CPS An Example Application: ITS

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IIT HYDERABAD

CONTENTS

Motivation

- Traffic delays and congestion are a major source of inefficiency, wasted fuel, and commuter frustration.
- Proliferation of commodity smartphones that can provide location estimates using a variety of sensors—GPS, WiFi, and/or cellular triangulation.
- Cheap embedded h/w systems with GPS units

Characteristics of Indian Cities

- Rapid industrialization
- Large population expansion
- Un-planned land use
- Growing traffic, esp 4-wheelers
- Mixed and erratic traffic
- Poor traffic sense and disrespect for traffic rules
- Inadequate public transport systems

Effects of Traffic Congestion

- High pollution levels
- More road accidents
- Increased travel times, loss of productivity
- Fuel wastage due to traffic jams
- Increase in vehicular wear and tear
- Negative impact on mental health of commuters

Solution 1: Supply strategies

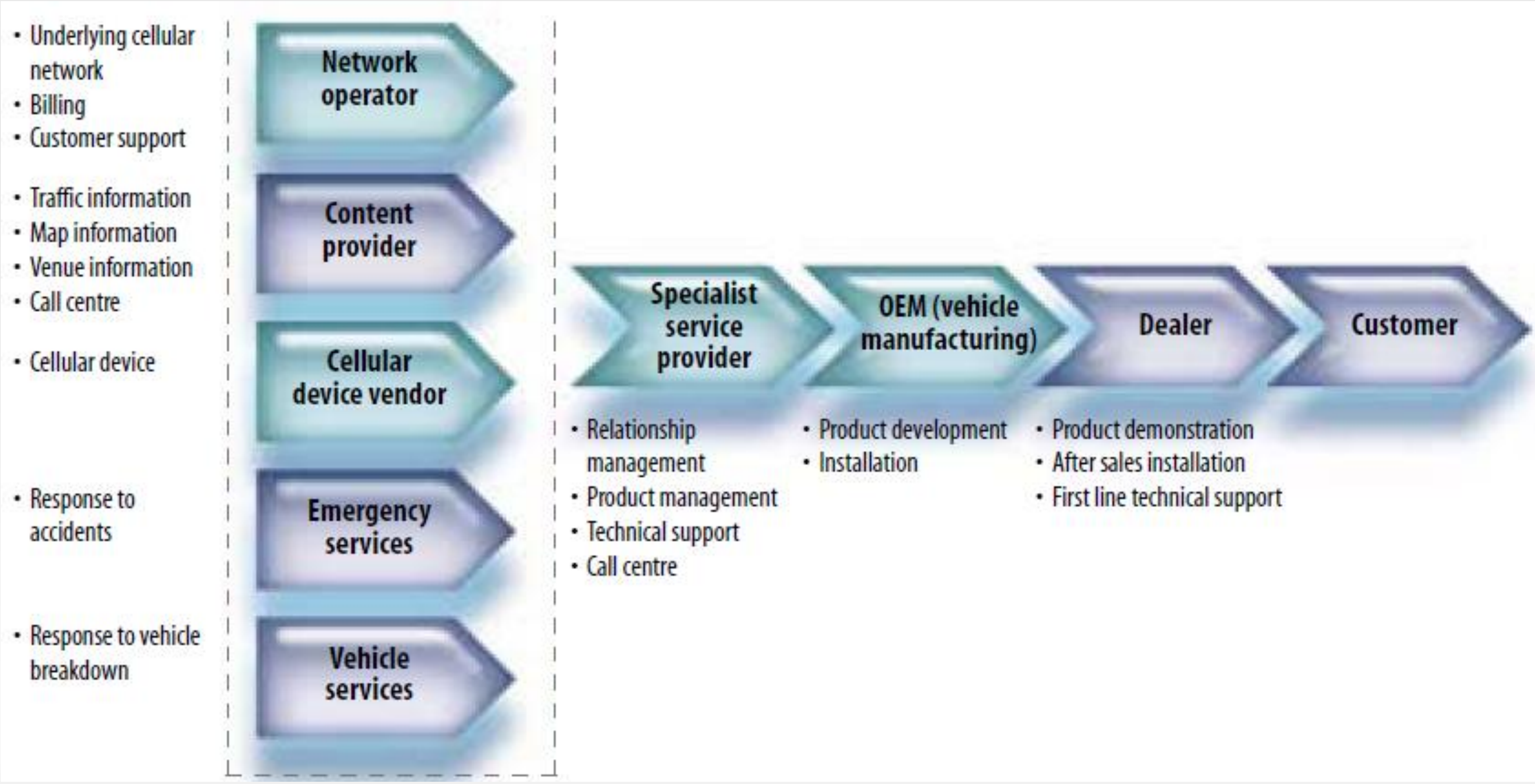
- Creating new transport infrastructure and expanding existing, e.g., new road, new buses, metro, adding lanes, etc
- Capability and efficiency improvements of existing facilities, e.g., cameras

Solution 2: Demand strategies

- Road pricing
- Parking charges in city centers
- Incentives for car pooling
- Improved public transport facilities
- Improvements of Bicycle and pedestrian paths
- Staggered work hours

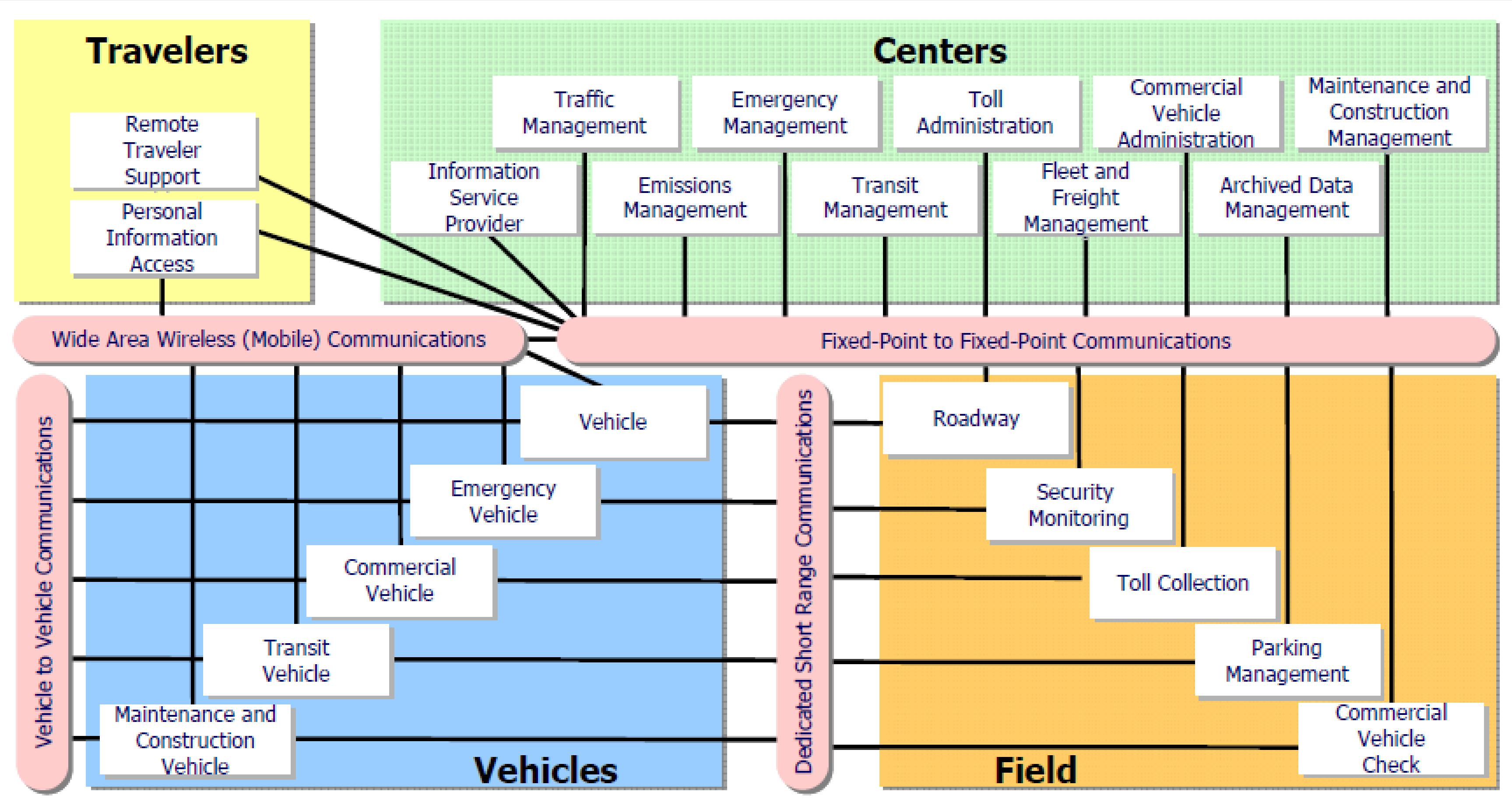
ITS brings in innovative, low-cost, and technology-driven solutions to increase the capacity and efficiency of transport facilities

ITS: Value Chain



Source: Deloitte Research

ITS Architecture



Source: USA National ITS Architecture

ITS Services

- 1. Travel and Traffic Management
  - 1.1 Pre-Trip Travel Information
  - 1.2 En-Route Driver Information
  - 1.3 Route Guidance
  - 1.4 Ride Matching and Reservation
  - 1.5 Traveler Services Information
  - 1.6 Traffic Control
  - 1.7 Incident Management
  - 1.8 Travel Demand Management
  - 1.9 Emissions Testing and Mitigation
  - 1.10 Highway-Rail Intersection
- 2. Public Transportation Management
  - 2.1 Public Transportation Management
  - 2.2 En-route Transit Information
  - 2.3 Personalized Public Transit
  - 2.4 Public Travel Security
- 3. Electronic Payment
  - 3.1 Electronic Payment Services
- 4. Commercial Vehicle Operations
  - 4.1 Commercial Vehicle Electronic Clearance
  - 4.2 Automated Roadside Safety Inspection
  - 4.3 On-Board Safety and Security Monitoring
  - 4.4 Commercial Vehicle Administrative Processes
  - 4.5 Hazardous Materials Security and Incident Response
  - 4.6 Freight Mobility
- 5. Emergency Management
  - 5.1 Emergency Notification and Personal Security
  - 5.2 Emergency Vehicle Management
  - 5.3 Disaster Response and Evacuation

ITS Services (Cntd …)

- 6. Advanced Vehicle Safety Systems
  - 6.1 Longitudinal Collision Avoidance
  - 6.2 Lateral Collision Avoidance
  - 6.3 Intersection Collision Avoidance
  - 6.4 Vision Enhancement for Crash Avoidance
  - 6.5 Safety Readiness
  - 6.6 Pre-Crash Restraint Deployment
  - 6.7 Automated Vehicle Operations
- 7. Information Management
  - 7.1 Archived Data
- 8. Maintenance and Construction Management
  - 8.1 Maintenance and Construction Operations

Probes for ITS

- Probe vehicles/humans
- GPS probes: Vehicles with mounted GPS
- Cellular probes: Mobile phones with GPS/A-GPS
  - Crowdsourcing: low cost
  - No mounting of GPS unit in vehicle
  - Large sample size
  - No hired vehicles or drivers!
  - GPS gives high accuracy compared to other location technologies in cellular networks

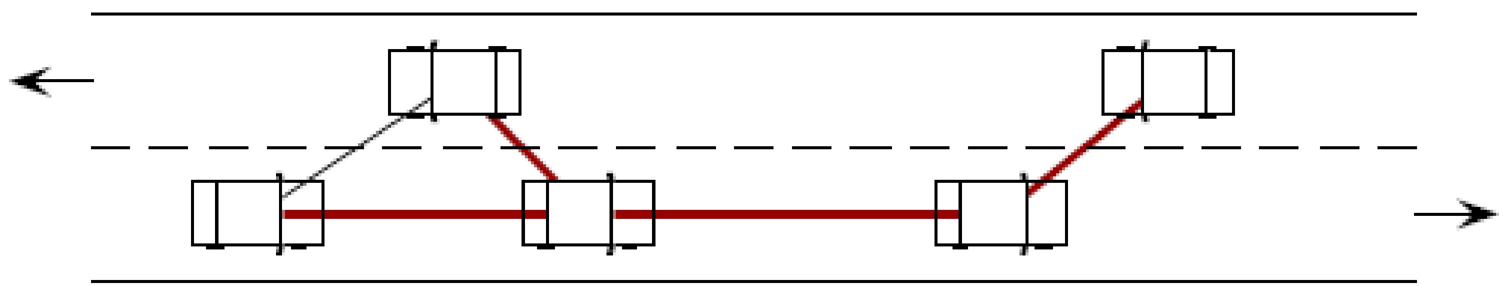
Vehicular Ad hoc Networks (VANETs)

VANET: Applications

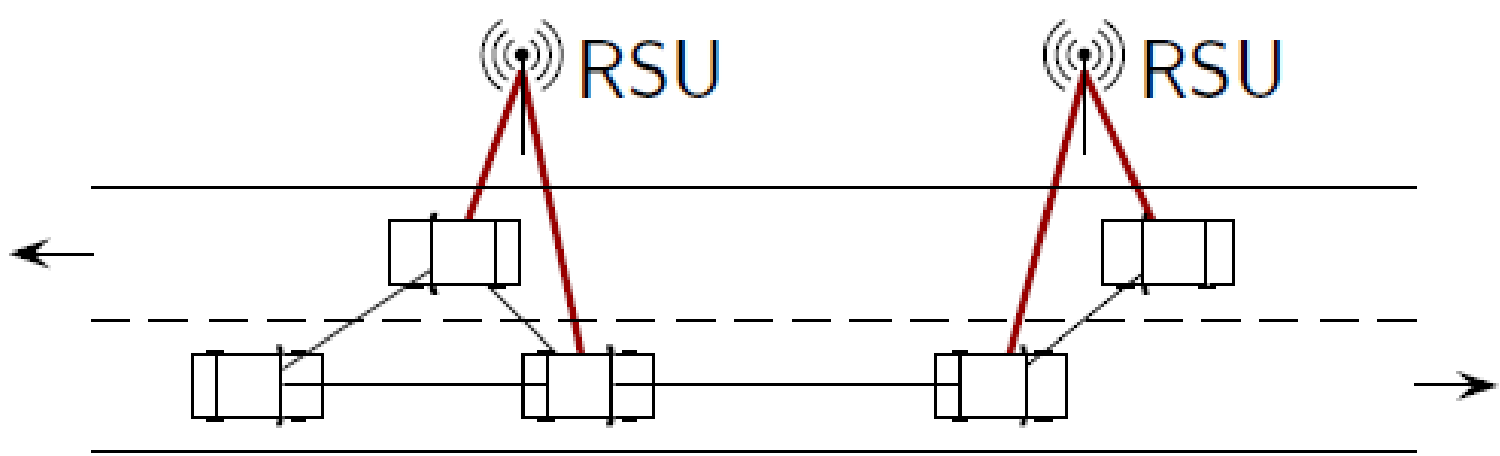
- Smart Routing, Real-time traffic updates, Road Safety alerts
- Toll collection, Congestion charging
- Collision Avoidance
- On-Road Internet, Entertainment like Network gaming

VANET: Communication Types

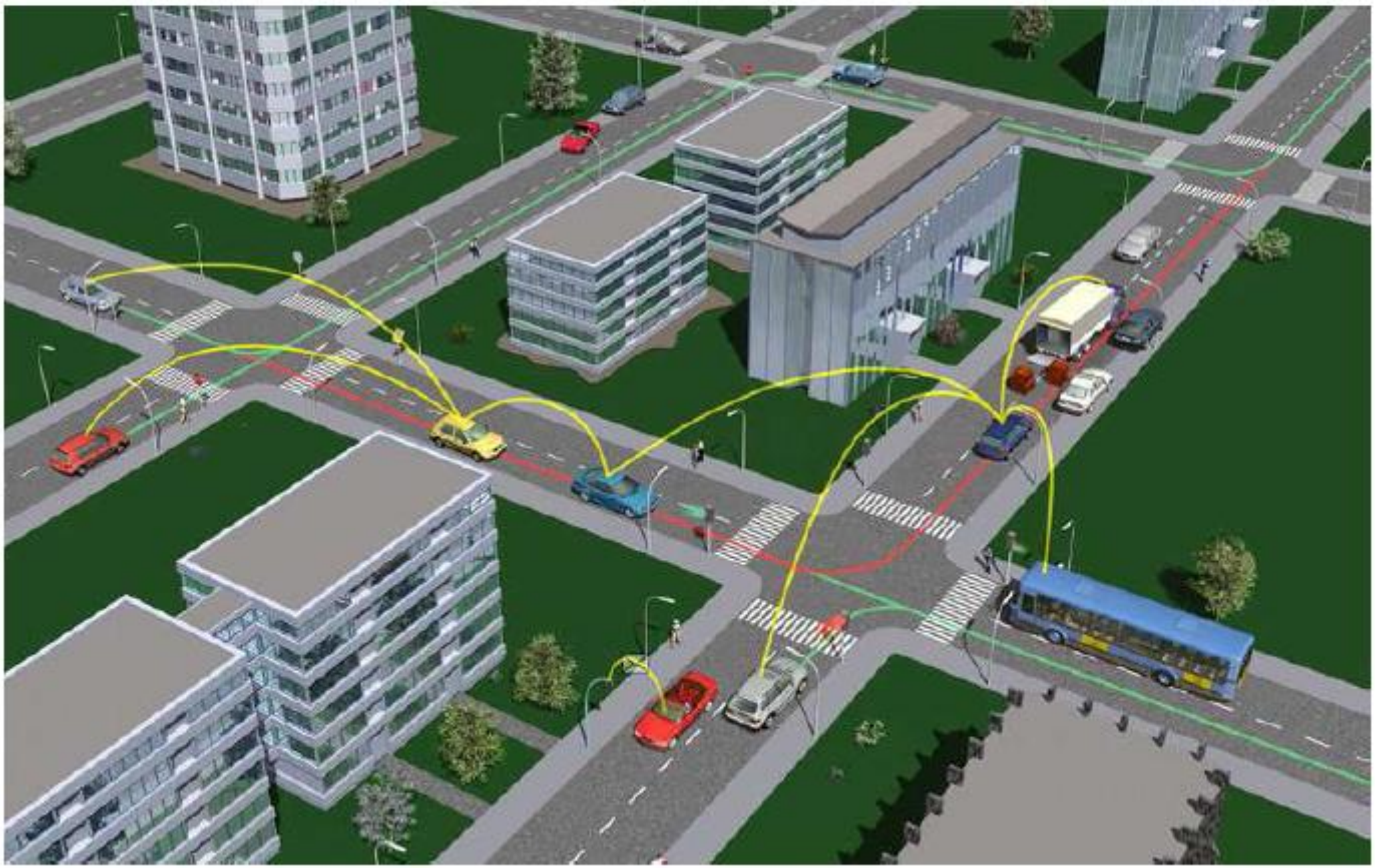
Vehicle-to-Vehicle (V2V)



Vehicle-to-Infrastructure (V2I)



Vision



[car-2-car.org]

Vision


SATELLITE COMMUNICATIONS
TERRESTRIAL BROADCAST
MOBILE
Intermodal Communications
Navigation
MAN
Vehicle-to-Vehicle
Safety Systems
Passenger Information
Travel Assistance
WLAN
Traffic Signs
FIRE
STOP
Adaptive Cruise Control
Trip Planning
Fleet Management
Toll Collection
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VANET: Challenges and Opportunities

- High mobility, Short range → Frequent Handoffs
- QoS for real-time and Value-added services

- Uni-directional and uniform movement of vehicles
- Fixed-order placement of RSUs
- Abundance energy source: vehicle’s battery pack!

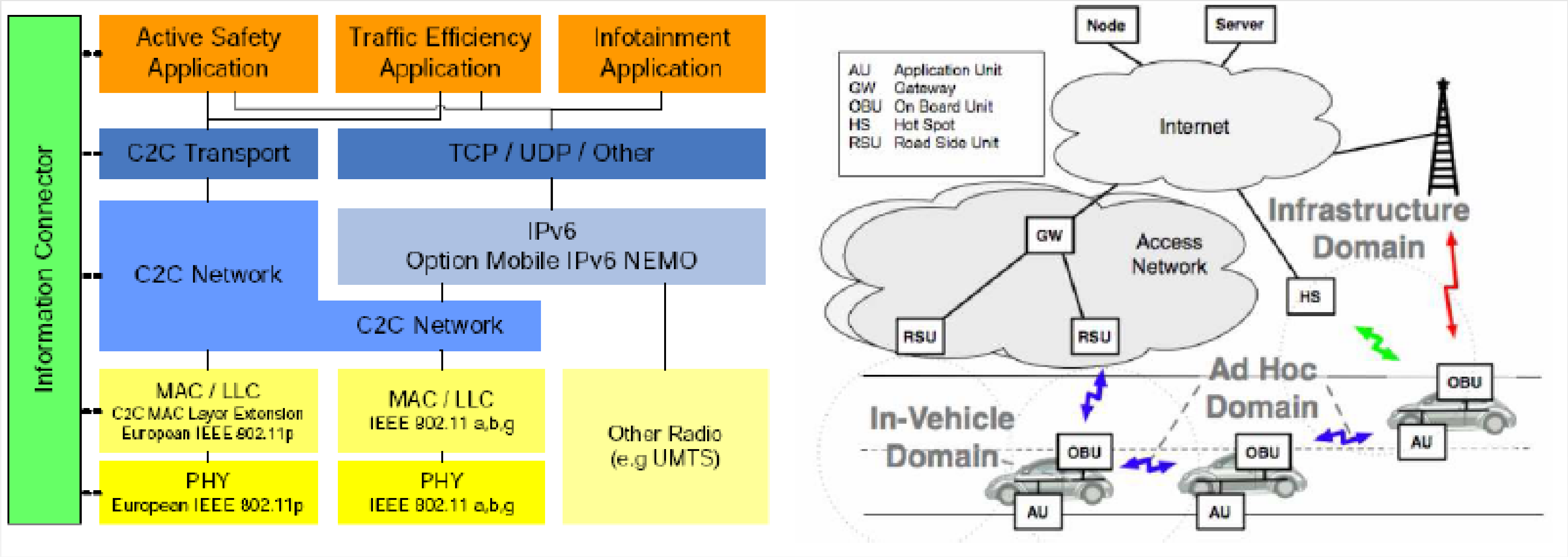
VANET Standards: PHY/MAC

- WAVE (IEEE 802.11p)
  - Dynamic Short Range Communication for V-2V and V-2-I
  - ITS Band: Licensed 75MHz BW at 5.9 GHz (U.S.), 5.8 GHz (Japan, Europe)
  - 300m range, 6-27 Mbps, Half-duplex
  - 7 channels of 10MHz each (1 dedicated control CH, 178)
  - No handoffs between RSUs
- 802.11n/4G Cellular ?
- Cognitive Radio Networks ?

VANET Standards: Network, Transport Layers

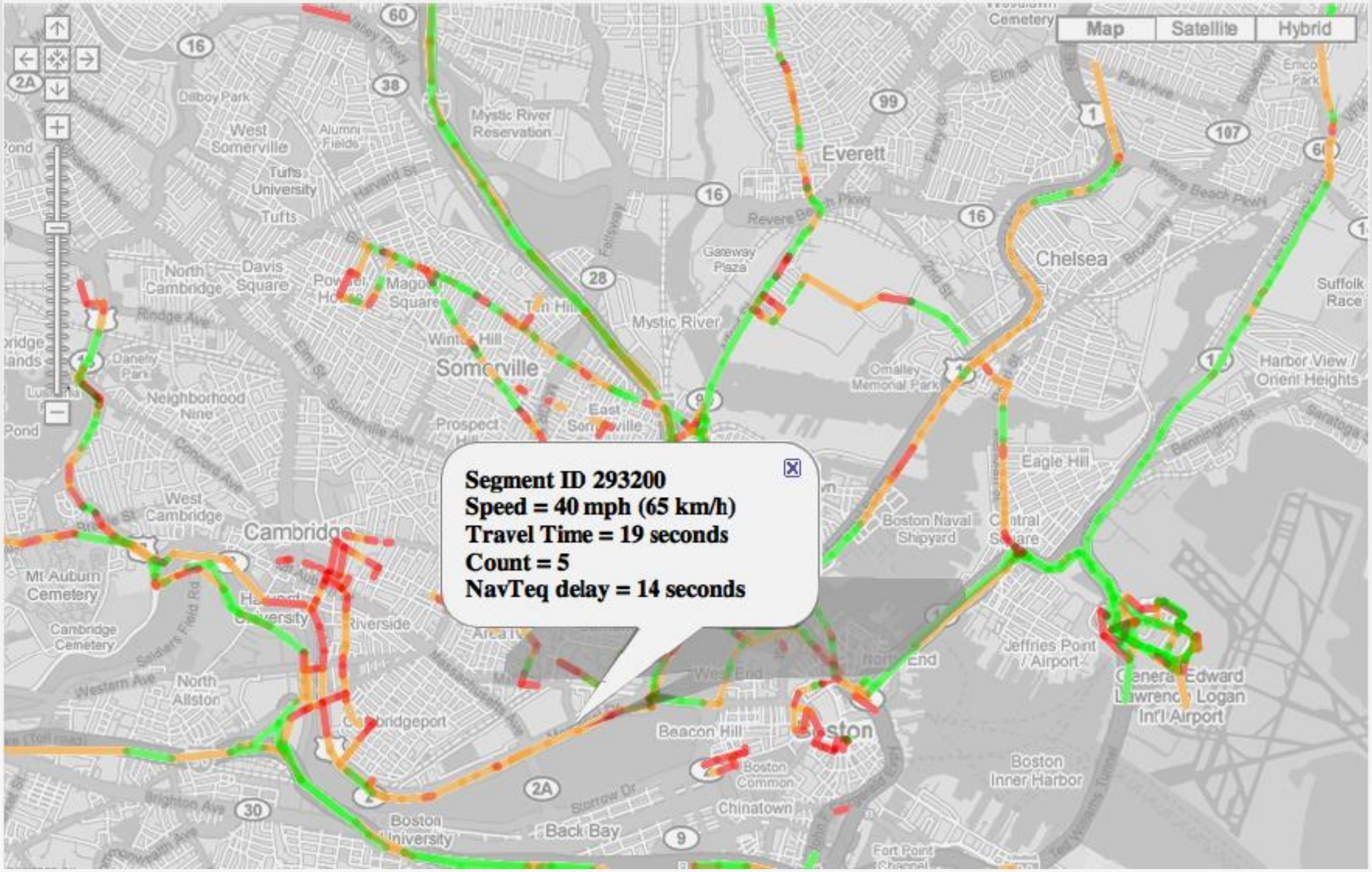
- VANET Routing Protocols
  - Broadcasting (geo-casting)
  - Routing
- Mobile IPv6
- NEMO
- TCP/UDP?

VANET Architecture



Source: Car-to-Car Consortium Manifesto

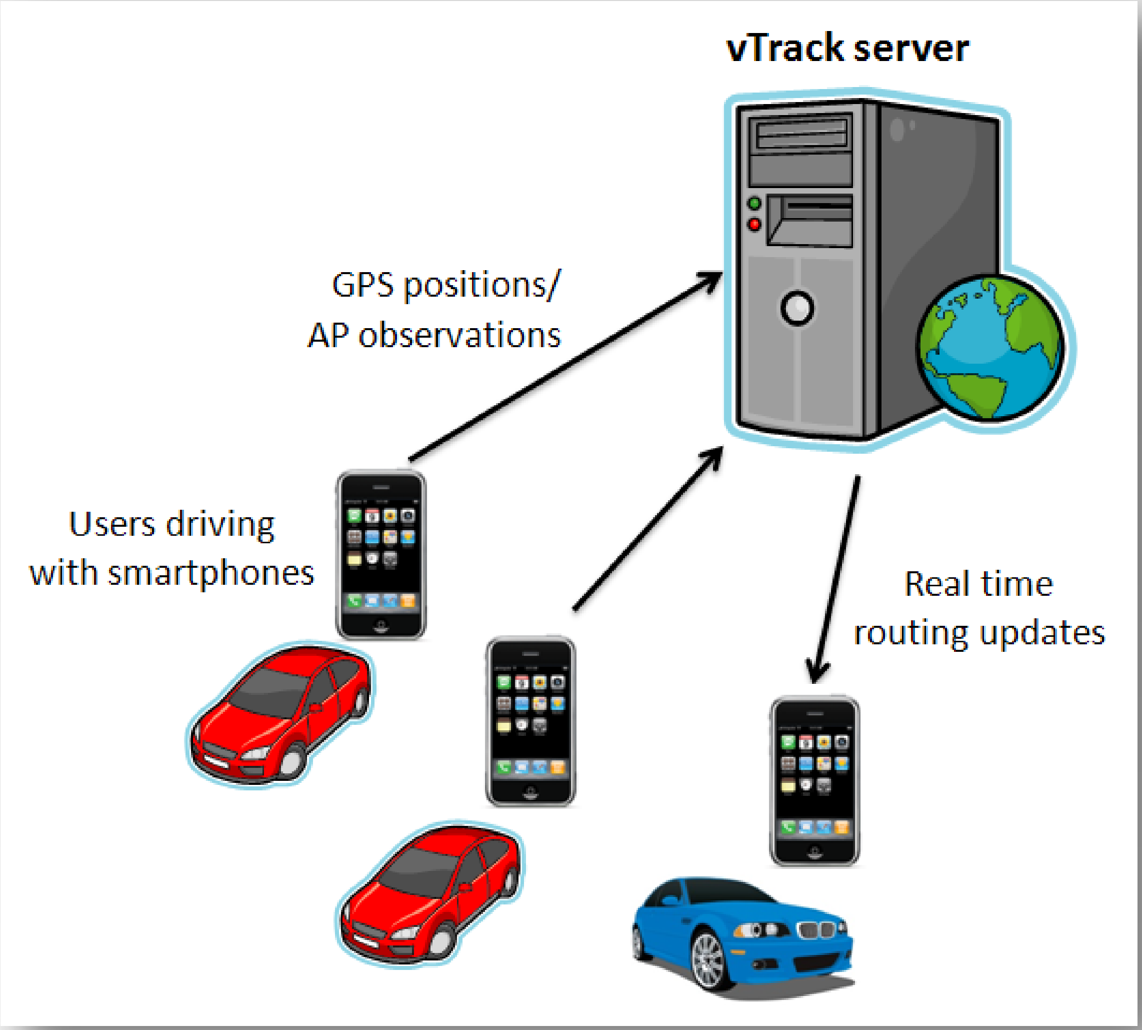
MIT vTrack : Accurate, Energy-aware Road Traffic Delay Estimation Using Mobile Phones



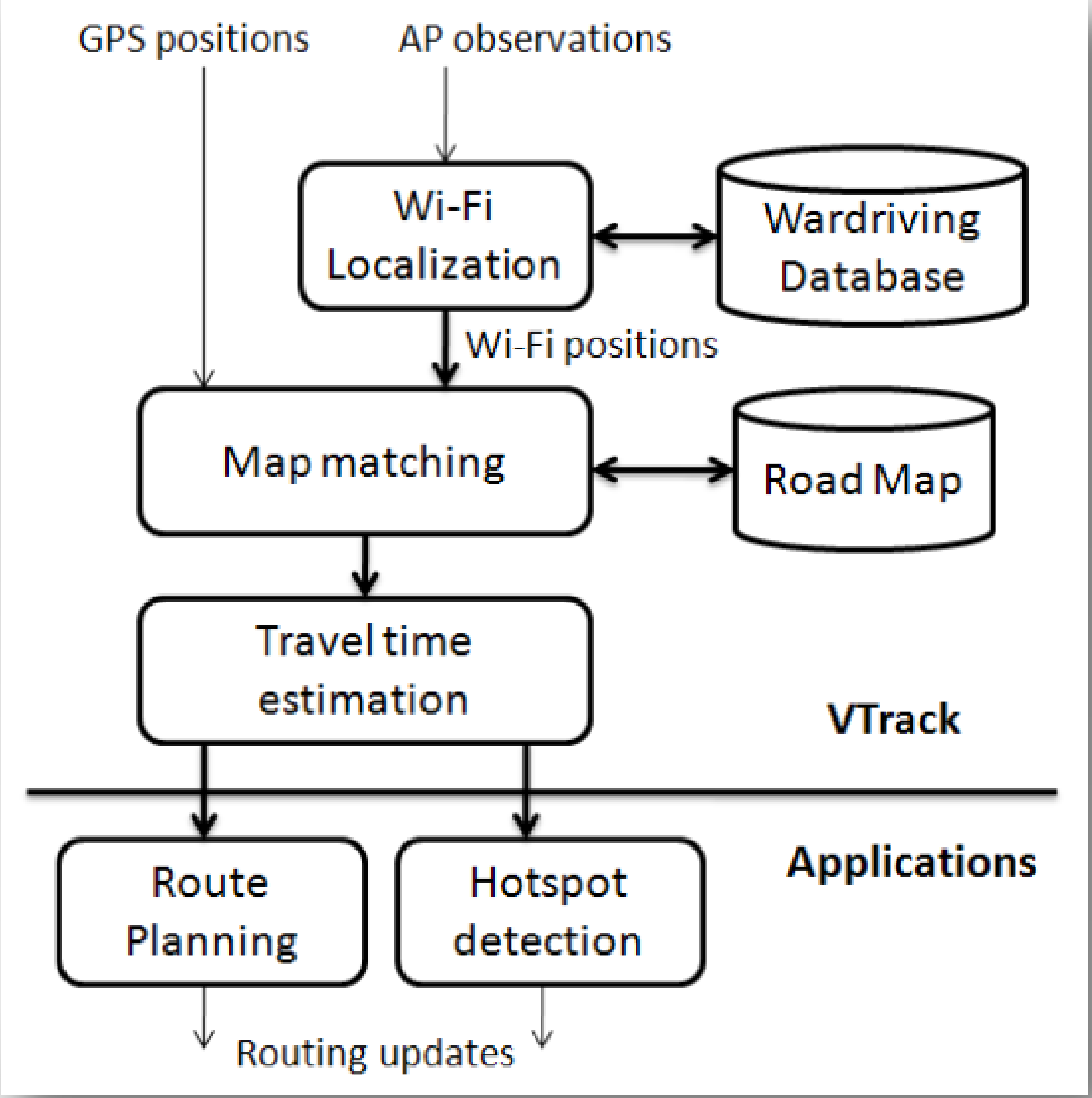
Salient Features of vTrack Project

- HMM-based map matching is robust to noise.
- Travel times from Wi-Fi localization alone are accurate enough for route planning, even though individual segment estimates are poor.
- Travel times estimated from Wi-Fi localization alone cannot detect hotspots accurately, due to the outages present in Wi-Fi data.
- When GPS is available and free of outliers, sampling GPS periodically to save energy is a viable strategy for both applications.

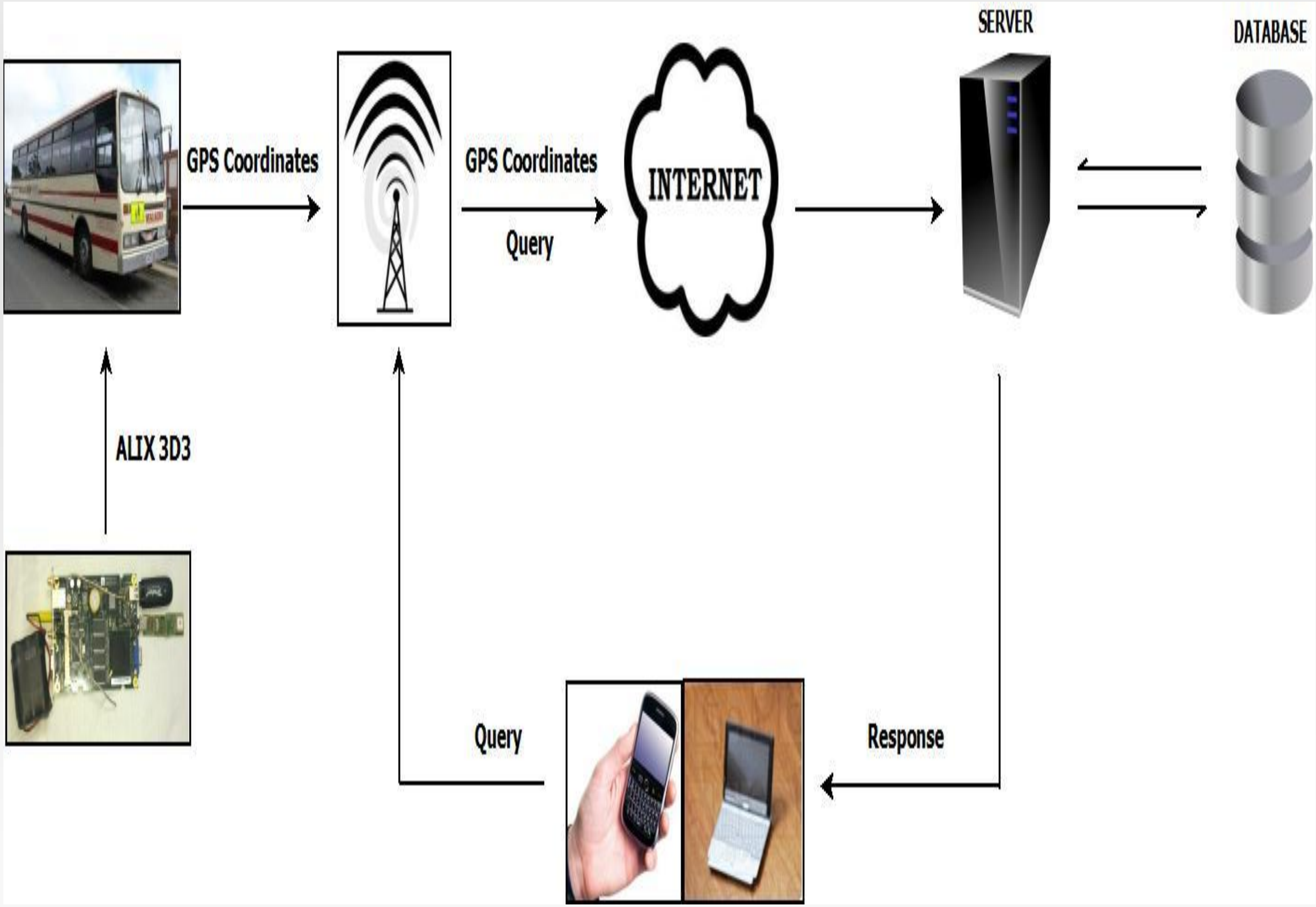
vTrack: Architecture



vTrack Server



ITS @ IITH: Smart Public Transport Notification System



Architecture of SPTNS

ITS: SPTNS System

- The total work can be subdivided into SIX modules:
  - Tracking buses in real-time with GPS receivers
  - Sending location feeds of GPS receiver to the server
  - Map matching
  - Data Handling
  - Travel-time estimation
  - Android apps for offering ITS services to commuters

Getting Data from GPS unit

- Tracking unit (GPS receiver embedded into ALIX3D3 SBC) obtains information about the latitude, longitude and instantaneous velocity of the vehicle, periodically
- Live feed is sent to a stationary server via 3G cellular radio connection of Tracking unit for number crunching.
- Sample Output:
  - GPS_ID: 1124

    Route_ID: 502

    UTC: 09H 18M 38S

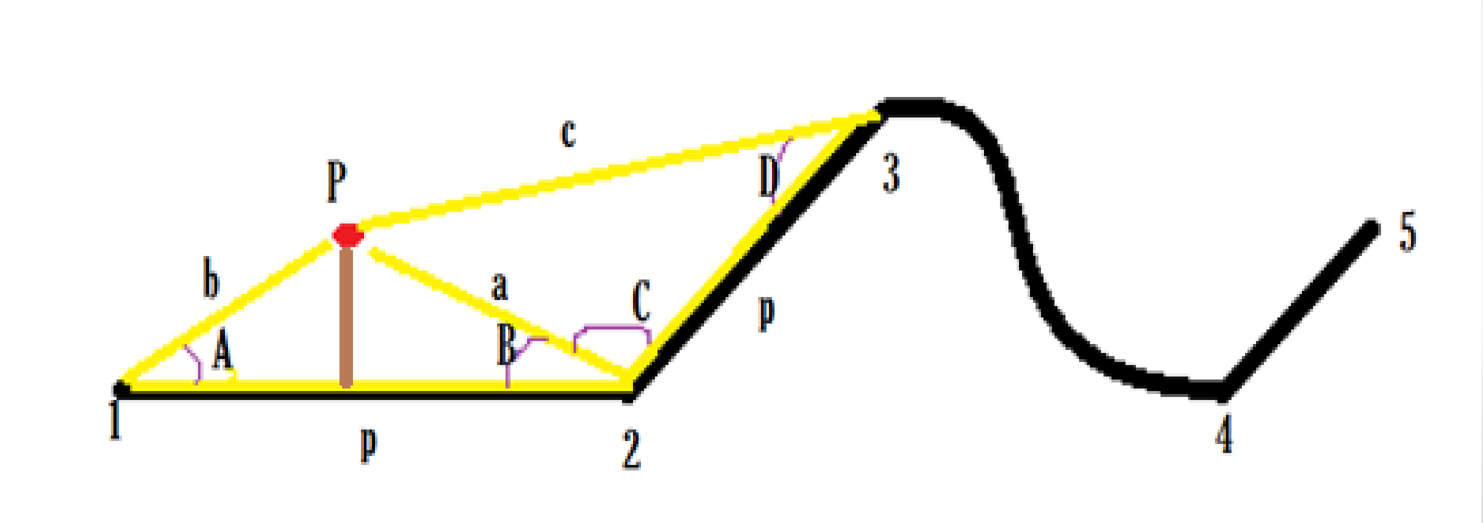
    Latitude:17.4936 N

    Longitude:78.1418 E

    Velocity:20 Kmph

Map Matching Algorithm

- The raw GPS coordinates received from GPS are map-matched to the bus route.
- By this map-matching algorithm, we determine the road segment of the bus at that time. Also, if there is some error in the sent coordinates, it maps it to the perpendicular foot on the road segment.
- Here 1,2,3,4,5 are the bus stops and P is any point received.



Data Handling

- The data received from tracking devices to the server are put in a properly designed Database system, so that any query can be efficiently and instantly answered.
- Different days of a week may have different type of traffic pattern. That is also taken care of in the Database.
- Current Data (i.e., all the data of that specific day) and History Data (i.e., all the past data) are maintained separately in the Database.

Algorithm Development

- The first thing is to calculate time taken by bus to travel from source to destination. For that we divided the route into different segments for which we have in the Database the current and the history data of time taken.
- If segments are from *i*=S1 to *i*=S10,

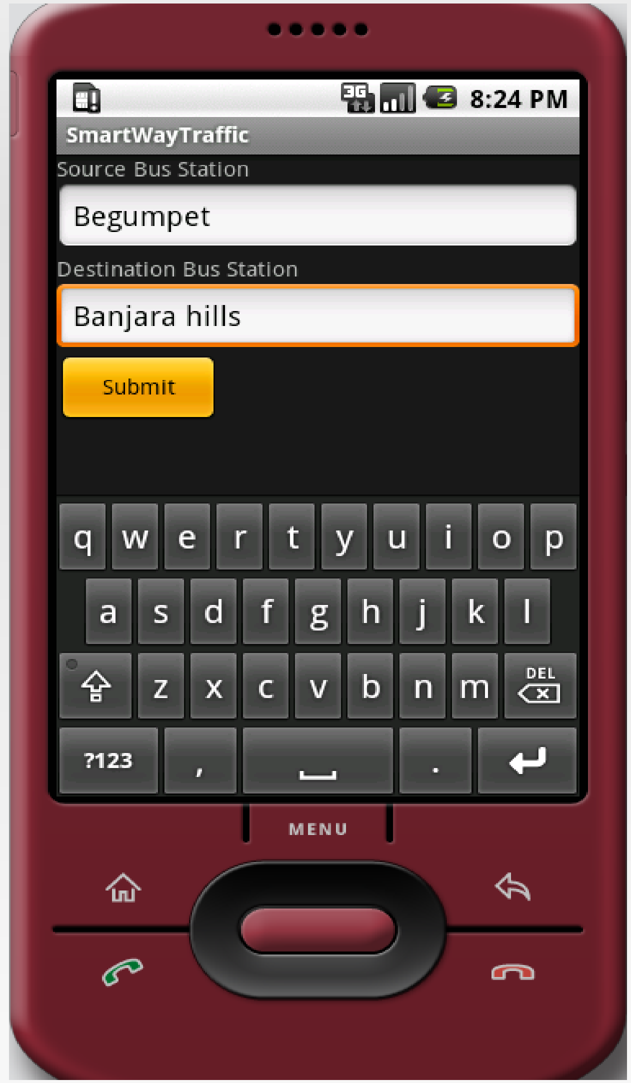
Then total time taken from source to destination will be

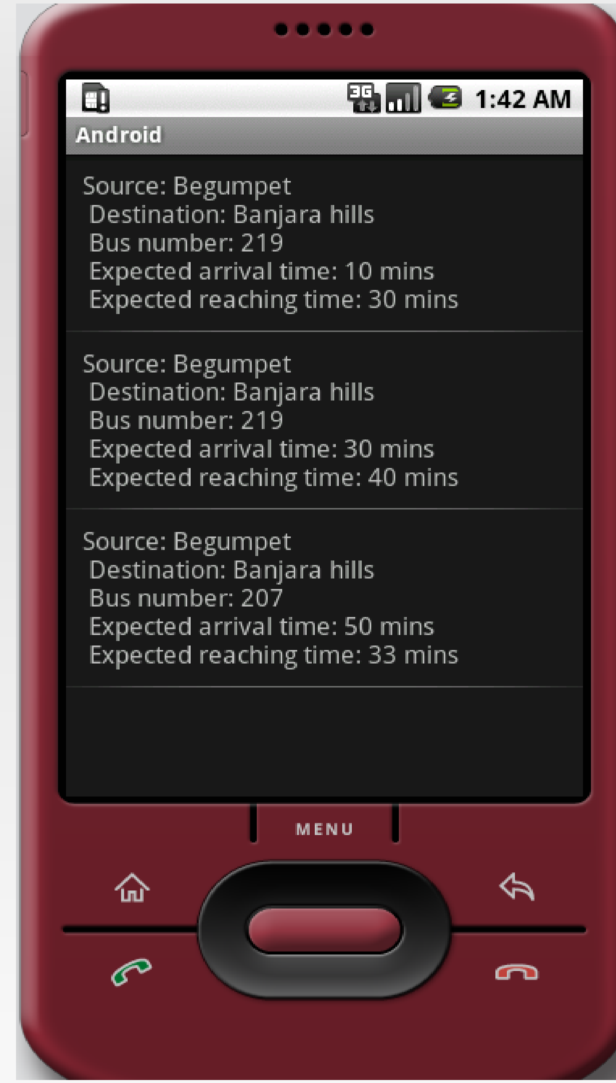
$T(total) = \sum x_i$ *(current estimated t.t. of Si) $+ \sum (1-x_i)$*(historically observed t.t. of Si)

The coefficient x is different for every segment but is not dependent on the segment, but on segment arrival in the route

Android App


11:43 PM
GPSLocation
Hello, SendingGPSData...
latitude=28.0&longitude=30.0&time=1310688000000&speed=0.0
MENU


8:24 PM
SmartWayTraffic
Source Bus Station
Begumpet
Destination Bus Station
Banjara hills
Submit
MENU


1:42 AM
Android
Source: Begumpet
Destination: Banjara hills
Bus number: 219
Expected arrival time: 10 mins
Expected reaching time: 30 mins
Source: Begumpet
Destination: Banjara hills
Bus number: 219
Expected arrival time: 30 mins
Expected reaching time: 40 mins
Source: Begumpet
Destination: Banjara hills
Bus number: 207
Expected arrival time: 50 mins
Expected reaching time: 33 mins
MENU

Conclusions

- ITS applications are fast emerging
- Exists several open research challenges in providing uninterrupted V-2-V and V-2-I communication
- In-car Internet connectivity and social games demand high network speeds from Radio Access Networks

References and Further Reading

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