Poster Abstract: CoSense – A Collaborative Sensing Platform for Mobile Devices

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ABSTRACT

We introduce *CoSense*, a collaborative sensing platform for mobile devices that opportunistically distributes sensing tasks between familiar devices in close proximity. We use empirical energy measurements together with data collected from everyday transportation behaviour to demonstrate that our solution can significantly reduce power consumption while maintaining the best possible sensing accuracy.

Categories and Subject Descriptors

I.5.4 [**Pattern Recognition**]: Applications: Signal processing; H.4.m [**Information Systems**]: Information Systems Applications: Miscellaneous

General Terms

Algorithms, Experimentation

Keywords

Mobile Sensing, Collaborative Sensing

1. INTRODUCTION

The sensing capabilities of mobile devices have rapidly improved, enabling increasingly complex sensing tasks being run on personal mobile devices. Unfortunately these tasks tend to be power-hungry, significantly impacting the battery life of the device. We introduce CoSense, a novel collaborative mobile sensing platform that distributes sensing tasks between familiar devices that are in close proximity of each other. As people often travel with their friends or family, and increasingly carry multiple mobile devices, there are numerous opportunities for distributing sensing tasks between devices. We use empirical energy measurements together with data collected from everyday transportation behaviour to demonstrate that CoSense achieves significant power savings (over 230% when 5 devices share GPS measurements for 5 minutes) compared to running sensing independently on devices, while at the same time maintaining the best possible sensing accuracy.

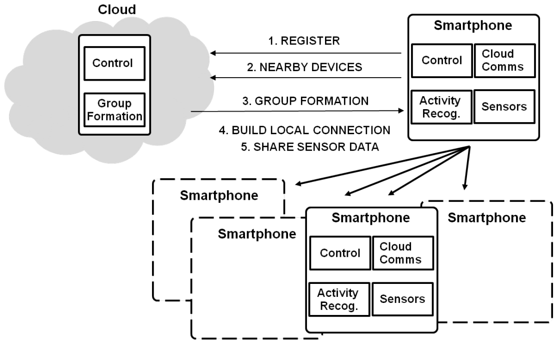

Figure 1: System Architecture Diagram.

2. THE COSENSE PLATFORM

We have developed CoSense to support typical mobile sensing tasks where mobile clients run certain sensing tasks and regularly communicate the sensed data to a backend server or a cloud component. CoSense extends the standard mobile sensing architecture by allowing devices that are in close proximity and are running the same sensing task to be grouped together into larger sensing units. Devices in a sensing unit then share sensor data and other resources between each other using local connectivity, significantly reducing power consumption compared to carrying out the tasks independently on each devices.

The sensing process of CoSense is illustrated in Fig. 1. Our current prototype runs on Android smartphones and uses a cloud backend for forming groups. The participating devices are required to register to the backend with their bluetooth mac address (1). The mobile clients initiate periodic Bluetooth scans whenever the user is mobile (detected using accelerometer and GSM) and send this information together with battery level, sensor status, network mode, and current activity to the cloud backend (2). When the backend detects collaboration opportunities, it informs the client nodes about the opportunity and the group members (3). The devices then use short-range communications to form a mobile ad-hoc network where a single device, *master*

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Component	Consumption
Receiving data	14/17/20 mW
Sending data	40/45/50 mW
GPS sensing	205 mW
Bluetooth Scan	4.2 J
Reporting to Cloud	2.0 J
Master node initialization	1.9 J

Table 1: CoSense Power Breakdown.

TMode	CSense	User 1	User 2	User 3
Stationary	70 / 71	57 / 79	76 / 55	42 / 67
Walk	95 / 99	98 / 93	95 / 96	99 / 92
Bus	72 / 86	71 / 82	55 / 86	71 / 90
Metro	76 / 91	60 / 78	63 / 83	67 / 82
Tram	92 / 70	89 / 63	78 / 63	88 / 60
Overall (%)	84	77	75	76

Table 2: Detection accuracy (precision / recall) of individual sensing versus collaboration.

node, serves as the gateway between the sensing unit and the backend (4). Currently we simply select the device with the highest battery level as the master node (5).

3. EXPERIMENTAL EVALUATION

CoSense is designed to provide significant savings in battery consumption while maintaining the best possible sensing accuracy. We use empirical energy measurements and data collected from everyday transportation behaviour to demonstrate that CoSense achieves these goals.

Energy efficiency. We evaluate energy efficiency through empirical power measurements collected using a Monsoon power monitor. We measured the power consumption of different CoSense components and compare these against the cost of running sensing tasks independently on multiple devices. We consider three distances between the sending and receiving devices: 15cm, 2m, and 10m. A decomposition of the power consumption for CoSense is shown in Table 1. From the measurements, we observe that both receiving ($14-20$ mW) and sending ($40-50$ mW) entail small cost, depending on the distance between the devices. Group formation, i.e., Bluetooth scan (4.2 J), reporting to the cloud (2.0 J) and the communication needed to initiate the master node (1.9 J) entail a constant power consumption of 7.1J.

Consider a scenario where n devices share the GPS measurements for t seconds. The cost of sensing on the n devices is $E_{CoSense} = t \cdot (E_{com} + E_{gps}) + P_{group}$ where $E_{com} = (n-1) \cdot 20mW + 50mW$ is the cost of short-range communications, $E_{gps} = 205mW$ is the cost of (continuous) GPS sampling, and $P_{group} = n \cdot (4.2J + 2.0J) + 1.9$ is the cost of group formation. Respectively, the cost of running the sensing independently on the devices is $E_{ind} = t * n * E_{gps}$. When $n = 5$, power consumption is reduced after 47 seconds, and halved after five minutes (133.4J vs. 307.5J, i.e., 231% savings). Note that these values do not take into account reporting costs and in practice the savings would be even higher as only a single device is sending data in CoSense compared to all n devices in personal sensing.

Sensing Accuracy. We next demonstrate the potential of CoSense to maintain, or even improve, accuracy while reducing power consumption. We consider data collected from three co-travelling mobile phones during everyday transportation behaviour. For transportation mode detection, we consider the GPS and accelerometer-based system presented in [3]. We consider the minimum of all accelerometer values to filter out user interactions, and use the GPS sensor with the highest accuracy. The results, detailed in Table 2, demonstrate an increase of $7-9$ % in overall F-score comparing to carrying out the sensing independently.

4. RELATED WORK

In one of the first works on collaborative sensing, the Haggle project [4] introduced a data-centric network architecture that can be used for collaborative sensing. Miluzzo et al. [1] introduce the Darwin phone, demonstrating the collaboration between nearby devices can improve accuracy of speaker recognition. Our work is also related to middleware frameworks for mobile sensing. An example is Code in the Air (CITA) [2], an API framework which supports creating task-based sensing applications and automatically distributes the code between the clients and the server. Closest to our work, *ErdOS* [5], is a mobile operating system which provides opportunistic access to computing resources in nearby devices. The authors demonstrate the energy-saving potential of ErdOS by simulating the sharing of GPS data between mobile devices. Contrary to our work, the focus of ErdOs is on providing opportunistic access to resources when needed, instead of trying to optimize resource consumption and sensing accuracy through collaboration.

5. SUMMARY AND OUTLOOK

We described CoSense, a collaborative sensing framework that allows mobile devices to form larger sensing units that share sensor data among themselves. We used a combination of empirical energy measurements and transportation behaviour data collected from everyday settings to show that CoSense can provide significant power savings while at the same time maintain, or even improve, the sensing accuracy. Our ongoing work focuses on improving support for dynamic topology changes resulting from the user mobility, e.g., devices leave or come in each others' proximity, and improving the resource allocation at the group formation stage.

6. REFERENCES

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