Mobile Crowdsensing (MCS) for Smart Cities

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Agenda

- History and Key Applications for MCS
- MCS Key Technologies
- My Research
- Conclusion
MCS for Smart Cities

- Traditional IoT refers to physical deployment of sensors that has many challenges like high costs, short sensing range, long response time, poor mobility pattern, etc.

- **Smartphones, UAVs, driverless cars etc.** all have equipped with rich sensors like camera, microphone, gyroscope, GPS, heartbeat/blood pressure sensors, that form a MCS environment.

Andrew T. Campbell, Nicholas D. Lane, et. al Dartmouth College
Shane B. Eisenman and Gahng-Seop Ahn Columbia University

On of the first paper to propose the “people-centric sensing” conception, where humans, rather than trees or machines, become the focal point of sensing.
A system for rich monitoring of road and traffic conditions, which uses the accelerometer, microphone, GSM radio, and/or GPS sensors in phones to detect potholes, bumps, braking, and honking.

**Early Apps**

**ACM SenSys 2008 Nericell**

A system for rich monitoring of road and traffic conditions, which uses the accelerometer, microphone, GSM radio, and/or GPS sensors in phones to detect potholes, bumps, braking, and honking.

**ACM MobiSys 2008 Micro-Blog**

Internet users can zoom into any part of the map and browse multimedia blogs at those locations. Users may query selected regions for desired information. Queries are serviced either through explicit human participation, or automatic physical sensing.

**Figure 2:** Micro-Blog screenshot and phone query. A microblog of the Opera House in Sydney, Australia, shown on the map. The multimedia blog plays on the right panel. The Internet user selects a region (shown by a square box on the map), and sends a query to phones in that region. The phone on the right, physically located in Sydney, receives the query. The user replies to it, and the reply is transmitted back to the server. The query and reply are associated to the blog, as shown in the right panel. This microblog was created during our demonstration of Micro-Blog at ACM SenSys 2007 (H1) held in Sydney, Australia.

A weather prediction app that employs any available sensor found on a mobile device to gather objective weather descriptive measurements, such as environmental pressure, temperature, luminosity and humidity levels.

Recent Apps

ACM UbiComp 2014 Atmos

A weather prediction app that employs any available sensor found on a mobile device to gather objective weather descriptive measurements, such as environmental pressure, temperature, luminosity and humidity levels.

Figure 3: The "PLACES" screen provides an overview of current weather conditions across several locations of interest by summarizing the estimations of other users. Clicking on a specific location grants access to additional information about current and future weather conditions as reported by other users.


AAAI 2017 ParkUs

It is for real-time vehicle parking detection. It utilizes accelerometer and magnetometer sensors found in all smartphones within a city environment.

MCS Key Technologies

- Participant Selection
- Incentive Mechanism
- Privacy Protection
- Truth Discovery
IEEE INFOCOM 2015

**Selecting Vehicles**

It proposes a new strategy to recruit participants by jointly considering the current and future locations of vehicles. Therefore, the quality of crowdsourcing for a period of time in the future can be guaranteed.

IEEE TMC 2017 **Online Task Assignment**

It proposes and formalizes the makespan-sensitive task assignment problems for MCS based on Mobile Social Networks (MSNs). They take into account the time of sending tasks and receiving results between users, which is subjective to users' mobility.


It investigates the joint task assignment and route planning problem in UAV-aided MCS systems from an energy efficiency perspective.

IEEE INFOCOM 2018
Personalized Task Recommender
It proposes a personalized task recommender framework that can recommend tasks to users based on a fine-grained characterization on both the users’ preference and reliability.

IEEE TCOM 2018 UAV-aided MCS

Incentive Mechanism

IEEE/ACM ToN 2016 Online Mechanism
A more realistic scenario where users arrive one by one online in a random order.

IEEE INFOCOM 2016 Network Effect
An incentive mechanism is proposed which considers the interaction and relationship between the individual behavior of participants and the behavior of other participants. It brings intrinsic rewards into the spotlight, with a focus on how network effects affect the mechanism design when a crowdsourcer provides extrinsic rewards to incentivize crowdsourcing systems.

Fig. 1. Illustration of a mobile crowd sensing system.


MCS Key Technologies

Privacy Protection

IEEE INFOCOM 2018
Non-Interactive PPTD system
It designs a non-interactive system that removes the online requirement with strong privacy guarantees. It does not reveal any intermediate results, and further supports “late-join” providers without protocol suspension/restart.

IEEE TMC 2018
Personalized Privacy-Preserving
It provides personalized location privacy protection that each worker uploads the obfuscated distances and personal privacy level to the server instead of its true locations or distances to tasks.


MCS Key Technologies

Truth Discovery

ACM SenSys 2016 RST
It develops a framework called “Redundancy and Sparsity Tackling (RST)” to estimate the true values of entities from redundant and sparse data.

ACM MobiHoc 2018 An optimal attack framework
The attacker can not only maximize his attack utility but also disguise the introduced malicious workers as normal ones such that they cannot be detected easily.


My Research

MCS for Smart Cities

Participant Selection

Unmanned Vehicle Scheduling

Quality of Information
Data Collection Ratio, Energy

Deep learning
Optimization
1. Participant Selection (1/2)

Challenge: Select minimum participants to ensure QoI, minimize energy consumption and satisfy user incentive requirements

Contributions:
- Proposed a Gur Game based selection method
- Results confirm that 4~5 times more collected data

Goal: maximize data quality satisfaction ratio & minimizing energy usage.

Maximize: \( u^q(\mathcal{X}) = 1 - \frac{\| R^q - O^q(\mathcal{X}) \|_F}{\| R^q \|_F} \),

Minimize: \( d^q(\mathcal{X}) = \frac{1}{M} \sum_{m \in \mathcal{X}} \left( \frac{\xi^q}{e_m} \right)^\tau \),

subject to: \( \mathcal{X} \subset \mathcal{M} \).
1. Participant Selection (2/2)

Challenge: overcome human unpredictable behaviors

Contributions:
- Quantified human behaviors w.r.t. energy consumption, and data contribution
- Improved data quality by 67.3%

Questionnaire to study relation between behaviors and energy

Goal: find optimal set of participants, given data quality and budget constraints

Maximize: $u_q(\mathcal{X}) = \frac{\sum_{\forall \mathcal{C} \in \mathcal{T} \cap \mathcal{C}} u_{l_t}^q}{\mathcal{L}_q T_q}, \quad \forall q \in \mathcal{Q}$

Subject to: $\sum_{\forall m \in \mathcal{X}} d_m \leq C, \quad \mathcal{X} \subseteq \mathcal{M}$
2. Unmanned Vehicle Scheduling

Challenge: MCS with energy constrained unmanned vehicles

Goal: max data collection ratio & geographical fairness
s.t. energy and sensing capability

Contributions:
- First to apply deep learning on MCS
- Proposed a new deep model for each vehicle
- Improved DeepMind NIPS'17 model by:
  - Spatiotemporal modelling
  - Prioritized and Recurrent Experience Replay Buffer
  - Decentralized training frameworking
Conclusion

- Next generation of smart cities is powered by MCS data collection, with a mixture of human and machine intelligence.
- It serves as the fundamental data source for many smart city apps.
Thanks a lot!

Questions?