CarTel: A Distributed Mobile Sensor Computing System

Bret Hull, Vladimir Bychkovsky, Yang Zhang, Kevin Chen, Michel Goraczko,Allen Miu, Eugene Shih, Hari Balakrishnan and Samuel Madden- at the 12th ACM
MOBICOM Conf., Los Angeles, CA, September 2006

But before we start…

- Categories of Sensor Networks
  - Static
  - Mobile

Mobile Sensor Networks

- Motivation
  - Need to sense the environment at much finer fidelity and higher scale.
- Technology push
- Application pull

Applications

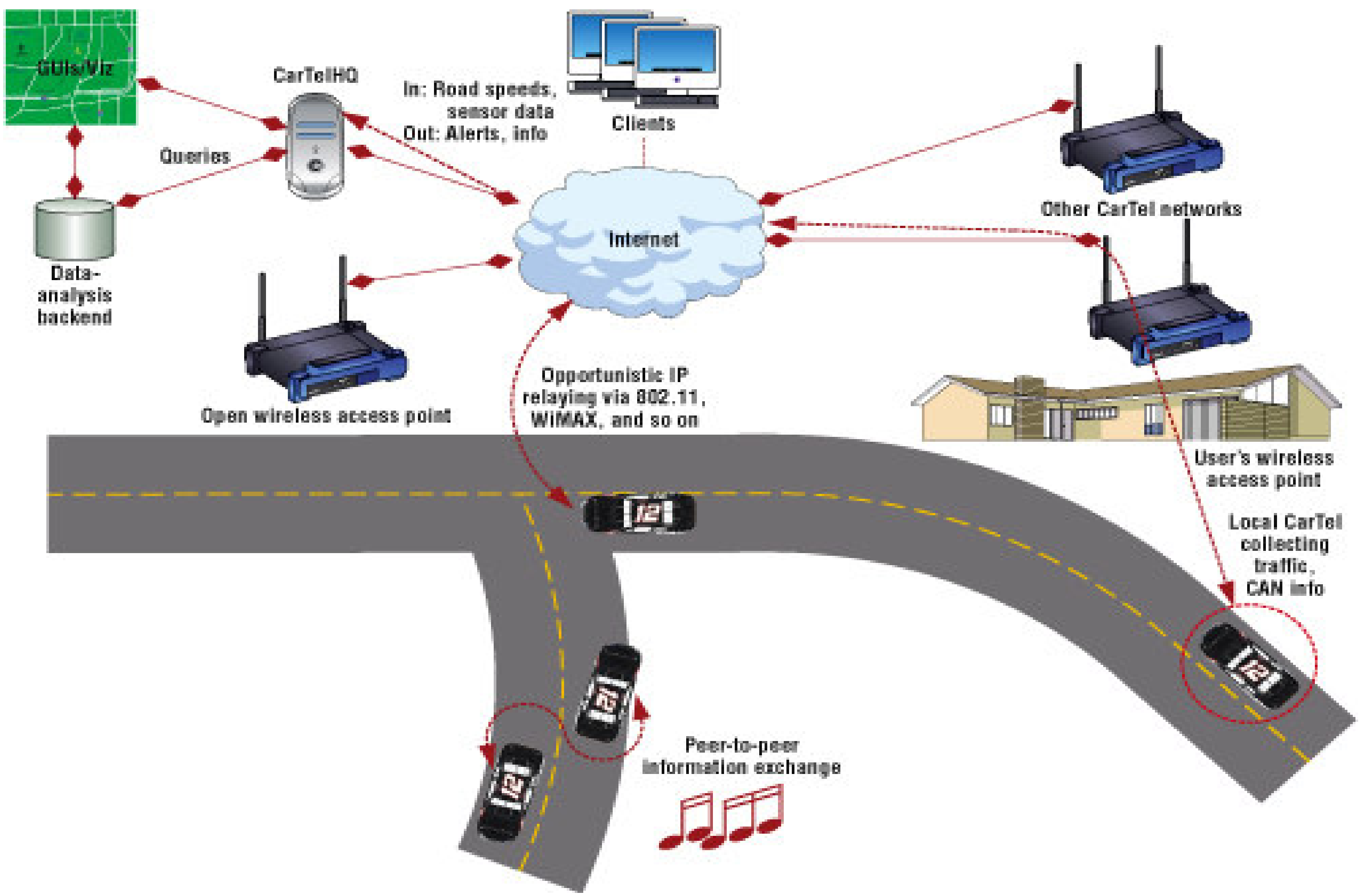
- Traffic Monitoring
- Environmental monitoring
- Civil infrastructure monitoring
- Automotive diagnostics
- Geo-imaging
- Data muling

What does CarTel offer?

- a mobile sensor computing system
  - to collect, process, deliver, and visualize data from a collection of remote, mobile, and intermittently connected nodes.

  - Provides a reusable software platform to build mobile sensing applications.

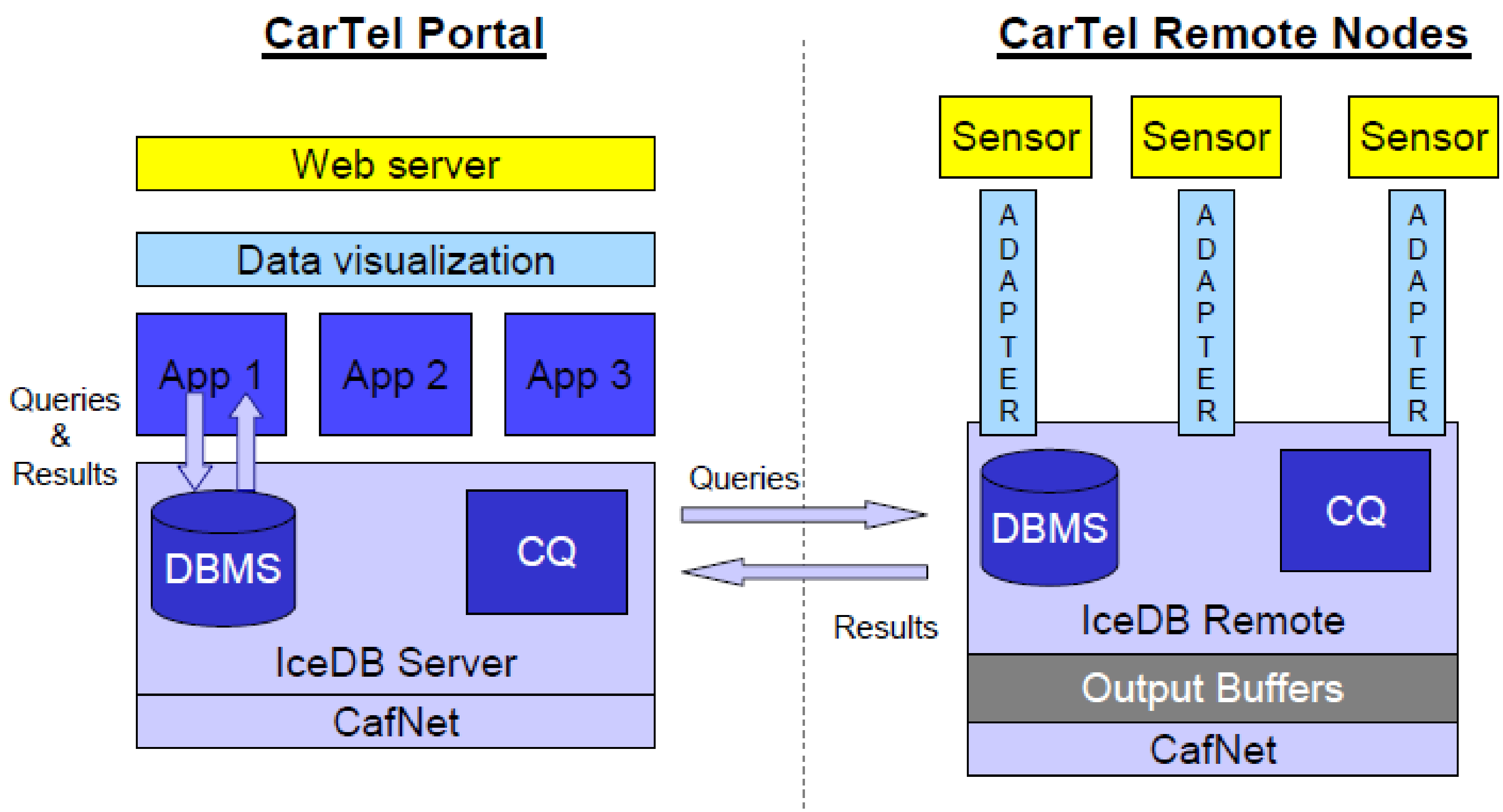
CarTel System Architecture



Design Goals

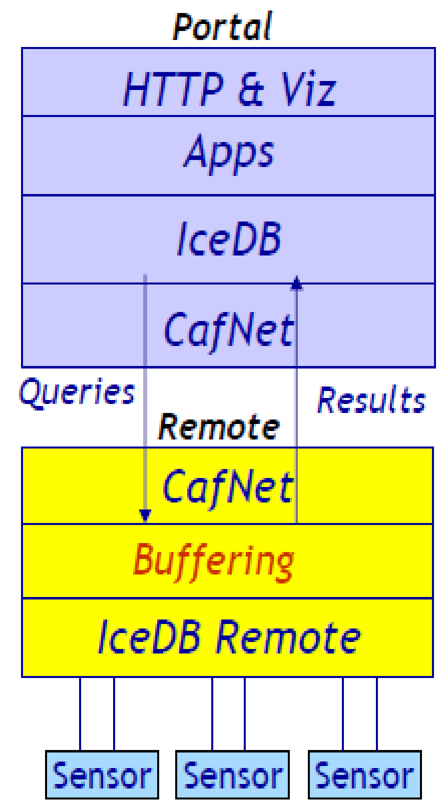
- Provide a simple programming interface
- Handle large amounts of heterogeneous sensor data
- Handle intermittent connectivity

CarTel Software Architecture



CarTel Components

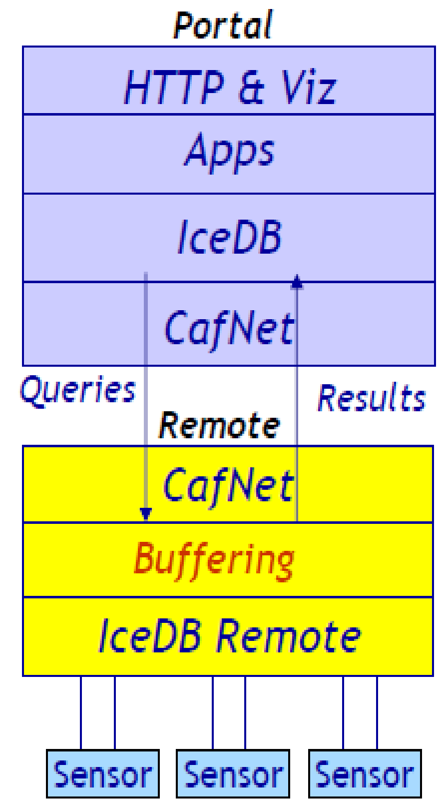
- Portal
  - Centralized
  - Visual user interface
- ICEDB
  - Delay-tolerant query processing
- CafNet
  - Delay-tolerant network stack



IceDB (Intermittently connected DB)

- Centralized declarative queries
  - Executed in distributed fashion by mobile nodes

- IceDB server and IceDB remote



IceDB (Intermittently connected DB)

- **Data Model**
  - Handle large amounts of heterogeneous data
  - Solution : Meta-data package describing attributes of sensor called *adapter*
  - Create local tables for sensor readings
  - Acquire tuples from sensor
  - Parse sensor readings

IceDB (Intermittently connected DB)

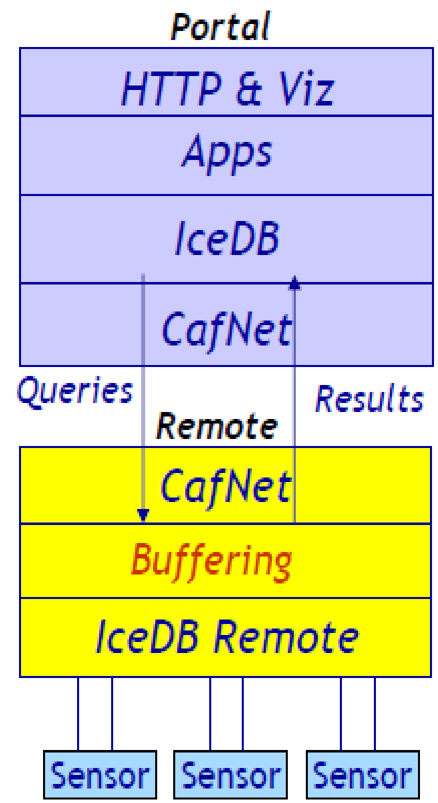
- **Continuous Query Model**
  - SQL Extensions for
    - Continuous Queries using the *rate* clause

```
SELECT carid,traceid,time,location FROM gps
 WHERE gps.time BETWEEN now()-1 mins AND now()
 RATE 5 mins
```

- Handling Intermittent Connectivity
  - Using Prioritization (Local and Global)

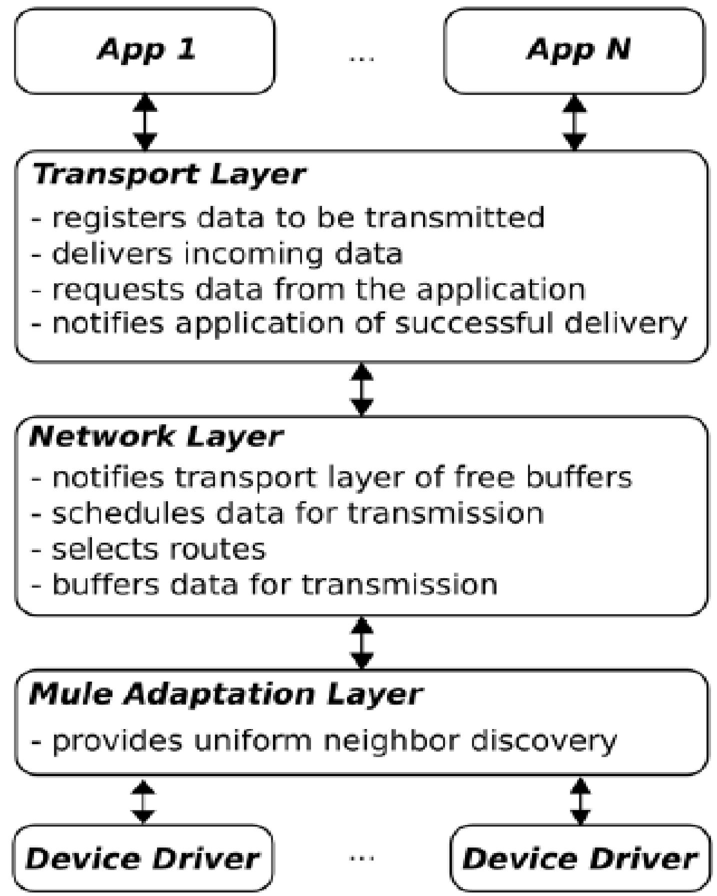
Contd…

- Local Prioritization
  - PRORITY
  - DELIVERY ORDER
  - User-defined function
- Global Prioritization
  - SUMMARIZE AS



CafNet: Delay-Tolerant Network Stack

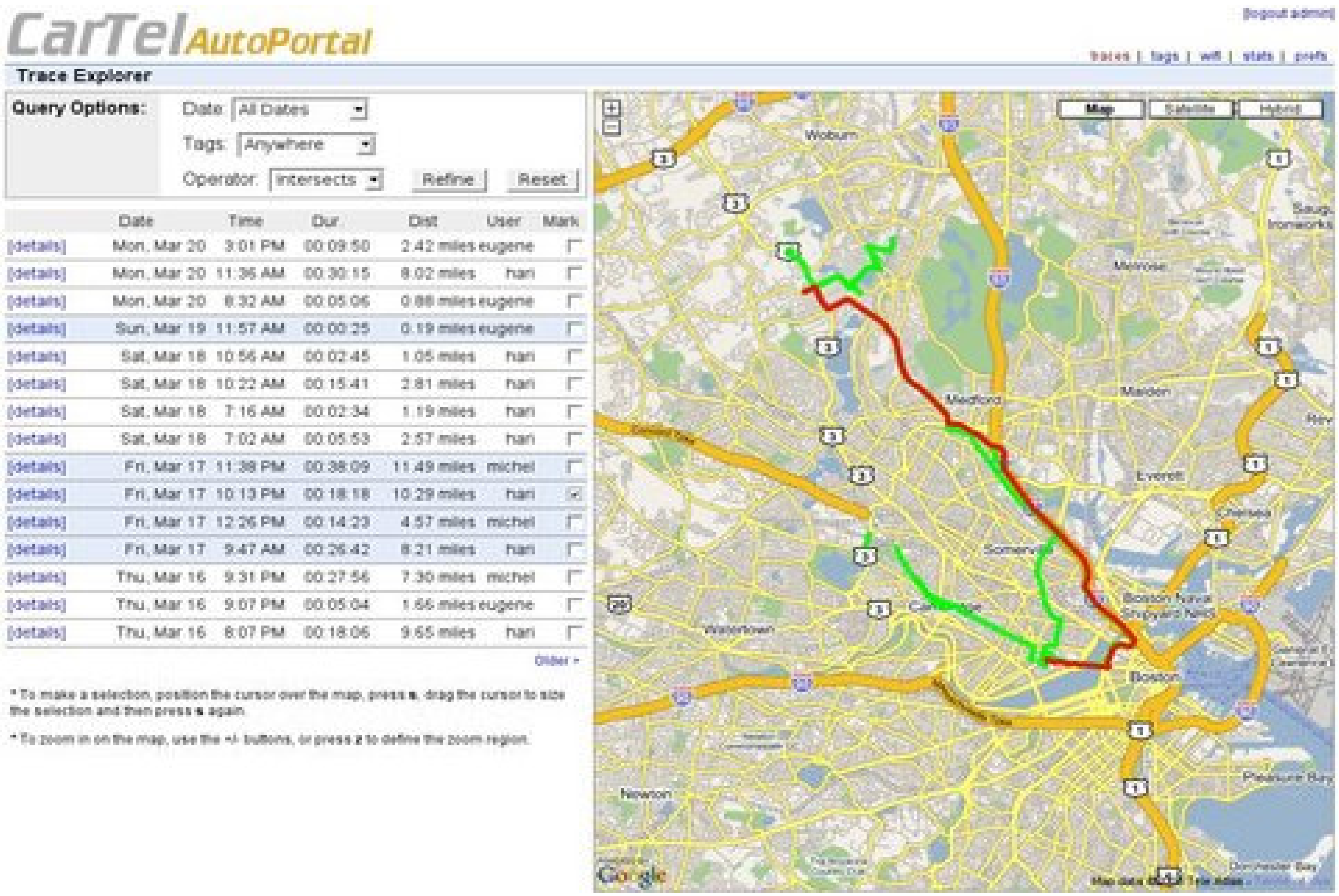
- CTL
  - Callback mechanism for dynamic prioritization
- CNL
  - Routing (best effort)
- MAL
  - Media-independent interface
  - Two types of callbacks



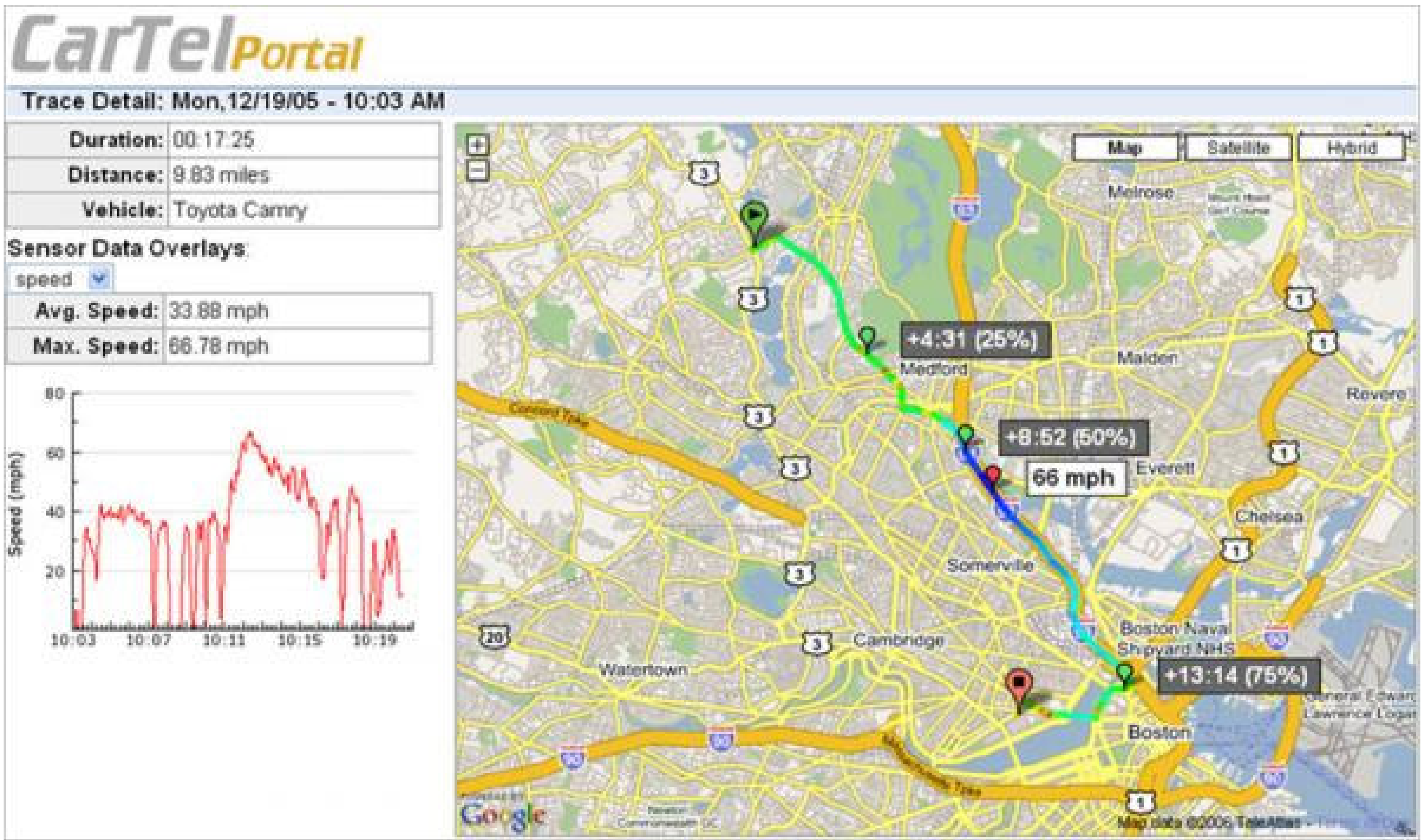
Portal

- Portal Framework
  - To build CarTel Applications
  - Navigate sensor data using web-based application
- IceDB
- Data visualization interface
  - *Trace* – data segmentation abstraction
  - For searching traces using spatial queries
  - Overlaying geographical attributes on a map

Spatial Queries



Overlaying geographic attributes



Case Study: Road Traffic Analysis

- For data collection,
  - Continuous query
  - GPS adapter
- Commute time analysis
  - Observe speed and delay for the particular trace

Route	Avg. Dist	Avg. Time	Std – dev
Freeway	9.94 miles	19:52	02:14
City Streets	9.83 miles	29:34	02:19
Frontage Road	9.27 miles	31:51	03:54

Case Study : Road Traffic Analysis

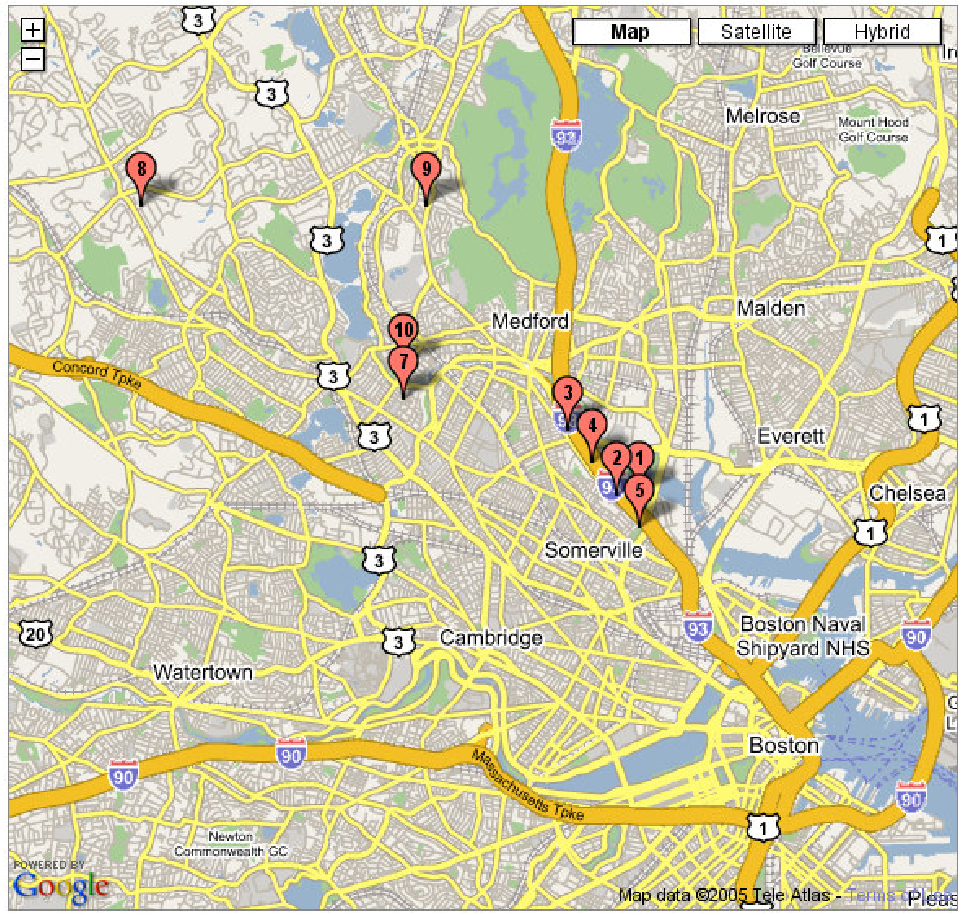
Traffic Hotspots

Start: 7 am End: 10 am Grid: .005

Update

Rank	Avg MPH	Std-dev	Count
1	25.3 mph	26.7 mph	176
2	29.3 mph	24.6 mph	315
3	33.0 mph	22.8 mph	267
4	39.4 mph	22.5 mph	245
5	16.0 mph	18.0 mph	729
6	32.9 mph	17.5 mph	187
7	20.4 mph	17.1 mph	635
8	34.2 mph	16.2 mph	53
9	17.9 mph	15.9 mph	365
10	17.2 mph	15.3 mph	313

* To zoom in on the map, use the +/- buttons, or position the cursor over the map and press **z** to define the zoom region and **x** to zoom out.



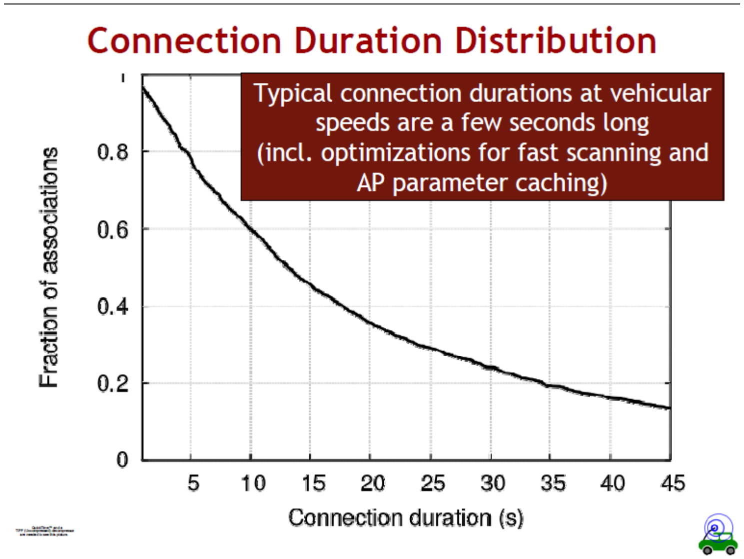
Case Study : Wide-area Wi-Fi Measurements

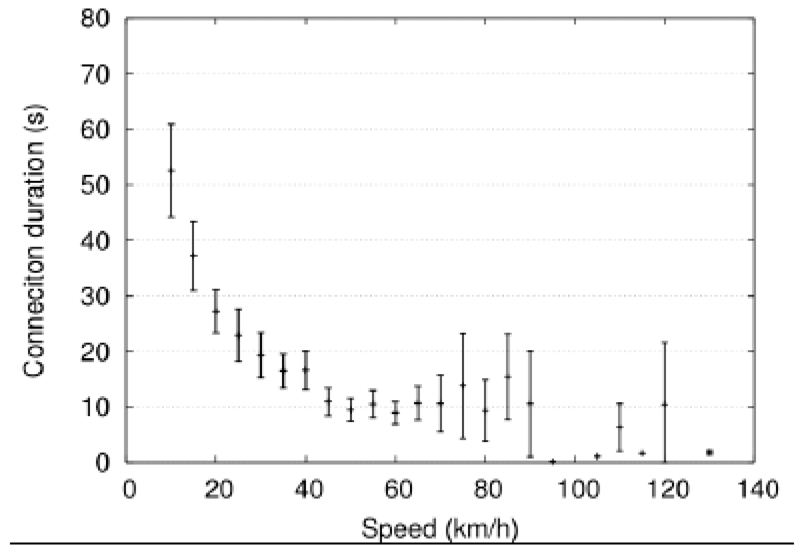
- Experimental Setup
  - 6 cars equipped with CarTel box and software
  - Driving normally in parts of the Boston area
  - ~300 drive hours
- Fast scanning of WiFi access points, caching of AP parameters to speed up connection establishment
- Careful (small and unobtrusive) TCP data transfers to measure throughput, latency, loss rates
- Track performance statistics: connection durations, throughput distributions, etc

Wide-area Wi-Fi Measurements

- Results:
  - Total Number of AP’s discovered – 32k
  - Total Number of associations – 5k
  - Mean Association Duration – 25s
  - Mean time between connection to Internet – 260s
  - Median Upload Throughput – 30KBytes/s

Wide-area Wi-Fi Measurement





Pros and Cons

- Framework for building mobile applications
- Provision of simple programming interface
- Dynamic Proritization
- Opportunistic Connectivity options
- Visual interface to specify visual queries

Relevance to SOS Project