# CobCel: Distributed and Collaborative Sensing of Cellular Phone Coverage Using Google Android

Jonathan Pino and Jorge E. Pezoa
*Electrical Engineering Department and The Center for Optics and Photonics*
*Universidad de Concepción, Concepción, Chile*
*Email: {jonpino,jpezoa}@udec.cl*

***Abstract*—This paper presents CobCel, a prototype Android application for measuring, in a distributed and collaborative manner, the cellular coverage as perceived by the users of mobile devices. Unlike specialized cellular coverage tests, CobCel samples the received signal strength indication (RSSI) using smartphones operated by their own users. The sensed RSSI is supplied with the geographical location of the device, and this supplemented information is next transmitted to a server which aggregates the collaboratively sensed data and displays a historical cellular coverage map as perceived by the cellphone users. Data collected by CobCel is intended to be used not only to report cellular coverage, but also to create open-source databases of cellular coverage and end-users mobility patterns. Further, it has been noticed after analyzing the data that real-world RSSI samples seems to follow a heavy-tail law instead of the chi-squared distribution usually assumed in theory.**

***Keywords*-Distributed Sensing; RSSI; Collaborative Sensing; Google Android**

## I. INTRODUCTION

Cellular networks are nowadays extensively used to provide voice and data services. The major concern of cellular service providers is supplying a high quality service to their customers. The aforementioned quality-of-service is primarily assessed by measuring cellular network coverage using standard tests and specialized equipment [1]. Lately, customers, which are always concerned about obtaining the quality-of-service they are paying for, have taken the matter (literally) in their own hands and exploited the capabilities of modern smartphones to conduct their own assessment of the cellular coverage. Examples of such efforts are the website CellReception [2] and applications like Sensorly and OpenSignalMaps [3], [4].

CobCel is yet another application for collaboratively measuring the cellular coverage of cellphone systems. CobCel is a prototype Android application that differs from specialized cellular coverage tests in several ways. First, specialized test use expensive equipment to take samples of the received signal strength indication (RSSI) [5] CobCel instead uses inexpensive smartphones as sensors. Second, specialized test take data on the streets from a moving or fixed vehicle [5], while CobCel collects samples of the RSSI not only on the streets, but also at any location a user of a mobile phone may visit during the day such as buildings, elevators, shopping malls, etc. Third, during drive-tests, antennas are usually either outside of the vehicle or inside of the vehicle at a place where occlusions can be reduced [5]. CobCel is an end-user application which no requires special attention from the user, hence, samples of the RSSI are typically taken from users' pockets, bags, purses, etc. Lastly, drive tests normally conduct measurements using pre-established routes and places [5]. Since CobCel takes samples from several users at any time in a collaborative manner, the geographical and temporal diversity achieved by the samples of the RSSI is large, thereby creating a well-representative data pool of the cellphone coverage. Because of this geographical and temporal diversity, data collected by means of CobCel is intended to be used not only to assess and report cellular coverage, but also to create an open-source database of cellular coverage and end-users mobility patterns.

This paper is organized as follows. In Section II, we present related work on the subject. In Section III, we describe the design of the CobCel application. Section IV presents results. Our conclusions are given in Section V.

## II. RELATED WORK

Among all the applications available to measure the cellular coverage, Sensorly [3], and OpenSignalMaps [4] are the most popular. These applications are of special interest to this work because they serve the same purpose as CobCel. Sensorly is an Android-based application and a website aiming to help cellular phone operators to improve their network quality [3]. Sensorly collects, processes, and displays end-user supplied measurements of the signal quality of 4G [6], CDMA [7], GSM [7], and WiFi [8] networks from all over the world, thereby providing "a unique perspective on network experience as perceived by real life users" [3]. Sensorly provides to its users free maps on both the Android Market and the Internet. Unlike CobCel, Sensorly provides as well information on the network speed, the cause of dropped calls, and means to compare different service providers. Similarly, the software OpenSignalMaps, developed by Staircase 3 Inc., has built a database of cell phone towers, cell phone RSSI, and Wi-Fi access points from all over the world. Data is sensed collectively by the end-users running OpenSignalMaps' Android application [4]. As in

 ISBN: 978-1-61208-231-8 

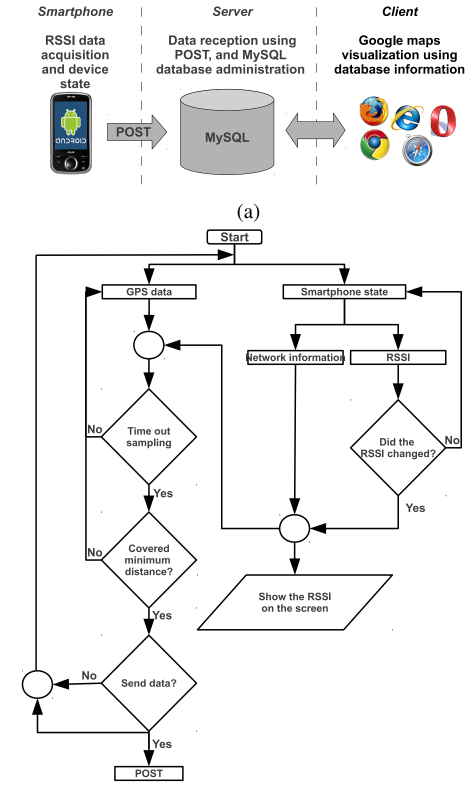
the case of Sensorly, OpenSignalMaps shows at its website the collected data and plots also heat maps exhibiting the strength of the received signal at any particular area. Some of the unique features of OpenSignalMaps are the display of the signal direction and the display of radar views of cell towers and Wi-Fi routers. It must be commented that both applications, Sensorly and OpenSignalMaps, take care of privacy issues, and aim to save processing power and battery. CobCel differs from any other application is that the data collected is intended to be used not only to assess and report cellular coverage, but also to create an open-source database of cellular coverage and end-users mobility patterns.

## III. Application Design

**Overview.** CobCel exploits the standard functions supplied by Google Android to read cellphone's RSSI. In addition, and to provide a fairly accurate geographical location for the measurements, GPS information is also collected. Once the RSSI is sensed, a fixed-size data packet, which contains additional information such as time, local area code (LAC), and mobile network code (MNC), is created and transmitted to a server which aggregates the sensed data and displays a historical cellular coverage map as perceived by the cellphone users. CobCel and its associated visualization system is an open-source effort which exploits both Google's software tools and MySQL [9] to yield a distributed sensing platform which allows to measure and display the RSSI at any geographical location. Figure 1(a) depicts the overview of the CobCel and its storage and display platform.

**Requirements.** In developing CobCel, the following requirements have been considered: (i) the operating system must be Android 2.2 for compatibility; (ii) a GPS locator must be available to accurately locate the RSSI samples; (iii) the smartphone must be able to query the LAC, the MNC, and the cellular tower ID, to properly store and display cellular network information; (iv) the use of CPU, storage, and batteries must be scarce; and (v) the anonymity of the sensed data must be guaranteed. The last requirement is achieved by never storing or sending smartphone's sensible information such as the international mobile equipment identity (IMEI). Also, the user must be capable of adjusting the following parameters: the minimum time between consecutive samples, the minimum distance between consecutive samples, and enabling/disabling the energy savings policy (ESP).

**Battery savings.** The following means have been provided in CobCel to save batteries. First, the type of communication to be used by the smartphone prior to transfer the sensed data. According to [10], a Wi-Fi connection consumes less power than a cellular data connection; we have prioritized the use of a Wi-Fi connection over cellular data. Second, due to the sensed data is not time-sensitive, an ESP that delays the transmission of the sensed data until the smartphone is connected to a Wi-Fi network has been




(a)

(b)

Figure 1: (a) Overview of the CobCel application and its storage and display platform. (b) CobCel's flow diagram.

implemented. Third, and also to provide the user a means to adjust the amount of data to be sensed and transmitted, we have included in CobCel parameters for selecting the sampling time and distance of the application.

**Application's state definition.** According to the modes of operation of a smartphone, the battery savings policy, and the application requirements, the following states have been defined for the CobCel application. *State 1:* the smartphone has cellular coverage, data service, and the ESP is disabled. *State 2:* the smartphone has cellular coverage, data service, and the ESP is enabled. *State 3:* the smartphone has cellular coverage yet no data service, and the ESP is either enabled or disabled. *State 4:* the smartphone has no cellular coverage. *State 5:* the smartphone is in airplane mode or any other mode where RSSI cannot be sampled.

All the aforementioned application states and requirements, as well as the energy constraints, have been considered in the design of CobCel's work flow, which has depicted in Fig. 1(b). The most relevant steps in the application work flow are detailed next. Once the application is executed the state of the smartphone is determined. If the smartphone is in state 1, 2, or 3, the RSSI is sampled using the function `getSystemService()`. Clearly, for the other two states, the RSSI cannot be retrieved. Simultaneously, and if the smartphone is in state 1, 2, or 3, the geographical location of the device is acquired using Android's class `LocationListener` and the function `requestLocationUpdates()`. Next, if the RSSI was sampled, CobCel checks if both the minimum time and the minimum distance criterion between consecutive samples has been fulfilled to store the sampled RSSI value. Finally, CobCel checks if the ESP is disabled, and if it does, it sends the data prioritizing the use of a Wi-Fi connection over a cellular data service. Otherwise, CobCel follows the ESP and delays the transmission of the sensed RSSI data until the smartphone is connected to a Wi-Fi network.

## IV. Results

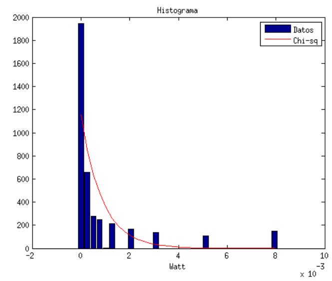
The CobCel application is available at the Google Play store [11]. To date, the application has been installed more than 5,000 times and data from several countries has been collected in our database. Figure 2(a) shows a sample map of the cellphone coverage in Concepción, Chile. We comment that date and time information are also transmitted with the RSSI and geographical position samples. Thus, we note that, with this spatial and temporal information, we may indeed use CobCel's sampled data to generate an open-source database of actual end-used mobility. As an example of this added feature, we comment that the map in Fig. 2(a) does correspond to a sample mobility test of an Android user in downtown Concepción.

Lastly and to show the potential of CobCel in generating an open-source database of cellular coverage, we fitted an empirical distribution for the RSSI and compared it to its theoretical distribution. According to most theoreticians, the RSSI in open areas follows closely a chi-squared distribution [7]. The fitted and theoretical distribution for the RSSI are shown in Fig. 2(b). The fitted distribution was constructed by pooling data from several users connected to the same cellular tower, and due to the non-Gaussian nature of the data, we employed Doane's formula to determine the number of data bins. From Fig. 2(b) we conclude that real-world data seems to follow a heavy-tail law instead of a chi-squared.

## V. Conclusion and Future Works

We presented CobCel, a prototype application for measuring, in a distributed and collaborative manner, the cellular coverage as perceived by the users of mobile devices. By sampling the RSSI and the geographical location of a mobile device, historical maps of cellular coverage can be displayed allowing the users to assess the service supplied by different service providers. Data collected by CobCel is intended to be used not only to report and assess cellular coverage, but also to create open-source databases of cellular coverage and end-users mobility patterns. The application is available for testing at Google Play and appears to be a useful tool for creating open-source databases of cellular coverage and end-users mobility patterns.


(a)




(b)

Figure 2: (a) Sample map of the cellphone coverage in Concepción, Chile. (b) Fitted and theoretical RSSI curves.

As a future work, we will merge the RSSI measurements with speed, reliability, and availability measurements and we will conduct surveys with the goal of measure the quality of experience of the users in regards to their service providers.

## Acknowledgment

The authors acknowledge the support of Fondecyt Project 11110078 and Basal Project FB024.

## References

[1] I. Kostanic, N. Mijatovic, and S. Vest, "Measurement based qos comparison of cellular communication networks," in *IEEE Int. Workshop on Com. Quality & Reliability*, 2009.
[2] Mobiledia, "Cell reception," Internet: http://www.cellreception.com/, 2002, [Online; retrieved: September 2012].
[3] Sensorly, "Coverage Maps Sensorly," Internet: http://www.sensorly.com/, 2011, [Online; retrieved: September 2012].
[4] Staircase 3 Inc., "OpenSignalMaps - Cell Phone Tower and Signal Heat Maps," Internet: http://opensignalmaps.com/,, 2012, [Online; retrieved: September 2012].
[5] W. Lee, *Mobile Communications Eng.* McGraw-Hill, 1982.
[6] E. Dahlman, S. Parkvall, and J. Skold, *4G: LTE/LTE-Advanced for Mobile Broadband*. Academic Press, 2011.
[7] D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*. Cambridge University Press, 2005.
[8] C. Smith and J. Meyer, *3G Wireless with 802.16 and 802.11: WiMAX and WiFi*. McGraw-Hill, 2011.
[9] Oracle, "MySQL," Internet: http://www.mysql.com, 2012, [Online; retrieved: September 2012].
[10] Google Inc., "Coding for Life–Battery Life, That Is," Internet: http://www.google.com/events/io/2009/sessions/Coding-LifeBatteryLife.html, 2009, [Online; retrieved: September 2012].
[11] J. Pino and J. E. Pezoa, "CobCel: Cobertura Celular," Internet: https://play.google.com/store/apps/details?id=itux.cobertura.cl, 2012, [Online; retrieved: September 2012].

 ISBN: 978-1-61208-231-8 