Sense-Aid: A framework for enabling network as a service for participatory sensing

Heng Zhang Purdue ECE, **Saurabh Bagchi** Purdue ECE,
He Wang Purdue CS, **Rajesh K. Panta** AT&T Labs


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Outline

- What is mobile crowdsensing
- What is Sense-Aid
- Implementation
- Evaluation
- Conclusion and Future work

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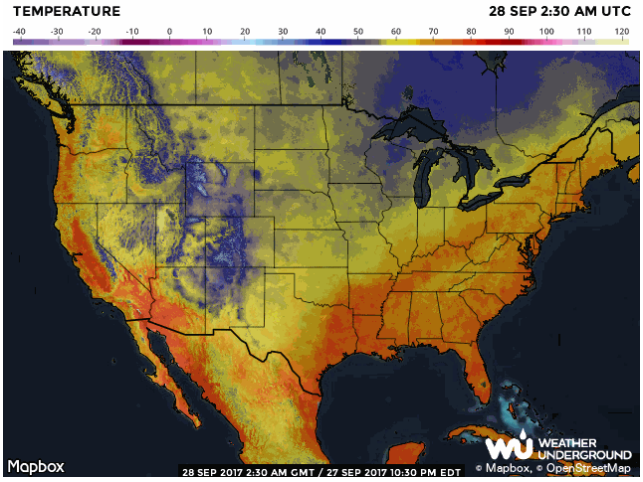
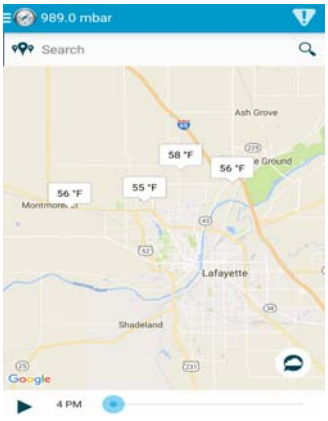
What is mobile crowdsensing (MCS)

Synthesize knowledge from mobile device information (e.g. sensor values)

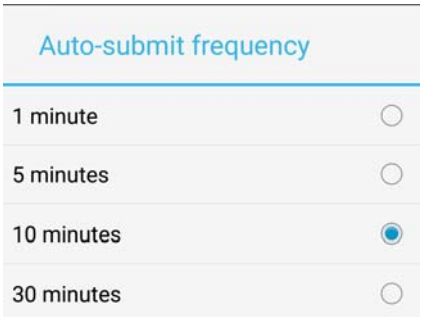


What is mobile crowdsensing (MCS)

Pressurenet



- Periodic sensing and submit
- Or manual submit

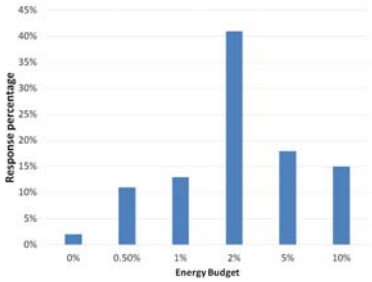


Why mobile crowdsensing

- Smartphones are ubiquitous and are equipped with highly sophisticated sensors
  - Barometer, gyroscope, accelerometer, thermometer can be used for various applications
  - Weather prediction, Noise pollution map, road and traffic condition reporting
- Reported information is real-time and less costly
- Network support
  - Fast and reliable

What is Sense-Aid

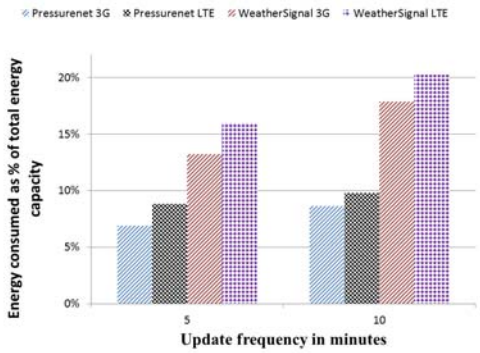
- A MCS infrastructure embedded at the edge of 4G network to provide energy-efficient mobile crowdsensing service
- Goal:
  1. Save per device energy as well as total energy for all mobile
  2. Ensure fairness among multiple devices
- Why do we care about energy consumption?



Result from 109 college students from the U.S., China, and India

Is MCS energy efficient enough now?

NO!



4 hrs for 5 mins frequency & 8 hrs for 10 mins frequency
Pressurenet: barometer
WeatherSignal: temperature, magnetic, light, etc

Sense-Aid Energy-Saving Techniques

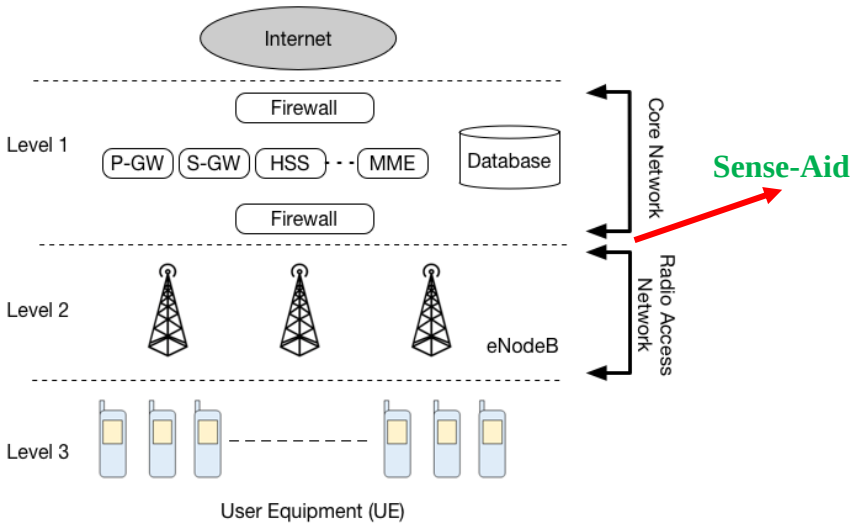
1. Piggyback MCS data packet
2. Cellular radio state opportunity
3. Orchestration among many devices

Energy Table

Component	Power Consumption
Accelerometer	21mW
Gyroscope	130 mW
Barometer	110 mW
GPS	176 mW
Microphone	101 mW
Camera	>1000 mW
LTE Module	594 mW to 1700 mW

Table 1. List of power consumption of some components on Samsung Galaxy S4 (In the case of camera, the value of power consumption is dependent on what activity user is doing with camera.)

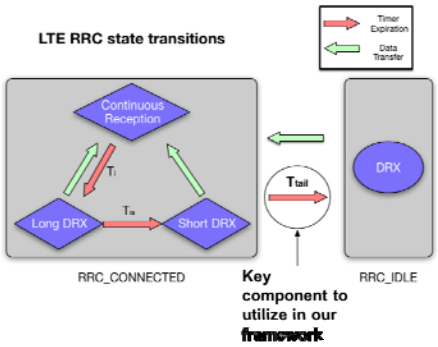
LTE Architecture



LTE State Machine

Radio state opportunity

- Tail time is roughly 11.5 secs in LTE (specified by RRC protocol)
- MCS traffic is short (600 bytes in our user study)
- Device RRC state is available in eNodeB



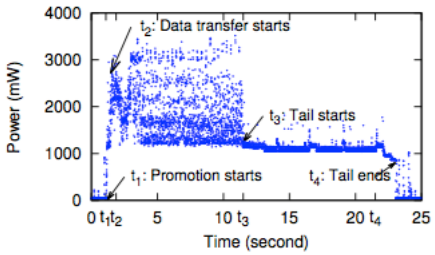
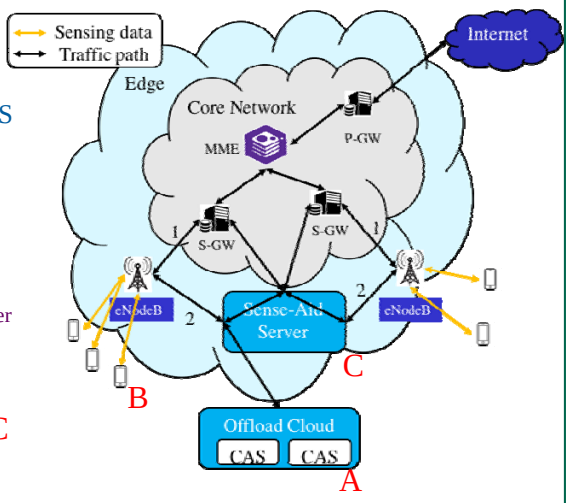


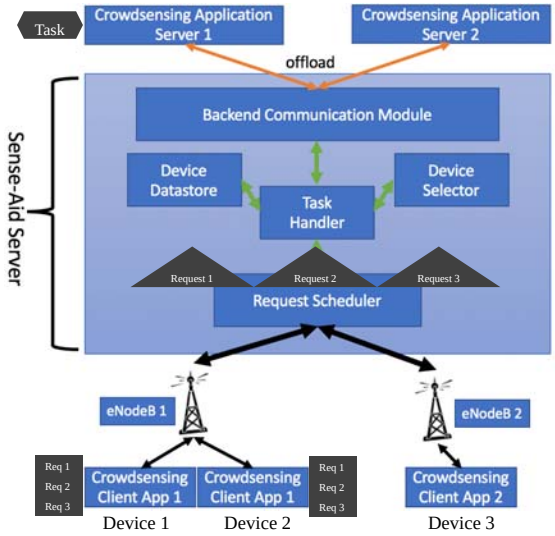
Figure 3: Power states of LTE.

Sense-Aid Architecture

- Pick device information that is available from MME and eNodeB
- Path 1 if incoming traffic to eNodeB does not include MCS data. Also the backup when failure at Sense-Aid Server
- Path 2 if MCS data in incoming traffic
- Terminology
  - Crowdsensing Application Server (Server of Pressurenet) A
  - Crowdsensing client application (Pressurenet) B
  - Sense-Aid Server (Scheduler) C



Sense-Aid Server Design



Control Parameter	Description
int sensor_type	Specifies what sensor is wanted for a MCS task
int sampling_period	Specifies the period between two consecutive samples
int area_radius	Specifies the circular task area radius
int spatial_density	Specifies the number of users are required

Sense-Aid Server Scheduling

Device selection (if n < N)

- Run scoring function over *N* (total available devices)
- Choose the lowest scored *n* (required number of devices) devices
- Maintain overall fairness
  - E_i : energy consumed by device i for the crowdsensing task.
  - U_i : number of times device i has been used
  - CBL_i : current battery level in percentage
  - TTL_i : current timestamp - timestamp of most recent radio communication (set to 11.5 if $TTL_i > 11.5s$)

The scoring function is defined as follows.

$$Score(i) = \alpha \cdot E_i + \beta \cdot U_i + \gamma \cdot (100 - CBL_i) + \phi \cdot TTL_i$$

Implementation

- Sense-Aid *Basic*
  - Resets tail timer
- Sense-Aid *Complete*
  - Does not reset tail timer
  - Saves more energy
- Baseline competition:
  - *Periodic*: Periodic sensing and communication with MCS server
  - *PCS* [Sensys-13]: Piggybacks the crowdsensed data to the PCS server based on prediction of the regular app usage on the device

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Evaluation

- User study for 1 week.
  - 3 groups. 20 students for each group. Each group is running one of the three frameworks: Sense-Aid, PCS, Periodic

Experiment Number	Varying parameter	Default parameters	Energy savings 1: *Sense-Aid Basic/Periodic* 2: *Sense-Aid Complete/Periodic* 3: *Sense-Aid Basic/PCS* 4: *Sense-Aid Complete/PCS* Average (Min, Max)
Experiment 1	Area radius 100m, 200m, 300m, 600m 500m, 1000m	test duration = 1.5 hrs/test number of tasks/device =1 sampling period = 10mins spatial density = 2	1: 94.3%(88.7%, 98.3%); 2: 94.9%(90%, 98.5%); 3: 79% (65.9%, 92.5%); 4: 81.4% (68.6%, 93.3%) ;
Experiment 2	Sampling period (1, 5, 10)[min]	test duration = 2 hrs/test number of tasks/device = 1 spatial density=3 area radius = 500m	1: 86.6% (80.9%, 89.6%); 2: 88.1% (83.1%, 90.7%); 3: 42.1% (27,2%, 57.8%); 4: 48.3% (35.1%, 62.4%);
Experiment 3	Spatial_density (1, 2, 5, 7)	test duration = 1.5 hrs/test number of tasks/device = 1 sampling period = 5mins area radius = 1000m	1: 87.5% (76.9%, 96.2%); 2: 88.8% (79.4%, 96.7%); 3: 55.7% (17.4%, 88.2%); 4: 60.5% (26.3%, 89.5%);
Experiment 4	Number of tasks per device (3, 5, 10, 15)	test duration = 1.5 hrs/test sampling period = 5mins spatial density = 3 area radius = 500m	1: 85.3% (84.4%, 86.5%); 2: 86.9% (86.1%, 87.9%); 3: 35.4% (16.7%, 57.8%); 4: 42.4% (25.7%, 62.4%);

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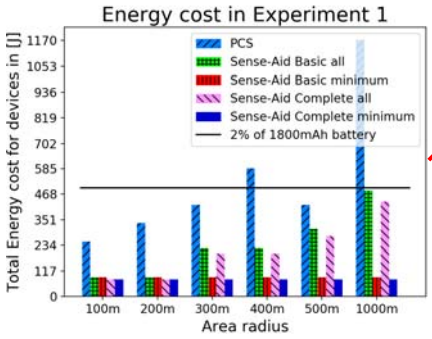
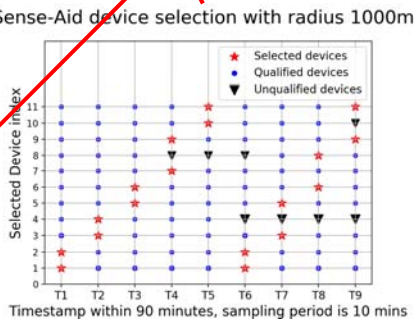
Evaluation

Orchestration → Fairness → Energy saving

- Overall energy cost
- Selection algorithm fairness

With more available users, benefits of Sense-Aid is more significant.
Users are fairly chosen.





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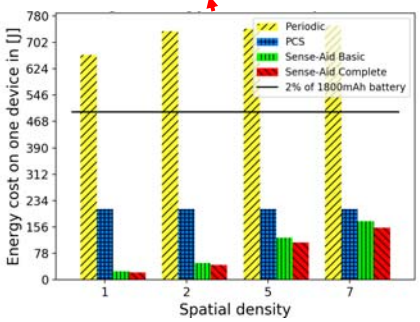
Evaluation

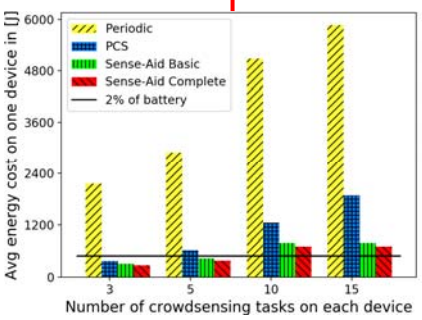
Radio tail opportunity → energy saving

- Energy cost per device

Spatial density increases so that given same number of available users, each user is selected more times.

Sense-Aid performs bad only when more than 10 tasks running simultaneously → more scalable





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Conclusion and Future work

- Take advantage of three opportunities
  - Piggyback MCS data packet
  - Cellular radio state opportunity
  - Orchestration among many devices
- Sense-Aid provides a generic framework for MCS development
  - Energy cost is below users' participation unwillingness threshold (2%)
  - Devices are fairly chosen to participate
- We will look at:
  - Dynamic tasks based on received data and coexistence with Wifi connected devices

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Q&A

Thank you!

Further discussion: zhan2614@purdue.edu

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