Opportunistic Sensor Data Collection Using Smart Phones

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Motivations

The Expected Large-Scale Wireless Sensor Network (WSN)

❑ Provide long-term services and cover a large area with sparse nodes

Challenges Faced By Data Collection

❑ Static sink nodes: too many sinks and expensive back-haul network
❑ Mobile data collectors: the cost of dedicated mobility

Key Observations

❑ Ubiquitous Smart Phones with various radios
❑ Many WSNs for delay-tolerant applications

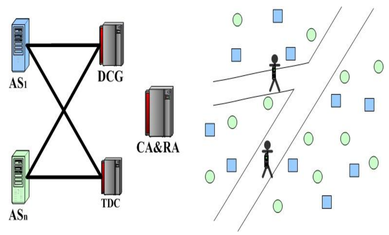
Our Proposal

❑ Collect data through smart phones carried by the public in their daily life.
❑ Data is collected opportunistically, i.e., the public won't change the route.
❑ Smart phone users can be motivated with small rewards and the cost of data collection can be reduced.

SOI [1]: The Architecture

Observation

❑ Unreasonable to let a smart phone collect data for one WSN
❑ A shared infrastructure (CA&RA, DCG/TDC, recruited smart phones, payment system, etc.) should be provided to reduce the overhead of WSN providers



CA&RA: Certificate Authority and Registration Agent; AS: Application Server
DCG: Data Collection Gateway; TDC: Task Distribution Center

Key Points

❑ Smart phones act as data mules that opportunistically ferry data between sensor nodes and their servers (through DCG&TDC)
❑ CA&RA --- establish trust relationship among these entities

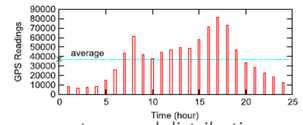
Human Mobility Analysis [2]

Aims

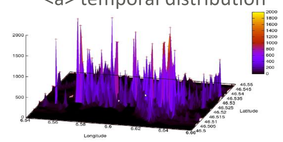
To carry out feasibility analysis for opportunistic data collection through smart phones and to identify human mobility patterns for designing efficient data collection protocols

Dataset

The smart phone users' mobility traces provided by **NOKIA** through Mobile Data Challenge (37 users, two years, GPS reading per 10s)



<a> temporal distribution



<b> spatial distribution

Key Findings

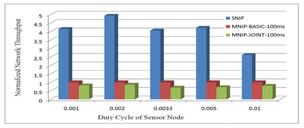
❑ The mobility of smart phone users can provide satisfying performance to many WSNs and the overhead on smart phone is acceptable.
❑ Both temporal and spatial localities exist in human mobility .

Contact Probing Mechanisms [3][4]

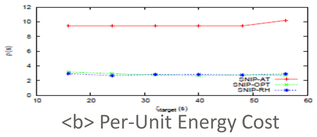
Contact Probing Problem

Before sensor data can be collected, smart phone and sensor node must first et to the presence of each other. This is hard to achieved since,

❑ The mobility of smart phone is uncontrolled.
❑ Sensor node must be deeply duty-cycled.



<a> SNIP vs. MNIP



<b> Per-Unit Energy Cost

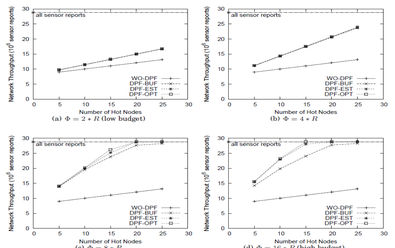
Key Findings

❑ SNIP [3]: Sensor node should broadcast beacons. Compared to mobile node-initiated probing, the performance can be improved by an order of 2-10.
❑ SNIP-RH [4]: Through exploiting temporal locality of human mobility, i.e., carrying out contact probing mainly in rush hours (the periods that smart phones appear more frequently), under a typical scenario, the energy consumed to collect the same amount of data can be reduced by 70%.

Data Pre-Forwarding [5]

Key Observations

❑ Even in sparsely deployed WSNs, there are still some connected components.
❑ Due to the spatial locality of human mobility, sensor nodes tend to be visited with different frequencies.
❑ Thus, sensor data should be send to hot nodes for collection.



<a> Results under a 10X10 Grid Topology

Our Work

❑ Instead of letting smart phone collect sensor data through multi-hop, data pre-forwarding, in which sensor nodes exchange data before the arrival of smart phones, is proposed by us for improving the total amount of data collected by smart phones. Several heuristics are proposed to make decisions about data exchange.
❑ Simulation and test-bed evaluation results indicate that these heuristics perform close to the optical.

Future Work

❑ Refine these protocols, algorithms, and parameters to improve the performance of opportunistic data collection.

❑ Carry out joint-optimization with considering both contact probing and data pre-forwarding.

❑ With smart phone users' mobility trace from **NOKIA**, trace-based simulations will be carried out to study our proposals under more realistic scenarios.

❑ Implement these mechanisms on smart phones with ZigBee radio (such as TPH-ONE from TazTag, http://www.taztag.com/) and carry out large-scale testbed evaluations.

❑ Considering data reliability (through replication) and the value of data (freshness, reading value) when carrying out data pre-forwarding.

❑ This project had also been supported by HEA through NEMBES.

Publications

[1] X. Wu, C. J. Sreenan, and K. N. Brown, "A Shared Opportunistic Infrastructure for Long-lived Wireless Sensor Networks", in Mobisense Workshop, in conjunction with ICST Mobilight 2011
[2] X. Wu, K. N. Brown, C. J. Sreenan, "Analysis of Smartphone User Mobility Traces for Opportunistic Data Collection in Wireless Sensor Networks", Elsevier Journal on Pervasive and Mobile Computing, DOI: http://dx.doi.org/10.1016/j.pmcj.2013.07.003
[3] X. Wu, K. N. Brown, and C. J. Sreenan, "SNIP: A Sensor Node-Initiated Probing mechanism for opportunistic data collection in sparse wireless sensor networks," in CPNS workshop, in conjunction with INFOCOM, 2011.
[4] X. Wu, K. N. Brown, and C. J. Sreenan, "Exploiting Rush Hours for Energy-Efficient Contact Probing in Opportunistic Data Collection," accepted by SN workshop, in conjunction with ICDCS, 2011.
[5] X. Wu, K.N. Brown and C .J. Sreenan, "Data Pre-Forwarding for Opportunistic Data Collection in Wireless Sensor Networks, INSS 2012 (invited paper)

By exploiting the regular mobility of smart phones, the cost of sensor data collection can be reduced significantly by avoiding the need to deploy fixed base-stations

CTVR Communications Showcase 2013