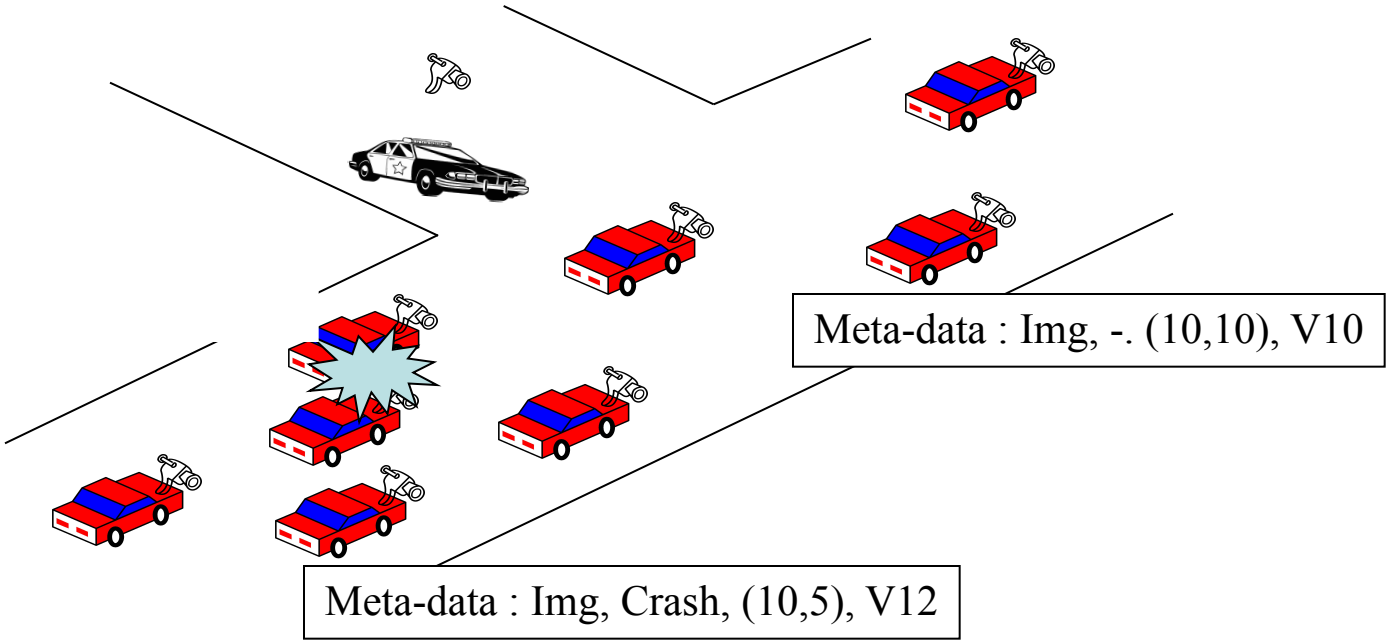


Vehicular Sensor Applications

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

Accident Scenario: storage and retrieval

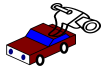
- **Designated Cars:**
  - Continuously **collect** images - cars, license plates etc (store data locally)
  - Process the data and **detect** an event
  - **Classify the event as** Meta-data (Type, Option, Location, Vehicle ID)
  - **Post** it on "distributed index" (P2P network)
- **Police search the index and retrieve data from "witness" cars**



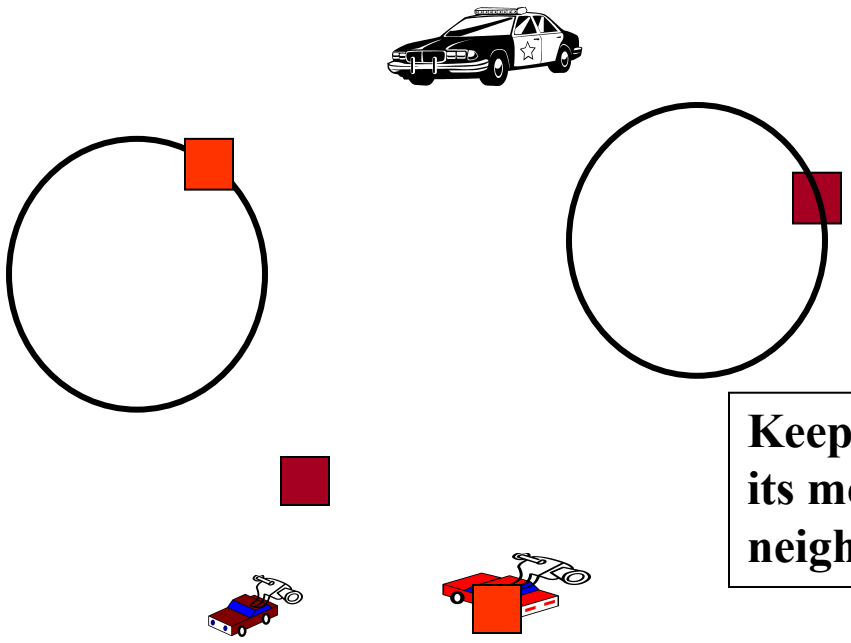
How to set up the index and retrieve the data?

- "Epidemic diffusion" :
  - *Mobile nodes* periodically broadcast *meta-data* of events to their neighbors
- A *mobile agent* (the police) queries nodes and harvests {event + witness ID}
- Data dropped when stale and/or geographically irrelevant

Epidemic Diffusion + Harvesting



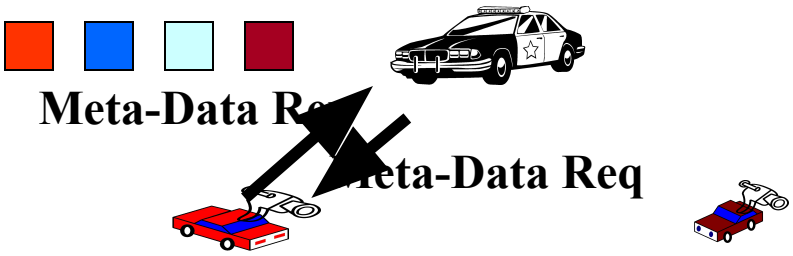
Epidemic Diffusion + Harvesting



Keep "relaying" its meta-data to neighbors

1) "periodically" Relay (Broadcast) its Event to Neighbors
2) Listen and store other's relayed events into one's storage

Epidemic Diffusion + Harvesting



1. **Agent (Police) harvests Meta-Data from its neighbors**
2. **Nodes return all the meta-data they have collected so far**

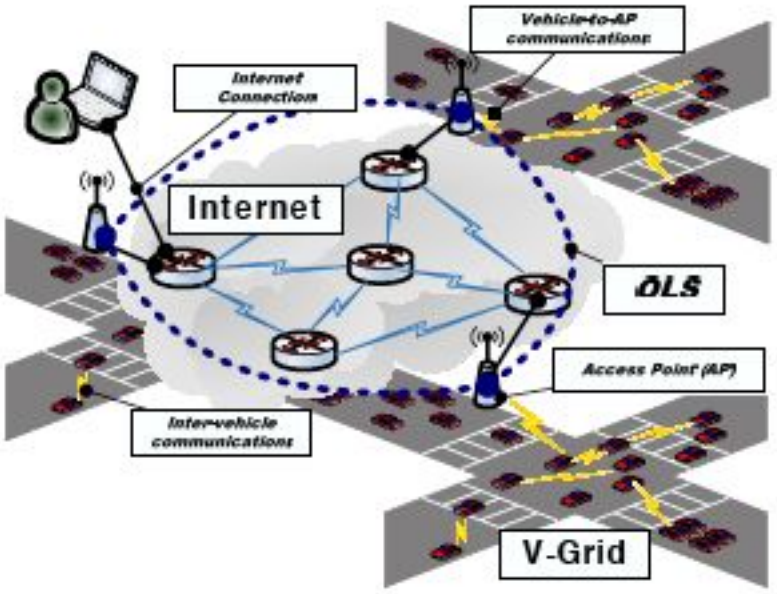
Routing in the Vehicle Grid

- Mostly "proximity routing"; some long range routing also present
- **Proactive routing** (eg OLSR)
  - Does not scale to hundreds of 1,000's
- **On Demand routing** (eg AODV)
  - AODV type flood search too costly
- Enter **geo-routing**
  - Most scalable (no state needed in routers)
  - GPS available; local coordinates used in blind areas (tunnels, parking lots, urban canyons)
  - Geo Location Service: distributed implementation

GLS (Geo Location Service)

- Equivalent to DNS to find geo addresses
- Maps vehicle ID (driver, VIN, license plate, etc) to the (more or less) current location
- A minimum of location history helps (say, location at T-1min and T- 2min)
- Distributed implementation
- For resilience, dual implementation:
  - In the urban Internet infrastructure
  - In the wireless Vehicle Grid (to survive Infrastructure collapse)

Infrastructure based GLS: Overlay Location Service (OLS)

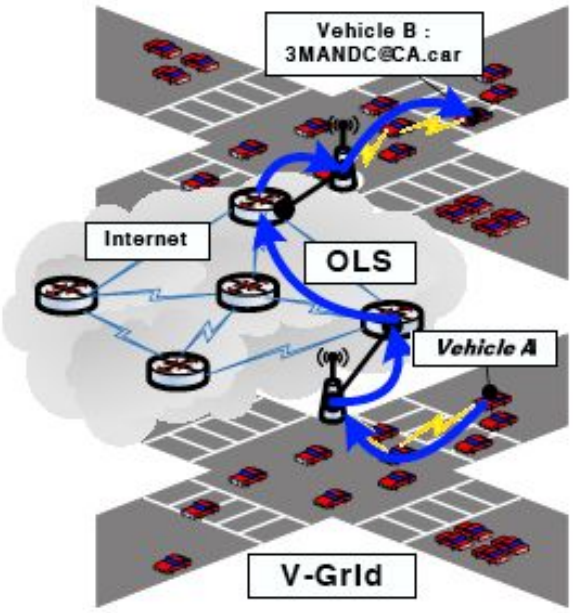


Vehicular ID hashed into overlay proxies (like Chord P2P overlay)

Mapping: Vehicular ID <=> location

Georouting through the infrastructure

- IPv6 addressing (xy coordinates in header extension)

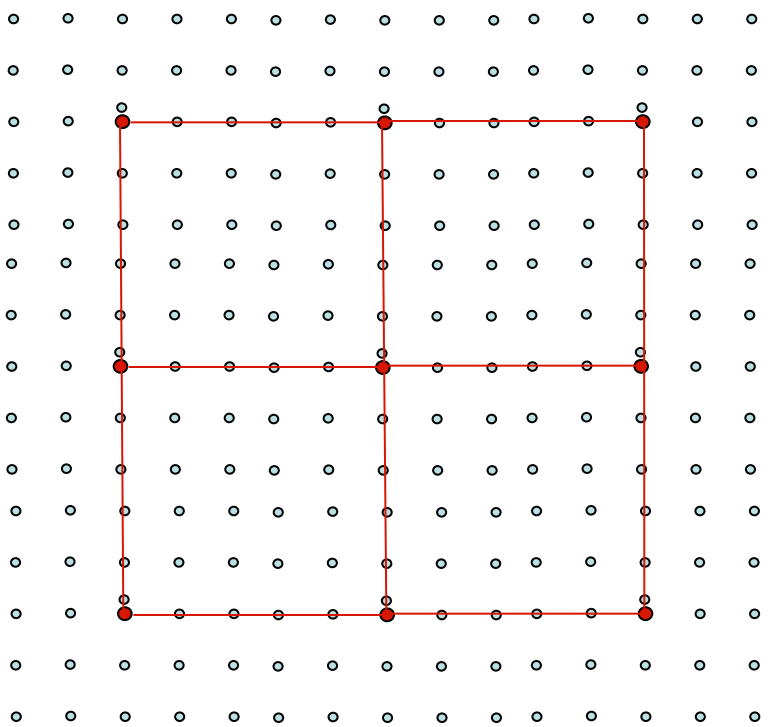


- How to make the system resilient to failures/attacks?
  - If access points fail, use GLS implemented in grid

Grid vs Infrastructure routing

- The trade offs: grid short paths vs fast wires
- Baseline: Shortest path routing
  - Short connections should go grid
  - Packets to remote destinations on infrastructure
- Next step: Access Points and Overlay assist in the decision
  - Propagation of congestion info from Overlay to wireless using 3 hop beaconing (say) every second

Simulation Experiments



Wired link

Car

AP

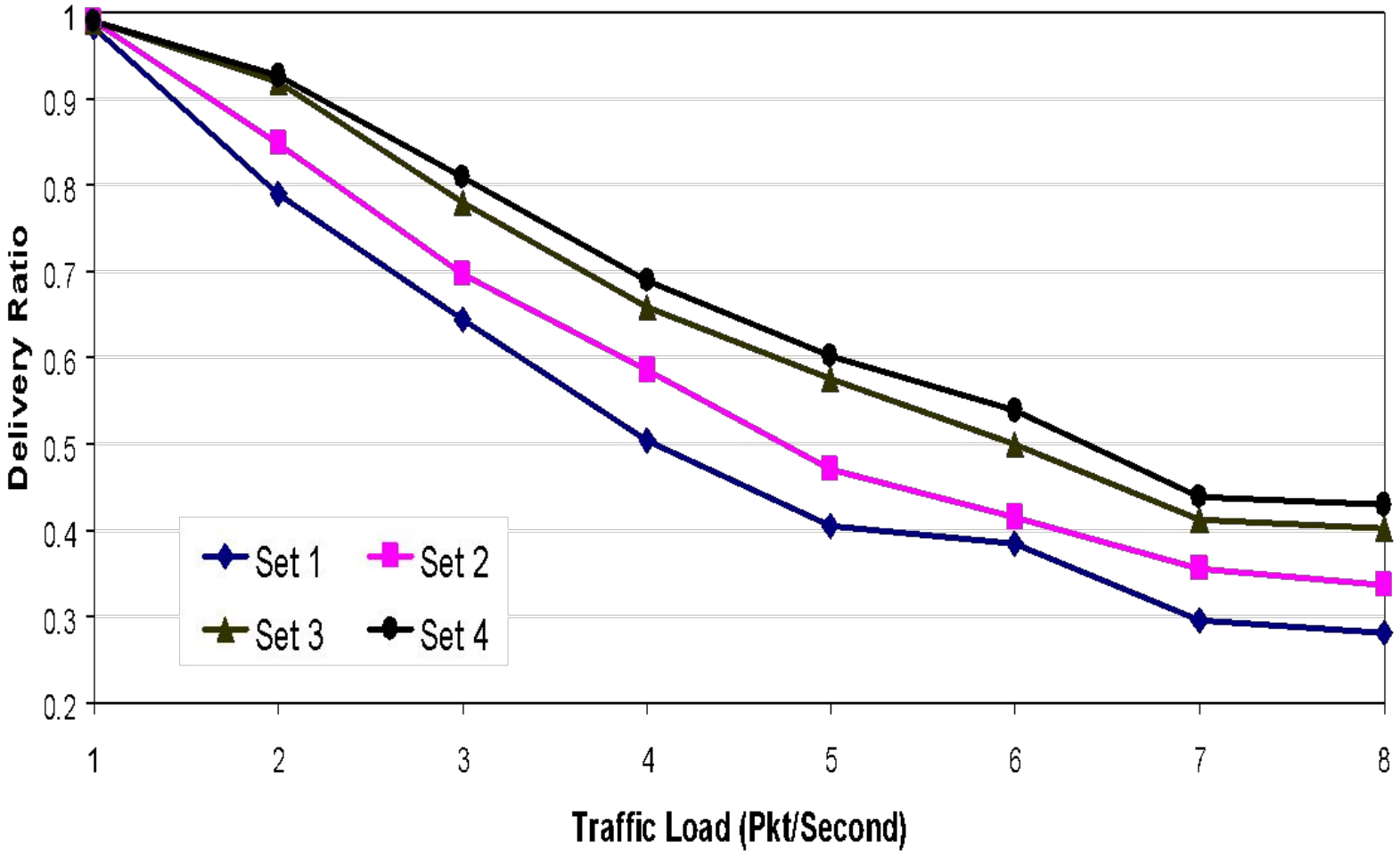
Traffic pattern

- Car to access point:
  - APT fraction of traffic (APT = 50%, 75%, 90%)
- Car to Car:
  - 1- APT Traffic fraction
- Source/destination pair distance
  - Say, 40% of pairs < 300 m away
  - 30% < 1km
  - 30% < 10 km
- Total # of sessions:
    - 200 UDP sessions with variable offered rate

Four routing strategies

- Set #1: all C2C connections are grid routed
- Set #2: all C2C connections are routed to the nearest AP's
- Set #3 - shortest geo-distance routing
- Set #4 - same as #3, but now use also the load info advertised by AP's

(APT = 25%, Total 200 CBR pairs)



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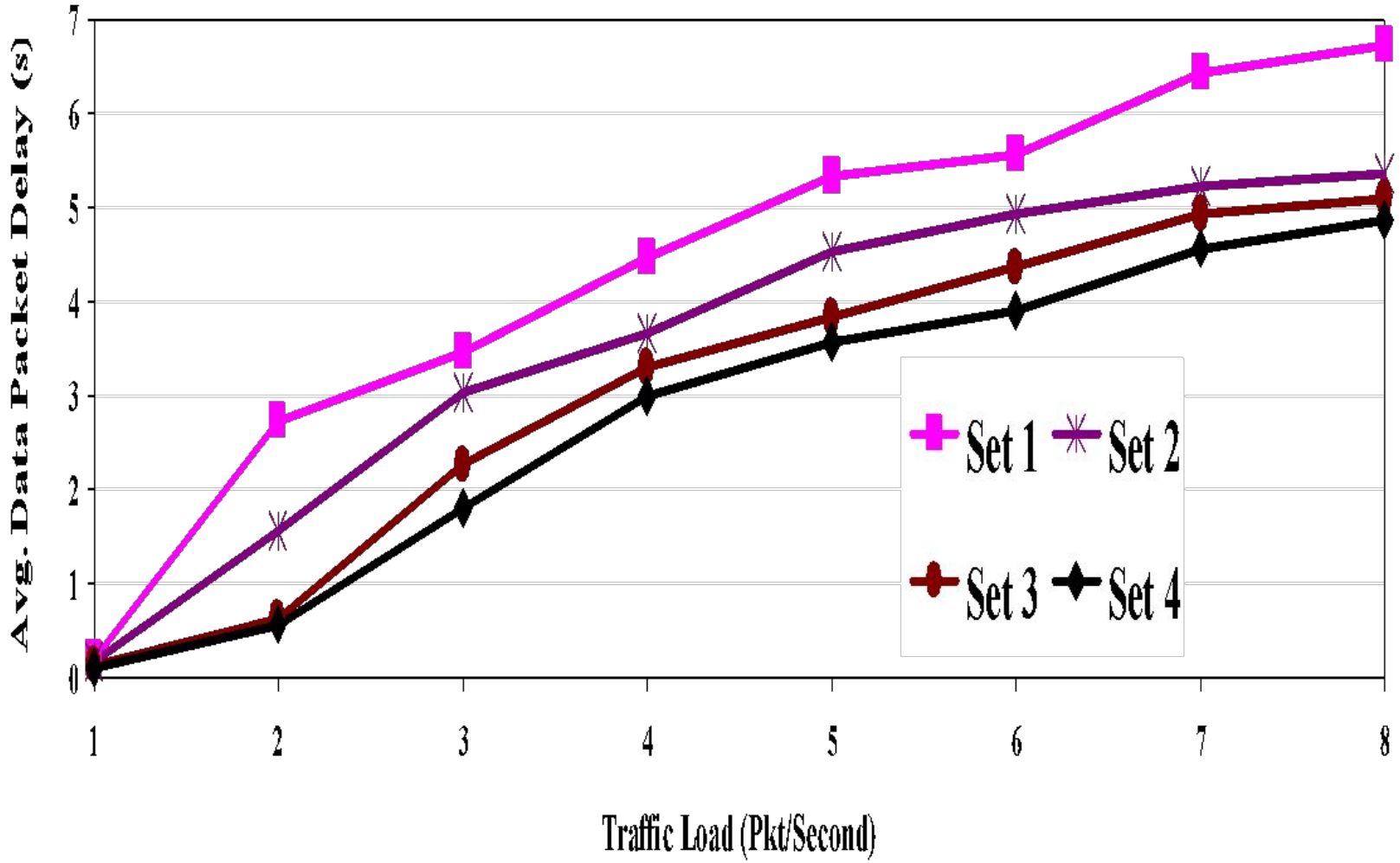
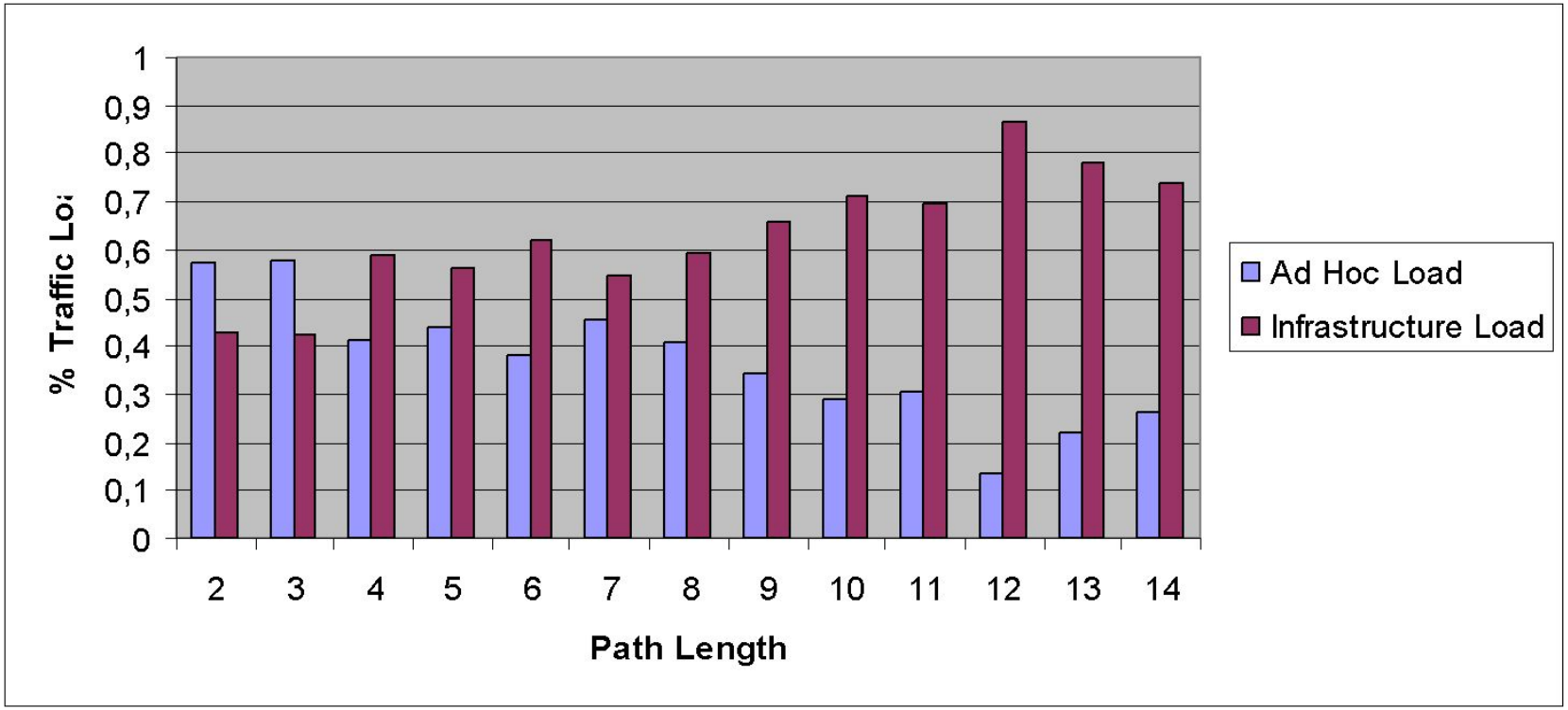


Wireless grid vs infrastructure load split as a function of path length



Summary

- Transparent Geo routing across Infrastructure
- Grid Efficient Grid/Infrastructure load balancing
  - Simulation (Qualnet)
  - Analytic, multicommodity flow optimization
- Seamless switch from "Infrastructure assist" to "grid only" mode in case of disaster/attack
- The "role" of the Internet
  - Geo Location Service Support
  - Load balance
  - V-Grid Congestion control
- Future work: Authentication; security; DoS protection

The case for geo-address

- IP address exacts very high maintenance cost
  - vehicles switch rapidly across different radio media (WiFI, WiMAX, 3G, Satellite, etc), changing IP address each time
  - Conventional Mobile IP and DHCP do not scale well to velocity; must re-register each IP address change
  - May group vehicles in mobile IP subnets - problems with merge/split

Geo Addressing

- Geo address is less disruptive:
  - Independent of radio medium
  - More predictable (motion prediction)
  - GPS is getting cheaper; efficient interpolation in GPS-blind spots (tunnels, urban canyons)