CarTel: A Distributed Mobile Sensor Computing System

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What is CarTel?

- Distributed software system that makes it easy to:
  - collect,
  - process,
  - deliver.

  - Visualize & analyze data from mobile sensors (cars, phones, etc)

  - Goals & Challenges:
    - Intermittent network connectivity + mobility
    - Lots of data (“media-rich” sensors)
    - Heterogeneous data
    - Programmability

CarTel System Architecture

CarTel Software Components

- CarTel Portal: Centralized, visual user interface
- IceDB: Intermittently connected DB
  - Centralized declarative queries
  - Executed in distributed fashion by mobile nodes
  - Delay-tolerant continuous query processing
- CarNet: CarTel's network stack
  - Handles variable and intermittent connectivity

CarTel Software Architecture

IceDB: Intermittently Connected DB

- Delay tolerant, distributed continuous query engine
  - Highly variable connectivity & bandwidth

  - SQL extensions to handle intermittent connectivity
  - To prioritize results

  - Adapters for managing heterogeneous data types
    - Meta-data package describing attributes of sensor
    - Create local tables for sensor readings
    - Acquire tuples from sensor
    - Parse sensor readings
(Traditional) Continuous Queries

- Current model for stream processing:
  - Process data streams via long-running queries
  - Windowed aggregates, filters, windowed joins, merges, etc.
- Network is assumed to be "always on"
  - Disconnection is a fault to be masked (or a failure occurs)

 Delay-Tolerant Continuous Queries

- IceDB stages data into output buffers to hide variable connectivity
- Key idea: Data in output buffers get re-evaluated dynamically, each time a new item arrives into it

Result Prioritization

- Limited BW necessitates deliberate ordering
- Three simple SQL extensions
  - For local (per-box) ordering:
    - PRIORITY (for whole queries)
    - DELIVERY ORDER BY (within query results)
  - For global ordering (according to feedback from the portal, possibly across all sensors):
    - SUMMARIZE AS

Prioritize

- Idea
  - Some queries are more important than others
- Details
  - Add PRIORITY clause to SQL
  - Drain output buffers in priority order

DELIVERY ORDER BY

- Idea
  - Prioritize tuples within query result
- Details
  - Query specifies transmission order via DELIVERY ORDER BY clause
  - User-defined ordering function
  - Operates over entire query output buffer

SUMMARIZE

- Idea
  - Nodes send server low-resolution summary of output buffer contents
  - Server sends back transmission ordering
- Details
  - Users specify "summarization query" alongside main query
  - Server ranks segments using app-defined metric
  - Ranking pushed to nodes to set output ordering
CafNet: A Delay-Tolerant Network Stack

- Data moves through regions of highly variable connectivity
- "Mule" = element that stores data to be relayed toward the destination when "the time is right"
- A delay-tolerant network (DTN)
- CafNet delivers results to portal and queries to nodes

CafNet Optimizations

- Basic version: Callback + no buffering
- Problem: Connectivity may not even be long enough to package and send data
- Solution:
  - Add buffering at CNL level
  - CNL sends whatever is in the buffer as soon as connectivity is available
  - Callback when there is space in buffer
- Buffer size requirements vary (vs. dynamic priority)
  - Allow applications to set desired size

CafTel Portal: Traces and Interest Regions

Library for Geographic Overlays

- Smart route finding & congestion mgmt
  - Fast + current data
- Fleet mgmt/automotive diagnostics
  - E.g., trucks, taxis, buses
- Visual mapping (images, video) of regions
- Pictures for driving directions
- Surveillance videos
- Civil and environmental monitoring
  - E.g., to measure pollution or potholes
- Wireless network monitoring
  - "can you hear me now"
Experimental Setup

- 6 cars equipped with CarTel box and software
  - Driving normally in parts of the Boston area
  - ~32K access points (APs) mapped in all on a relatively small number of distinct routes
  - ~300 drive hours
- Fast scanning of WiFi access points, caching of AP parameters to speed up connection establishment
- 25sec connections
- Median upload: 30KB/s

Conclusions

- Mobile sensor networks can sense at much higher scale over large areas than static networks
- Several applications: traffic, fleet management, automotive diagnostics, wireless network monitoring, civil/environmental monitoring, ...
- Key challenges: heterogeneous data, intermittent connectivity, programmability, privacy
- In urban areas, Wi-Fi is a viable uplink technology
  - Legal/privacy issues?
  - Cheaper than using cell-based?
  - They also discuss using CarTel on cell phones