Finding a Data Blackhole in Bluetooth Scanning

Eiko Yoneki
University of Cambridge
Computer Laboratory
Cambridge, United Kingdom
Email: eiko.yoneki@cl.cam.ac.uk

Fehmi Ben Abdesslem
University of St. Andrews
School of Computer Science
St. Andrews, United Kingdom
Email: fehmi@cs.st-andrews.ac.uk

ABSTRACT

Bluetooth scanning has now been widely used in different scenarios to study users' mobility and their underlying social network. However, scanning for Bluetooth enabled devices does not always detect all the devices in range, mainly because of interference and obstacles. We are interested in quantifying the number of missed devices in different environments. The ExtremeCom workshop is an excellent opportunity to conduct measurements using GPS and Bluetooth scanning on mobile phones held by participants to infer how much data is missing in a rural environment.

1. INTRODUCTION

To analyse human mobility and understand the backbone social networks, we have been using the traces collected by phones and sensor boards (e.g. iMote) that detect the proximity of two devices by Bluetooth scanning. Bluetooth for proximity detection is widely available and a lot of people carry a Bluetooth enabled mobile phone with them. However, the Bluetooth protocol has some restriction to detect all the devices around, even when setting the scanning with recommended parameters. The rate of device discovery is also influenced by the number of devices in proximity distance. To better quantify this missing data, we are interested in measuring how many devices are missed by Bluetooth scanning in different scenarios such as in urban or rural environments.

The ExtremeCom workshop is an excellent opportunity to measure people's proximity in a rural environment. In this scenario, there will be only workshop participants' devices, making it easier to obtain clean data on proximity by Bluetooth scanning, with limited interference and open space environment. Each device will be featuring a GPS module, along with our custom software for Bluetooth device discovery. Device proximity will be logged, as well as their GPS location during at least 3 days. By comparing detected devices against in range devices (according to GPS positions), these experimental results will provide us with an idea of the scale of missing devices when scanning with Bluetooth. Moreover, another purpose of the experiment is to help designing appropriate algorithms to locate users with a minimum set of GPS devices.

We also plan to conduct a similar experiment in a urban environment by the time of ExtremeCom workshop, which reveals the scale of inference when many devices are in proximity range.

In our previous research, we inferred contact and intercontact time from the traces [2], which did not get too much impact from such missing data. However, we are looking into transitivity values for distinguishing co-location [6] and interaction and missing edges give high impact.

2. DEVICE DISCOVERY IN BLUETOOTH

Bluetooth is a low-power open standard for Personal Area Networks (PANs) and has gained its popularity due to its emphasis on short-range, low-power and easy integration into devices.

It is a complex task to collect accurate connectivity traces using Bluetooth communication, as the device discovery protocol may limit detection of all the devices nearby. Bluetooth uses a special physical channel for devices to discover each other. A device becomes discoverable by entering the inquiry substate where it can respond to inquiry requests. The inquiry scan substate is used to discover other devices. The discovering device iterates (hops) through all possible inquiry scan physical channel frequencies in a pseudo-random fashion. For each frequency, it sends an inquiry request and listens for responses. Therefore, a Bluetooth device cannot scan for other devices and be discoverable at the same time. Bluetooth inquiry can only happen in 1.28 second intervals. An interval of $4 \times 1.28 = 5.12$ seconds gives a more than 90% chance of finding a device. However, there is no available data when there are many devices around. The Bluetooth standard, recommends being in the inquiry scan substate for 10.24 seconds in order to collect all responses in an error-free environment. The power consumption of Bluetooth also limits the scanning interval. The iMote connectivity traces in Haggle [4] use a scanning interval of approximately 2 minutes, while the Reality Mining project in MIT [3], with mobile phones, uses 5 minutes.

In mobile phones, the Bluetooth range is usually 10m. We have observed the devices can be detected in 20m range if there is no obstacles, while if there is any obstacles such as a thick wall it limits to 5m range.

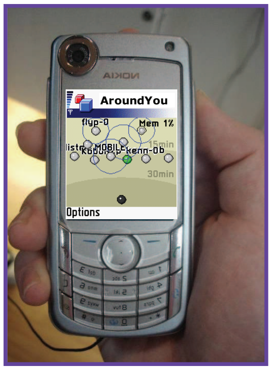

Figure 1: AroundYou running on a mobile phone

3. EXPERIMENTAL SETUP

The experiment will run over at least 3 days during the ExtremeCom workshop in a rural area. Participants can download our software called '*AroundYou*' from a web site to their mobile phones. Alternatively we can distribute devices with preloaded software to the participants (up to 20 devices). The software is written in Java J2ME and detects devices in proximity range and GPS information when the discovery is running. Those data are logged in the phone. Each day, we will operate *AroundYou* with a different scanning interval ranging from 2 minutes to 10 minutes to determine the optimal granularity of scanning interval. The power consumption is recorded in a daily base along the scanning interval and device classification.

AroundYou: *AroundYou* is an enhanced version of the software Wireless Rope [5], which collects information of surrounding Bluetooth enabled devices by periodic device inquiries and visualizes the results on the display of the phone. Logged data are kept within the device until the information can be automatically transmitted to a tracking device. The program does not involve any additional costs, e.g. for going online. The only requirements on the phones are the Java and built-in Bluetooth support, along with the JSR-82 API installed (available on-line). GPS information is collected when the phone gets into the device discovery operation. Figure 2 depicts the screenshot of *AroundYou* showing surrounding devices.

4. POST ANALYSIS

There will be series of analysis using the experiment results. Because the experiment is run in unique environments in a rural area, we focus on the follow two aspects:

Missing devices from Bluetooth discovery: We will obtain an accurate device location information when the device runs Bluetooth discovery. As we know device discovery range in the environment, the devices that should be discovered can be inferred. Especially since there are no obstacles in the open space, the estimation should give high accuracy. We plan to conduct the same type of experiment in a urban environment, where devices are always surrounded by many other Bluetooth devices. Comparing those two results will uncover the scale of missing devices in two different environments. The result can be used to obtain more accurate analysis in human connectivity traces. We are particularly interested in using the result for inferring 'meeting-group', where we infer interaction of people separating from collocation of people using transitivity closure values. High accuracy of device discovery is essential.

Localization: When we conduct human proximity information collection, a larger number of participants will give richer information. Thus far, we ran such experiments with iMote or inexpensive mobile phones without GPS. Now we are eager to obtain location information, since spatial information is important for understanding human activity and movement. Using GPS on all the devices would give the most accurate locations. However GPS is still far from being featured in every mobile phone nowadays. Moreover, GPS fails to acquire satellite signals indoors, and consumes far more energy than Bluetooth [1]. The experiment will provide sufficient data to help finding how we can efficiently locate all the devices with a minimum set of GPS equipped devices. It will also help determining the minimum ratio of GPS capable devices required to achieve localization of all the devices.

5. CONCLUSION

We propose to conduct an experiment in the ExtremeCom workshop to collect human proximity data in rural environment using Bluetooth scanning and GPS location. This serves as an experiment to collect data for later analysis. Particularly, the results enable us to infer the scale of missing devices when scanning with Bluetooth in a rural environment. Also, it will be useful to explore an efficient localization method with a minimum set of GPS equipped devices.

Acknowledgment. This research is funded in part by the EU grants for the Haggle project, IST-4-027918, and the SOCIALNETS project, 217141.

6. REFERENCES

[1] F. Ben Abdesslem, A. Phillips, and T. Henderson. Less is more: Energy-efficient mobile sensing with SenseLess. In *Proceedings of ACM SIGCOMM Mobiheld workshop*, Aug. 2009.

[2] A. Chaintreau, P. Hui, J. Crowcroft, C. Diot, R. Gass, and J. Scott. Impact of human mobility on the design of opportunistic forwarding algorithms. In *Proceedings of INFOCOM*, pages 1–13, Apr. 2006.

[3] N. Eagle and A. Pentland. Reality mining: sensing complex social systems. *Personal and Ubiquitous Computing*, v10(4):255–268, May 2006.

[4] Haggle Project. http://www.haggleproject.org, 2008.

[5] T. Nicolai, E. Yoneki, N. Behrens, and H. Kenn. Exploring social context with the wireless rope. In *On the Move to Meaningful Internet Systems 2006: OTM 2006 Workshops*, pages 874–883. Springer, Nov. 2006.

[6] E. Yoneki, D. Greenfield, and J. Crowcroft. Dynamics of inter-meeting time in human connectivity networks. In *Proceedings of ASONAM*, 2009.