MobEyes: Smart Mobs for Urban Monitoring with Vehicular Sensor Networks*

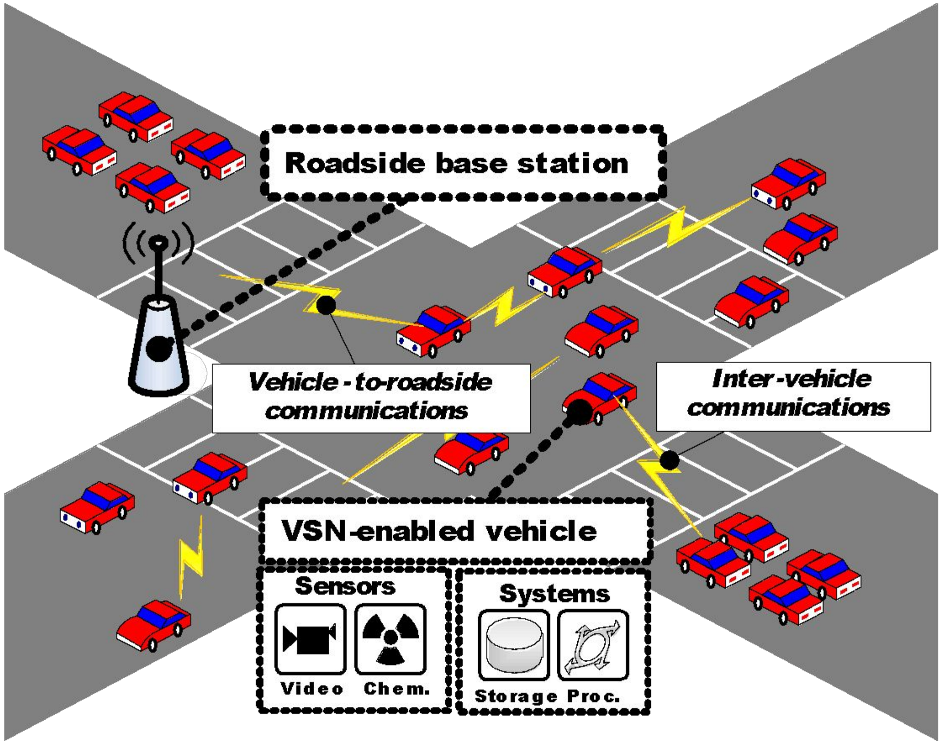
Uichin Lee, Eugenio Magistretti, Mario Gerla, Paolo Bellavista, Antonio Corradi

Network Research Lab
CS, UCLA

* Uichin Lee, Eugenio Magistretti, Biao Zhou, Mario Gerla, Paolo Bellavista, Antonio Corradi "MobEyes: Smart Mobs for Urban Monitoring with a Vehicular Sensor Network," *IEEE Wireless Communications, 2006*

Vehicular Sensor Network (VSN)

- Onboard sensors (e.g., video, chemical, pollution monitoring sensors)
- Large storage and processing capabilities (no power limit)
- Wireless communications via DSRC (802.11p): Car-Car/Car-Curb Comm.



Vehicular Sensor Applications

- Traffic engineering
  - Road surface diagnosis
  - Traffic pattern/congestion analysis
- Environment monitoring
  - Urban environment pollution monitoring
- Civic and Homeland security
  - Forensic accident or crime site investigations
  - Terrorist alerts

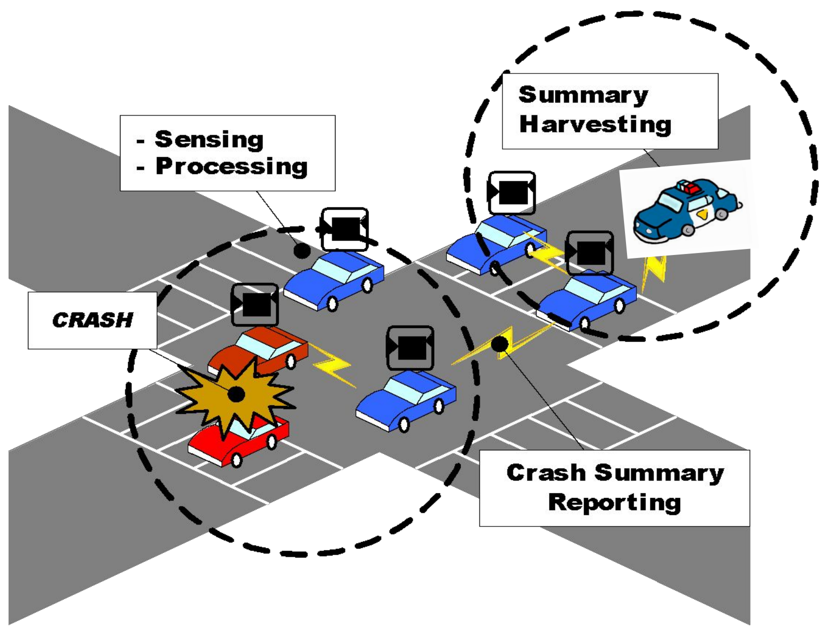
Contents

Smart Mobs for Proactive Urban Monitoring with VSN

- Smart mobs: people with shared interests/goals persuasively and seamlessly cooperate using wireless mobile devices (Futurist Howard Rheingold)
- Smart-mob-approach for *proactive* urban monitoring
  - Vehicles are equipped with wireless devices and sensors (e.g., video cameras etc.)
  - Process sensed data (e.g., recognizing license plates) and route messages to other vehicles (e.g., diffusing relevant notification to drivers or police agents)

Accident Scenario: Storage and Retrieval

- **Private Cars:**
  - Continuously ***collect*** images on the street (store data locally)
  - Process the data and ***detect*** an event (if possible)
  - ***Create meta-data*** of sensed Data
    -- **Summary** *(Type, Option,* ***Location****, Vehicle ID,* ***...****)*
  - ***Post*** it on the distributed index
- **The police *build an index* and *access* data from distributed storage**



Problem Description

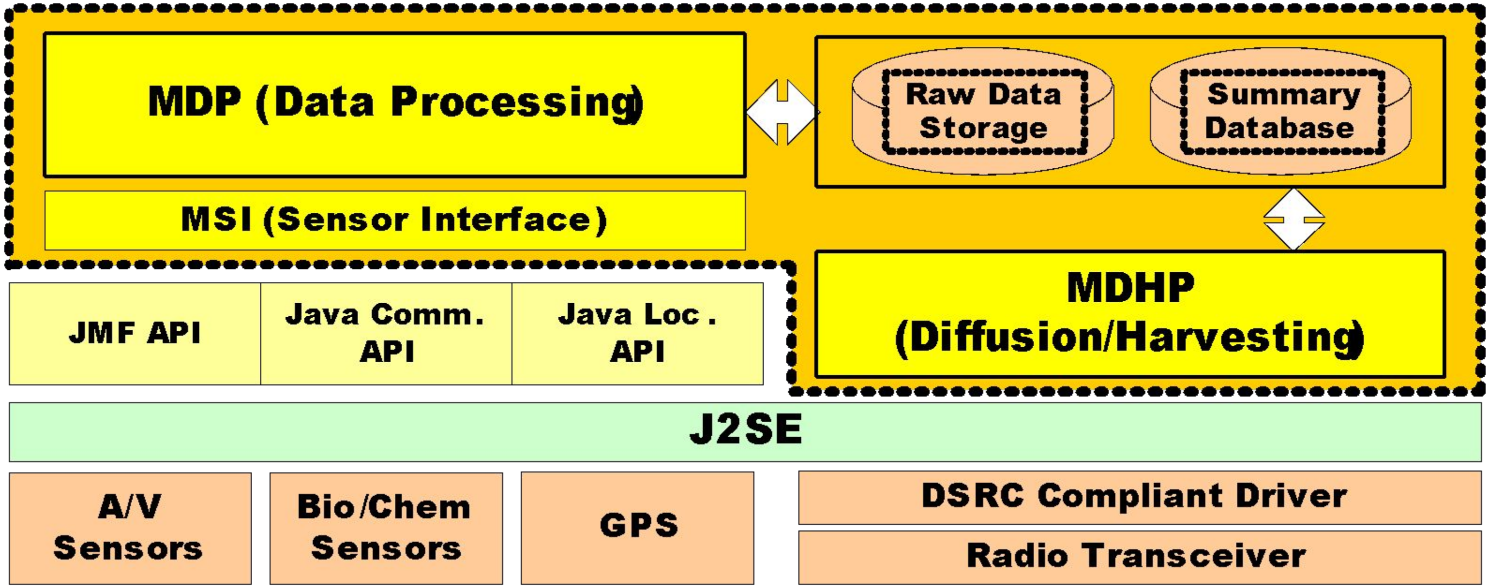
- VSN challenges
  - *Mobile storage* with a "*sheer*" amount of data
  - *Large scale* up to hundreds of thousands of nodes
- Goal: developing *efficient* meta-data harvesting/data retrieval protocols for mobile sensor platforms
  - **Posting** (meta-data dissemination) *[Private Cars]*
  - **Harvesting** (building an index) *[Police]*
  - **Accessing** (retrieve actual data) *[Police]*

Searching on Mobile Storage - Building a Distributed Index

- Major tasks: Posting / Harvesting
- Naïve approach: "Flooding"
  - ***<u>Not scalable</u>*** to thousands of nodes (network collapse)
  - Network can be ***<u>partitioned</u>*** (data loss)
- Design considerations
  - ***Non-intrusive***: must not disrupt other critical services such as inter-vehicle alerts
  - ***Scalable***: must be scalable to thousands of nodes
  - ***Disruption or delay tolerant***: even with network partition, must be able to post & harvest "meta-data"

MobEyes Architecture

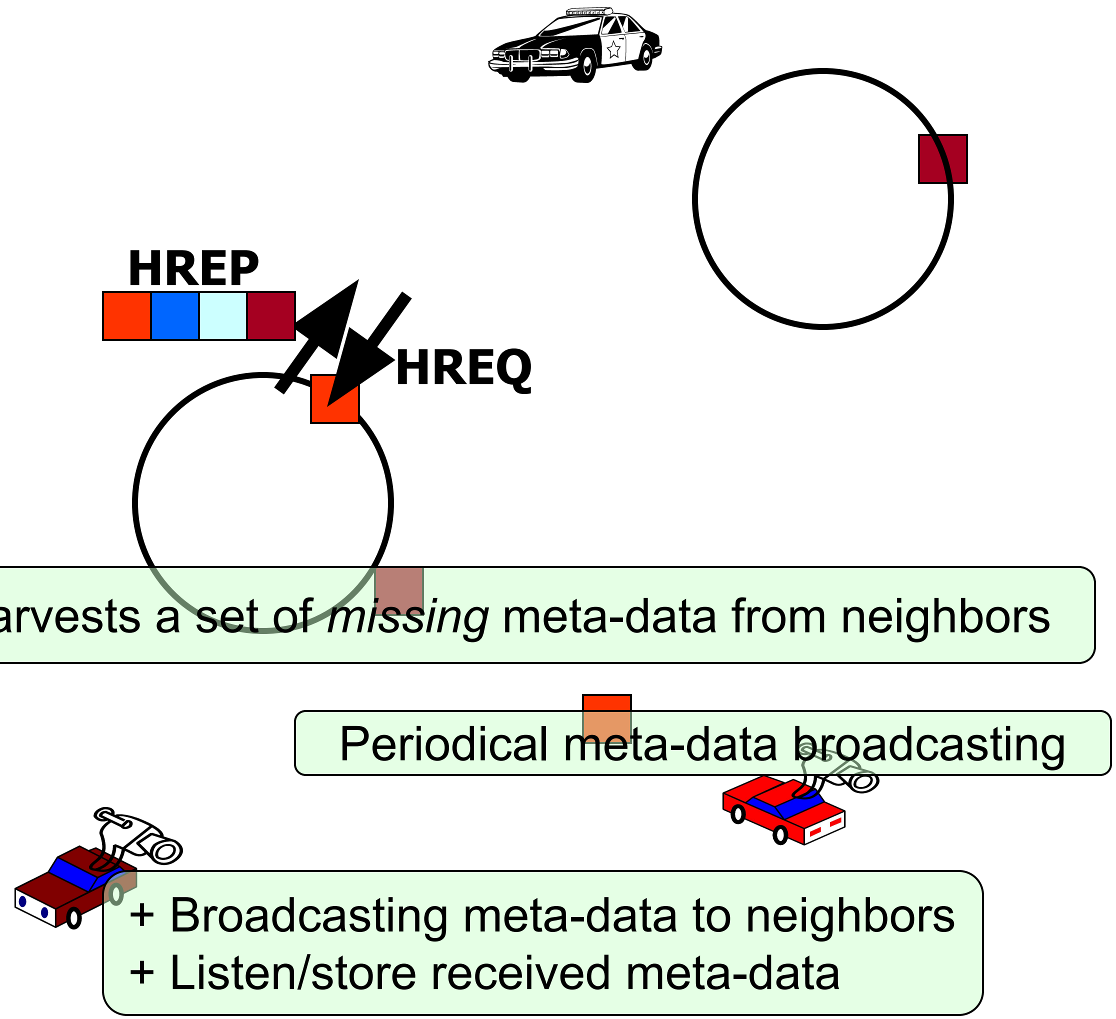
- MSI : Unified sensor interface
- MDP : Sensed data processing s/w (filters)
- MDHP : opportunistic meta-data diffusion/harvesting



Mobility-assist Meta-data Diffusion/Harvesting

- Let’s exploit “**mobility**” to disseminate meta-data!
- *Mobile nodes* are periodically broadcasting meta-data of sensed data to their neighbors
  - Data “owner” advertises **only** “his” own meta-data to his neighbors
  - Neighbors listen to advertisements and store them into their local storage
- A *mobile* agent (the police) harvests a set of “missing” meta-data from mobile nodes by actively querying mobile nodes (via. Bloom filter)

Mobility-assist Meta-data Diffusion/Harvesting

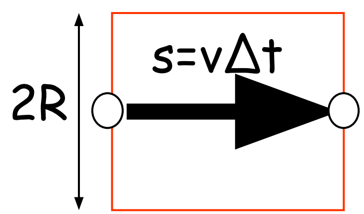


Diffusion/Harvesting Analysis

- Metrics
  - Average summary delivery delay?
  - Average delay of harvesting all summaries?
- Analysis assumption
  - Discrete time analysis (time step $\mathbf{\Delta t}$)
  - *N* disseminating nodes
  - Each node $\mathbf{n_i}$ advertises a single summary $\mathbf{s_i}$

Diffusion Analysis

- Expected number (α) of nodes within the radio range
  - *ρ* : network density of disseminating nodes
  - *v* : average speed
  - R: communication range



$$\alpha = \rho v \Delta t 2R$$

- Expected number of summaries "passively" harvested by a regular node (E_t)
  - Prob. of meeting a not yet infected node is $1-E_{t-1}/N$

$$E_t - E_{t-1} = \alpha \left(1 - \frac{E_{t-1}}{N}\right)$$

$$E_t = N - (N - \alpha)\left(1 - \frac{\alpha}{N}\right)^t$$

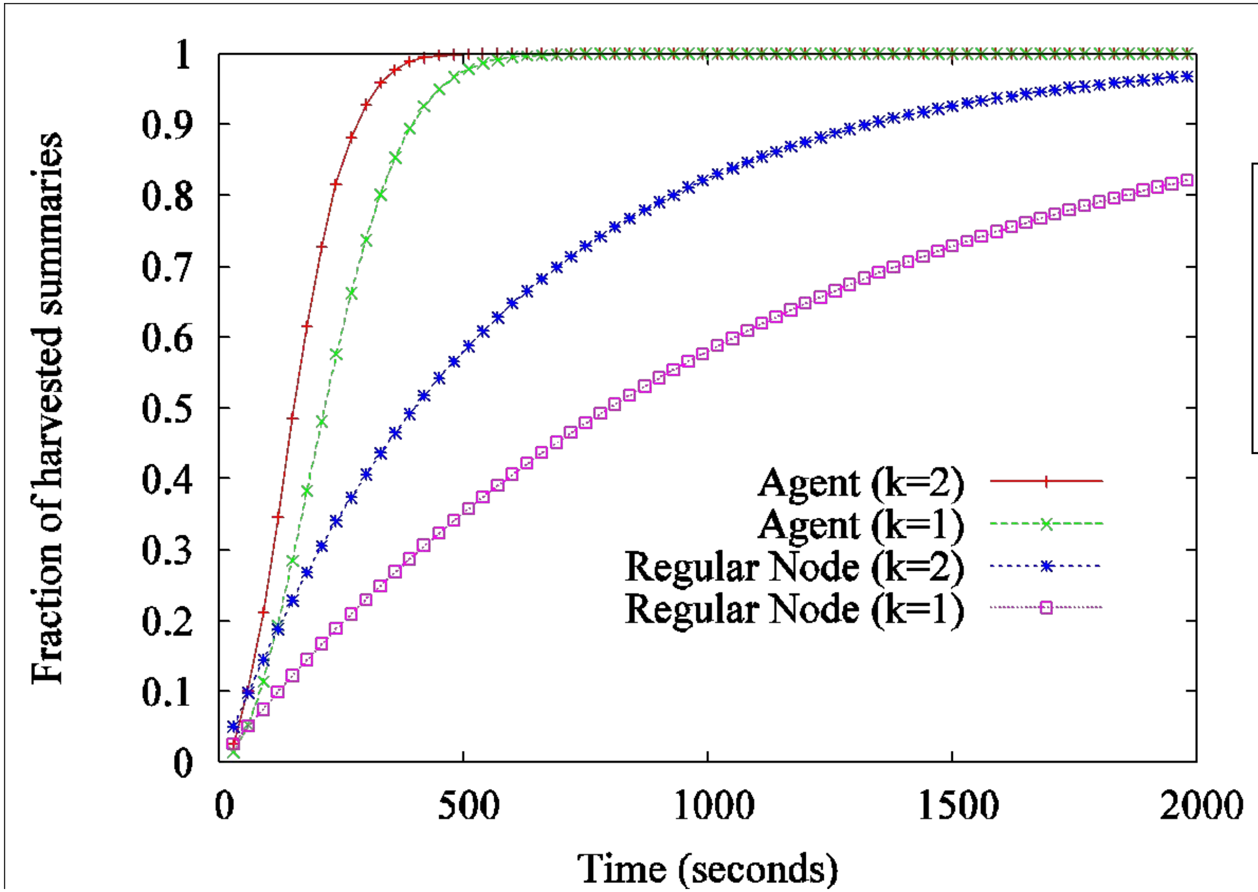
Harvesting Analysis

- Agent harvesting summaries from its neighbors (total ɑ nodes)
- A regular node has "passively" collected so far E_t summaries
  - Having a random summary with probability E_t/N
- A random summary found from ɑ neighbor nodes with probability $1-(1-E_t/N)^{\alpha}$
- E^*_t : Expected number of summaries harvested by the agent

$$E_t^* - E_{t-1}^* = N\left(1 - (1 - \frac{E_{t-1}}{N})^{\alpha}\right)\left(1 - \frac{E_{t-1}^*}{N}\right)$$

Numerical Results

- Numerical analysis



Area: 2400x2400m^2
Radio range: 250m
nodes: 200
Speed: 10m/s
k=1 (one hop relaying)
k=2 (two hop relaying)

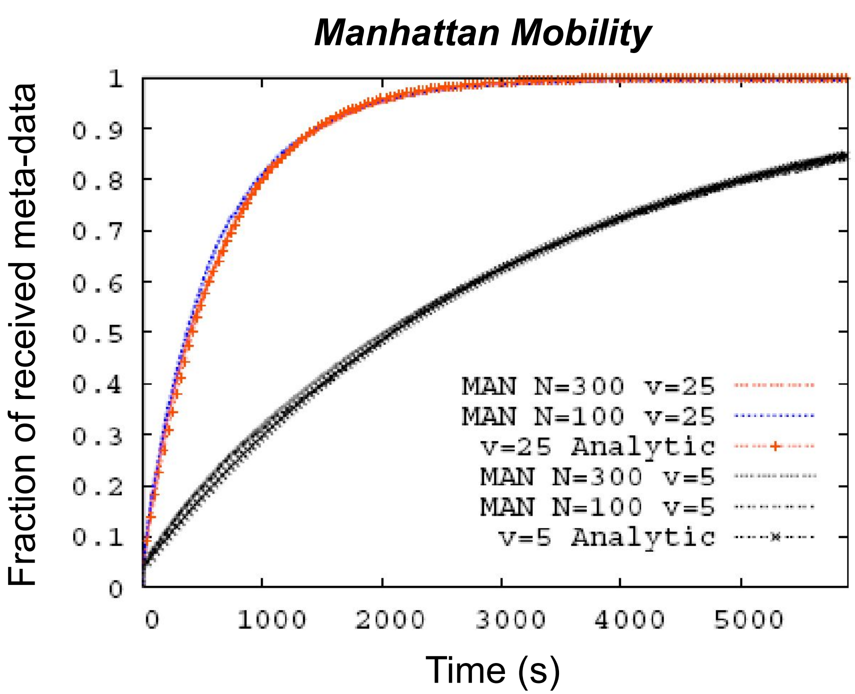
Simulation

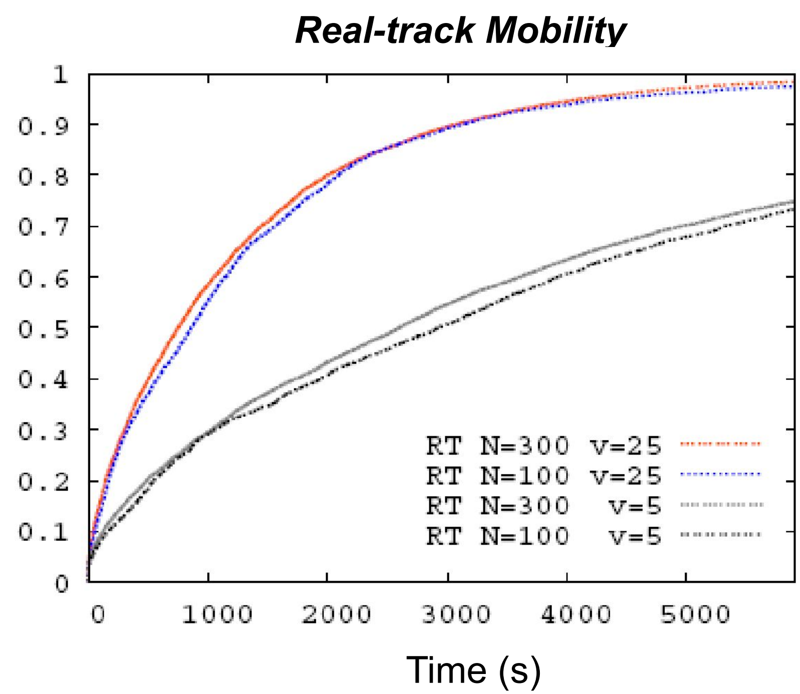
- Simulation Setup
  - Implemented using NS-2
  - 802.11a: 11Mbps, 250m transmission range
  - Network: 2400m*2400m
  - Mobility Models
    - Random waypoint (RWP)
    - Real-track model:
      - Group mobility model
      - Merge and split at intersections
      - *Westwood* map

Westwood Area

Meta-data Diffusion Results

- Meta-data diffusion: ***regular node passively collects meta-data***
- Impact of node density (#nodes), speed, mobility
  - Higher speed, faster diffusion
  - Density is not a factor (increased meeting rate vs. more items to collect)
  - Less restricted mobility, faster diffusion (Man>Westwood)

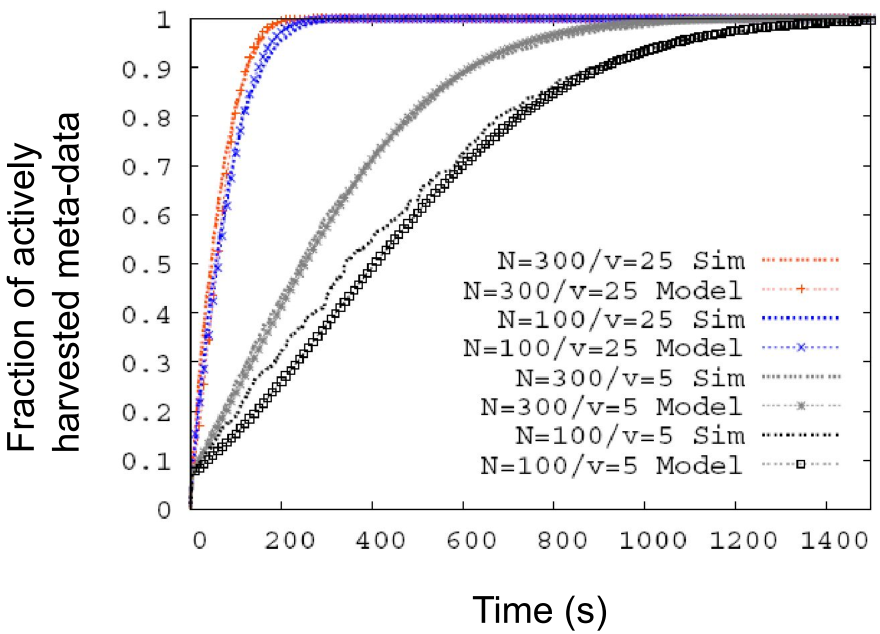




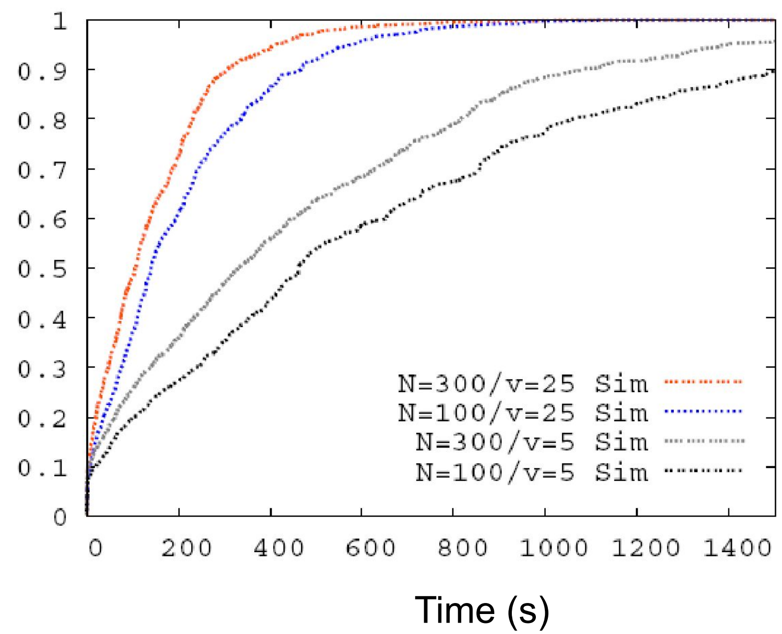
Meta-data Harvesting Results

- Meta-data harvesting: ***agent actively harvests meta-data***
- Impact of node density (#nodes), speed, mobility
  - Higher speed, faster harvesting
  - Higher density, faster harvesting (more # of meta-data from neighbors)
  - Less restricted mobility, faster harvesting (Man>Westwood)

Manhattan Mobility

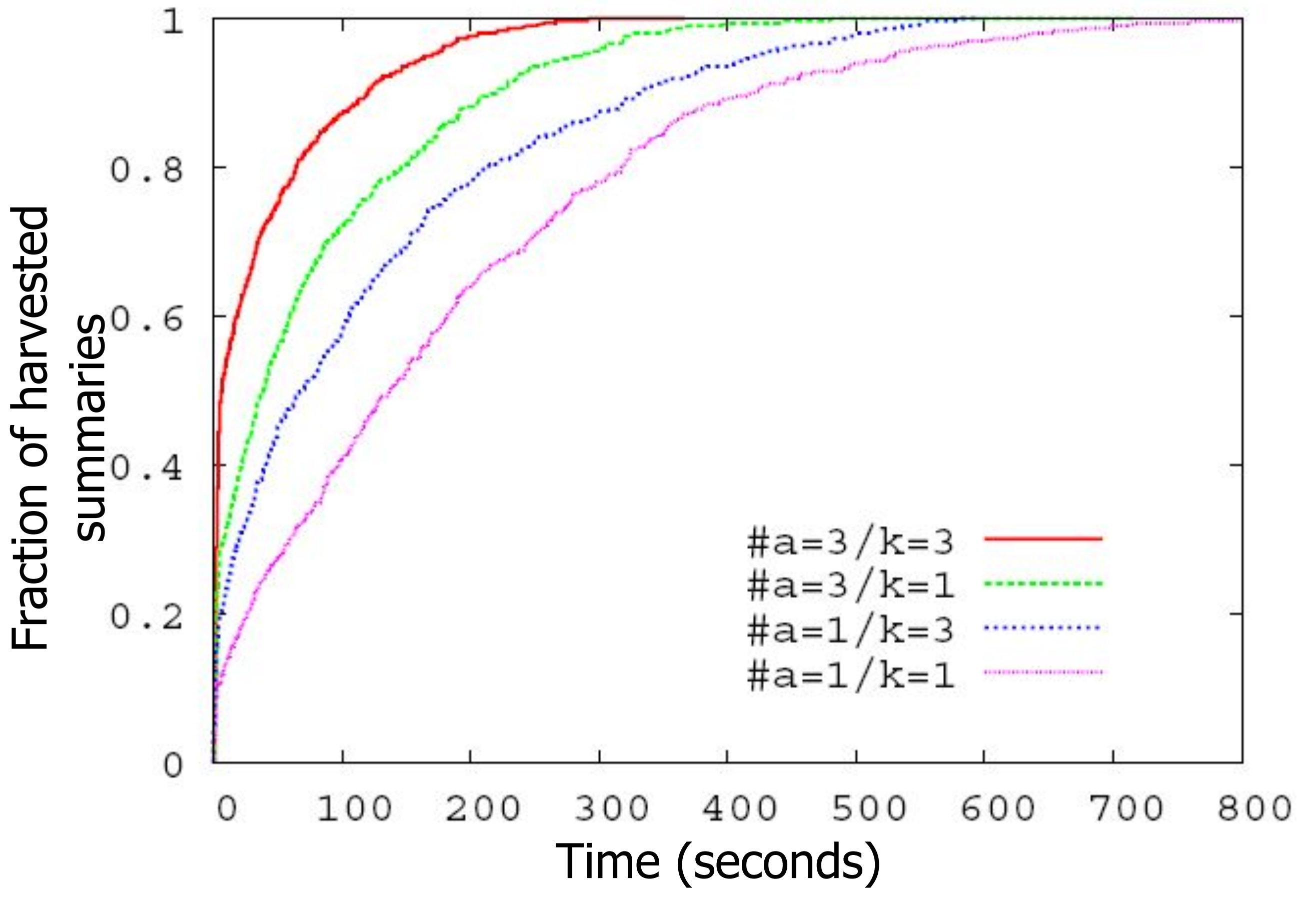


Real-track Mobility



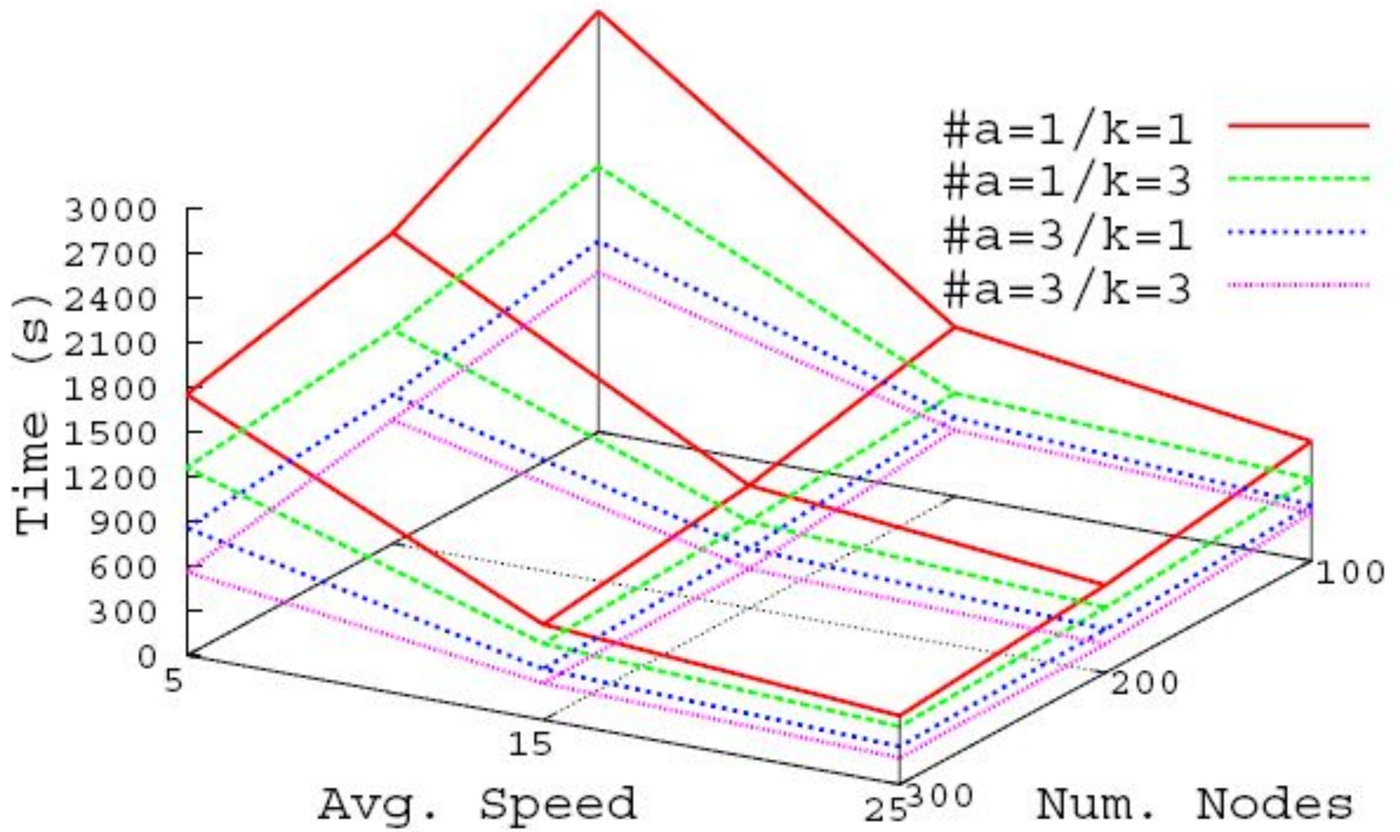
Simulation

- k-hop relaying and multiple-agents (RT)



Simulation

- k-hop relaying and multiple-agents (RT)



Conclusion

- Mobility-assist data harvesting protocol
  - Non-intrusive
  - Scalable
  - Delay-tolerant
- Performance validation through mathematical models and extensive simulations