# Making Crowdsensing Possible

*A short review for "Crowdsourcing to Smartphones: Incentive Mechanism Design for Mobile Phone Sensing"*

Edited by Pavel Korshunov

*D. Yang, G. Xue, X. Fang, and J. Tang, "Crowdsourcing to Smartphones: Incentive Mechanism Design for Mobile Phone Sensing," in Proceedings of ACM International Conference on Mobile Computing and Networking (MobiCom), pp. 173-184, 2012.*

The number of smartphones in use globally has reached the 1-billion milestone in the third quarter of 2012. It is projected that this number will double by 2015 [1]. Meanwhile, smartphones are programmable and equipped with a set of cheap but powerful embedded sensors, such as accelerometer, digital compass, gyroscope, GPS, microphone, and camera. These sensors can collectively monitor a diverse range of human activities and surrounding environment. One can leverage millions of personal smartphones and a near-pervasive wireless network infrastructure to collect and analyze sensed data far beyond the scale of what was possible before, without the need to deploy thousands of static sensors. The term *crowdsensing* is coined specifically for this type of sensing paradigm [2].

Realizing the great potential of crowdsensing, many researchers have developed numerous applications and systems, such as Sensorly [3] for making cellular/WiFi network coverage maps, Nericell [4] and VTrack [5] for providing traffic information, PIER [6] for calculating personalized environmental impact and exposure, and Ear-Phone [7] for creating noise maps. However, most of such systems are based on voluntary participation, which is not a fair model of crowdsensing for the users providing the information.

When smartphone users participate in a crowdsensing task, they consume their own resources such as battery and computing power. The users also expose themselves to potential privacy threats by sharing their sensed data with embedded location tags. Therefore, an incentive-based model of crowdsensing would be fairer to the participating users.

In this paper, the authors consider two main types of incentive mechanisms for crowdsensing systems: platform-centric and user-centric. In a more conventional platform-centric incentive based system, the total payment is set by the platform and users can only choose their actions accordingly. In systems adapting the user-centric incentive mechanism, a user sets a reserve price, the lowest price at which he is willing to sell a service, and the platform selects a subset of users that it can afford to pay them not lower than the specified reserve price.

The paper presents important theoretical foundations for two incentive mechanisms under consideration, presenting proofs, algorithms, and approximations for optimal or near optimal behavior strategies of the platform and users. A set of desirable properties for such strategies is also provided with simulation experiments evaluating different parameters of the approximation algorithms.

Platform-centric incentive mechanism is modeled after Stackelberg game [8], and, hence, finding optimal strategies for the platform and the users is reduced to efficient algorithms for computing Stackelberg Equilibrium. The authors provide proofs and algorithms for the platform to efficiently, with complexity similar to sorting, compute an optimal value of the overall incentive. Similar, an optimal strategy for the users is provided, which maximizes their payment when a known overall incentive value is set by the platform.

For a user-centric incentive mechanism, the authors prove, using reverse auction model [9], that the problem of finding optimal strategy is NP-hard. Therefore, two approximation strategies are presented: Local Search-Based (LSB) and MSensing. Simulation experiments demonstrated that both strategies satisfy the following set of desirable properties: 1) computational efficiency: the platform is able to compute the outcome of the auction in polynomial time; 2) individual rationality: each honest participating user can expect a non-negative utility value; 3) profitability: the value contributed by the selected smartphone users is not less than the total payment paid to the winning users; and 4) truthfulness: each smartphone user maximizes its utility by reporting its true cost.

To summarize the overall contribution, the paper sets an important theoretical foundation for practical crowdsensing systems that want to utilize sensing capabilities of millions of smartphones. The authors consider platform-centric and user-centric models of incentive mechanism for motivating smartphones users to participate in crowdsensing. Necessary algorithms and guidelines are provided that can help in designing efficient incentive-driven scalable crowdsensing applications.

**References:**


[1] J. Yang, "Smartphones in Use Surpass 1 Billion, Will Double by 2015," *Bloomberg*, October 22, 2012. http://www.bloomberg.com/news/2012-10-17/smartphones-in-use-surpass-1-billion-will-double-by-2015.html

[2] R.K. Ganti, F. Ye, and H. Lei, "Mobile crowdsensing: current state and future challenges," IEEE Communications Magazine, vol. 49, no.11, pp.32–39, November 2011

[3] Sensorly. http://www.sensorly.com.

[4] P. Mohan, V. N. Padmanabhan, and R. Ramjee, "Nericell: rich monitoring of road and traffic conditions using mobile smartphones," In Proceedings of ACM Conference on Embedded Networked Sensor Systems (SenSys), pp. 323–336, November 2008.

[5] A. Thiagarajan, L. Ravindranath, K. LaCurts, S. Madden, H. Balakrishnan, S. Toledo, and J. Eriksson, "VTrack: accurate, energy-aware road traffic delay estimation using mobile phones," In Proceedings of ACM Conference on Embedded Networked Sensor Systems (SenSys), pp. 85–98, November 2009.

[6] M. Mun, S. Reddy, K. Shilton, N. Yau, J. Burke, D. Estrin, M. Hansen, E. Howard, R. West, and P. Boda, "PIER, the personal environmental impact report, as a platform for participatory sensing systems research," In Proceedings of ACM International Conference on Mobile Systems, Applications, and Services (MobiSys), pp. 55–68, June 2009.

[7] R. Rana, C. Chou, S. Kanhere, N. Bulusu, and W. Hu, "Ear-Phone: An end-to-end participatory urban noise mapping," In Proceedings of ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN), pp. 105–116, April 2010.

[8] D. Fudenberg and J. Tirole. Game theory. MIT Press, 1991.

[9] V. Krishna. Auction Theory. Academic Press, 2009.


**Pavel Korshunov** is a postdoctoral researcher in Multimedia Signal Processing Group at EPFL. He received his Ph.D. in Computer Science from National University of Singapore and Dipl. Sci. in Mathematics from Saint-Petersburg State University (Russia). He is a recipient of ACM TOMCCAP Nicolas D. Georganas Best Paper Award in 2011. He is involved in EC funded VideoSense project (privacy in video surveillance), as well as, COST Actions HDRi (high dynamic range imaging) and Qualinet (quality of experience in multimedia). His research interests include computer vision and video analysis, video streaming, video and image quality assessment, crowdsourcing, high dynamic range imaging, and privacy issues in multimedia.