Smart Parking with Fine-grained Localization and User Status Sensing Based on Edge Computing

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***Abstract*—Parking at an affordable place is the precedent task for all activities of the everyday life in urban environments such as shopping, working, exercising, etc. So, it is the most common and essential requirement of all users in a car park to fast search a preferred parking spot closely associated their current intent. Although modern parking lots have installed the sensing and display systems to inform drivers on the availability of parking areas, such systems are unable to tell drivers exact parking spots and make any recommendation to improve the traffic conditions and driver experiences. In this paper, a novel analytic-based smart parking system clustering Internet of Things, smart mobile devices and edge computing is proposed. This novel parking system aims at providing customized parking experience to users through highly accurate positioning and user status detection which are achieved by joint mobile sensing-machine learning based analytics as the edge intelligence. Based on the proof-of-concept implementation, the proposed scheme can achieve 99.1% positioning accuracy of a parking spot; in terms of user status sensing, especially getting in a car and out of a car, detection accuracy shows 96%; finally, it shows much shorter service consumption time of 15.6 times than the legacy approach.**

***Index Terms*—Smart parking, Internet of Things, Bluetooth low energy, status sensing, proximity detection, analytics.**

I. Introduction

Nowadays, parking is one of the most important and highly common daily behaviors. However, searching not only a parking lot but also a parking spot in a lot is highly time-consuming application for people in many urban environments such as on-street parking lots in down towns, shopping mall parking buildings, campus parking places, and so on. So, various intelligent schemes for parking have been developed so far [2] - [6]. The schemes have mainly taken into account solutions and mechanisms regarding to restrictions and difficulties of parking service providers in citywide. Hence, they have concentrated on optimizing utilization of parking places in the citywide view, fact allocation of a parking lot with rough spot availability information, etc.

In a parking lot, Global Positioning System (GPS) and WiFi signal strength based localization are commonly employed for parking position detection of vehicles [2] - [10]. GPS is usually used to indicate the position of a parking lot due to its large error scale and restriction in indoor environments [13]. On the other hand, such WiFi based technologies such as WiFi fingerprint or trilateration are able to offer tens-meter-scale localization, but it also not precise and flexible enough for vehicle position detection. If a car park is an outdoor parking lot, they do not fulfill well since signals are usually lower in outdoor environments. Moreover, WiFi is an expensive technology considering the number of access points required for a big parking lot or multi-layered parking building. According to a state-of-the-art research [10], the accuracy of WiFi fingerprint with one access point per 100 m^2 is 8.5 meter in an indoor place. It cannot achieve about 1.5 meter-scale localization to distinguish each parking spot.

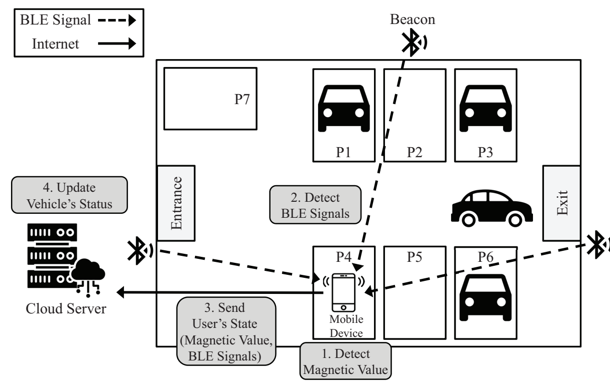

Fig. 1. M2PARK architecture of an outdoor parking lot.

In recent, Apple Inc. introduced iBeacon in 2013 and Google launched Eddystone in 2015 which are the classes of Bluetooh low energy (BLE) based beaconing systems. The beacons of such systems are battery-functioned small devices to periodically broadcast IDs to proximity. Up-to-date research has proposed more accurate localization or indoor position-based applications [10] [15]. Meanwhile, smart mobile devices have become popular for sensing user behaviors and actions via embedded sensors on the mobile devices such as GPS, accelerometer, gyroscope and compass [11]- [15]. This sensing can help to understand user situation. However, the accuracy of existing studies for BLE beacon based localization does not achieve the resolutions for the parking spot scale (i.e., about 5 meters [10]). So, fine-grained localization of vehicles in indoor and even outdoor places should be newly designed and conducted for smarter parking application.

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Since the existing parking schemes [2] - [6] have been mainly developed in perspectives of service providers as well as the localization accuracy is not high enough, the paper comes up with a novel smart parking scheme to breakthrough such restriction of previous studies in terms of positioning accuracy and user understanding. The proposed scheme relies on mobile sensing and machine learning to recognize user status in parking places and high resolution localization of vehicles with users, denoted by M2PARK (Mobile sensing and Machine learning to provision customized PARKing). M2PARK consists of three layers: 1) high resolution localization, 2) comprehensive user and vehicle status sensing, 3) user status change analyses. M2PARK is developed with BLE-beacon based IoT infrastructure, smart mobile devices with interface applications, and edge computing. In this paper, the proof-of-concept over a real test-bed at an outdoor parking lot in the campus is implemented, and all experiment results are conducted through the real test-bed and implementation. Fig. 1 illustrates of architectural overviews of M2PARK.

The rest of this paper is structured as follows: Section II explains related work; Section III presents high resolution localization; Section IV addresses user/vehicle status sensing and user intent detection with data analysis data from mobile devices; Section V describes our testbed with experiment metrics and Section VI shows the results of the evaluation; and Section VII concludes the paper and provides future work.

II. Related Work

The previous studies on smart parking systems have mainly worked on dealing with available parking space search and parking fee reduction among multiple parking lots. For these purpose, SPARK scheme [2] propose a parking scheme for large parking lots through vehicular communication. SPARK provides the drivers with real-time parking navigation service and friendly parking information dissemination. In addition, another system [3] is based on intelligent resource allocation, reservation, and pricing. The proposed system solves the current parking problems by offering guaranteed parking reservations with the lowest possible cost and searching time for drivers and the highest revenue and resource utilization for parking managers. The other system [4], named iPaker, is proposed for a smart parking for an urban environment. iPaker assigns and reserves an optimal parking space based on the driver's cost function which combines proximity to destination and parking cost. Also, in [5] C. Tang *et al.* provides a avalable parking lot information service in a citywide area by the vehicular ad hoc networking (VANET) and fog computing technologies. In addition, [6] introduces the on-street parking places searching technology based on the sonar and camera embedded on a vehicle which has GPS devices and cellular communication channels.

Indoor positioning is a mature research field [7]- [10] [15]. The focus is on positioning through pattern-matching the current signal detection to a previously surveyed map of signal strengths. Today the most common technology used in indoor places is WiFi [10]. WiFi positioning is tightly integrated into many mobile platforms, providing urban localization on the scale of about 10 meters. WiFi signal pattern matching, or fingerprinting, is the de-facto localization technique for indoor positioning on user devices today. Other candidates for radio fingerprinting are cellular and Bluetooth signals. Cellular sources are typically too sparsely distributed to provide good indoor fingerprints, whereas most notably the very lengthy scan times. The recent introduction of the Bluetooth 4.0 specification has potentially addressed these problems via the Bluetooth low energy (BLE). The recent work for indoor BLE beacon fingerprinting [10] shows about 5 meter accuracy.

Recent smart interactive systems are commonly based on notification by BLE advertising to smart mobile devices such as smartphones and tablets. When a user receive a notification in terms of availability of interaction, i.e., smart mobile devices receive BLE advertising message, the user can recognize such smart way. Smart home application is built with BLE beacons for interactive services and energy saving [15]. Also, interactive digital signage is exploited to increase the effectiveness of advertising [16]. For edutainment sector such as museums, galleries, exhibition halls, classrooms, etc., smart mobile devices-beacon interactive features can enhance the users' learning experiences [17].

In consequence, the existing smart parking systems are mainly based on the high utilization of parking spots over multiple parking lot environments. Also, the accuracy of locating cars is merely a car park level or parking zone scale, based on GPS or WiFi in common. On the other hand, BLE beacon is deployed at indoor places for smart mobile device-proximity things interaction in common. Furthermore, the current BLE beacon based positioning technology cannot achieve accuracy requirement for parking spots.

III. M2PARK Design

Urban public spaces are being progressively fitted with Internet of Things (IoT) composed of ambient sensors, actuators and beacons running Bluetooth Low Energy (BLE) that help to offer continuous observability and interactivity from/to physical environments. Each beacon device constantly broadcasts its unique identifiers to nearby smart mobile devices to perform creative interactions between a mobile applications and an associated cloud system for users in close proximity. So, the clustering such paradigms (i.e., BLE beacon based IoT infrastructures, smart mobiles and cloud computing) is clearly a compelling and timely research issue. Fig. 1 shows this jointed architecture for smart applications. Here, the BLE beacon infrastructure is deployed at indoor place as well as outdoor places. Then, based on this systemic infrastructure, M2PARK is conducted as mobile applications and a edge computing system mainly. In mobile applications, M2PARK has three key functionalities as follows:

1) acquisition of radio signal strength indicators (RSSIs) of BLE beacon deployed at a parking lot and sensing data from smart mobile devices of a user (driver) of a vehicle into an edge computing node;

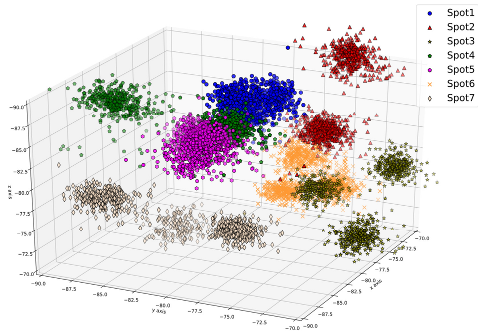

Fig. 2. Raw RSSI data before denosing autoencoder

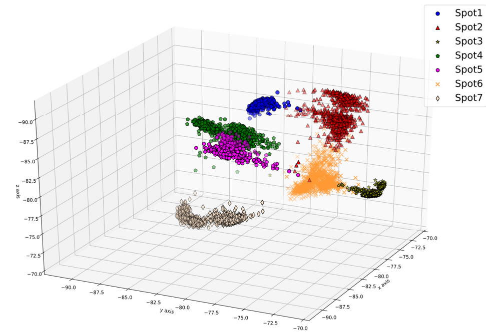

Fig. 3. RSSI data after denosing autoencoder

2) fine-grained localization measurement of the vehicle and user status detection through machine learning technologies, support vector machine (SVM), multilayer perceptron (MLP), convolutional neural network (CNN), and autoencoder;

3) user status change recognition based on user status detection and fine-grained localization for user-customized parking services.

In addition, in the edge there are four main functionalities such as smart space environmental and deployed equipment manager, user and content managers for parking and its relevant services, and push notification manager.

Fig. 1 shows the real on-street parking lot testbed in the campus where BLE beacon are deployed and a associated building with three entrances exists. Table I addresses possible status of users or vehicle in a car park and reactions from user intent detection based on the status. To react such actions to users in a car park, this paper describes the high-resolution positioning mechanism.

A. *High-Resolution Proximity Estimation*

In order to empower smart parking system with capabilities to make recommendation and analytics based on occupancy rate, localization of user/vehicle plays a pivotal role. However, to enable this vision, construction of reliable and scalable infrastructure and corresponding localization method is vital. In this section, high-resolution proximity estimation system, a novel localization method that utilized BLE beacon infrastructure, is introduced. Commonly, BLE beacons are not suitable for fine-grained localization application due to its severe fading effects. Consequently, BLE beacons were mainly used for application that requires proximity detection, where each beacon was mapped to a single physical location to provide contextual/locational information. However, proximity based infrastructure is quite expensive due to the number of beacons required. The proposed system attempts to improve the existing proximity based infrastructure, by compromising accuracy for its deployment cost.

1) Setup and Methods: To conduct this experiment, testbed of BLE beacon infrastructure was constructed as shown in Fig. 1. The testbed was composed of 3 BLE beacons, configured at advertising interval of 800 ms. To collect training data, RSSIs of BLE beacons at each parking spots were recorded for 10 minute. Raw data was constructed with following elements: time of reception is ms, MAC address of BLE beacon, RSSI value, parking spot where the signal was received. Raw data consisted of 14,000 training examples.

Spot	1	2	3	4	5	6	7	Recall
1	997	1	3	0	0	0	0	1.00
2	0	987	3	6	4	0	0	0.99
3	0	1	999	0	0	0	0	1.00
4	0	8	0	987	2	3	0	0.99
5	5	0	1	9	985	0	0	0.99
6	0	20	0	0	0	980	0	0.98
7	0	0	0	0	1	0	999	1.00
Precision	1.00	0.97	0.99	0.99	0.99	1.00	1.00	

Fig. 4. Confusion Matrix of CNN for localization

After the setup of raw data, we exploit an autoencoder for denosing the data to differentiate core features of data. Fig. 2 illustrates raw RSSI data before denosing autoencoder and Fig. 3 shows denosed RSSI data after the autoencoder. As shown in these two graphs, denosing autoencoder could distinguish signal difference more clearly. The denosed data become the input data of three machine learning technologies to measure positions of user.

2) Estimation Results: The proximity estimation results of 1,000 test data via those three methods are 98.5% (SVM), 99% (MLP), and 99.1% (CNN). In fact, these results are based on 1.60%, 1%, and 0.4% increment comparing with results by the raw data before autoencoder denosing, respectively. Fig. 4 presents the confusioni matrix of CNN results.

B. *User Status Sensing and Status Change Recognition*

This subsection explains procedures of user and vehicle status sensing, which are addressed in Fig. 5 and Table I, through BLE beacon signals, GPS, accelerometer, magnetometer, and so on. Although many previous studies mentioned restriction of some wireless signals and sensors are not affordable and feasible for user status sensing, we have done our own preliminary experiments about all possible sensor and signal data. By preliminary experiments, we have ensured that light sensor, WiFi, cellular, and accelerometer could not be considered for this parking system case. On the other hand, magnetometer and orientation sensors show very meaningful data for detecting user and vehicle status. Particularly, magnetometer sensing results illustrates practical features to detect user activities

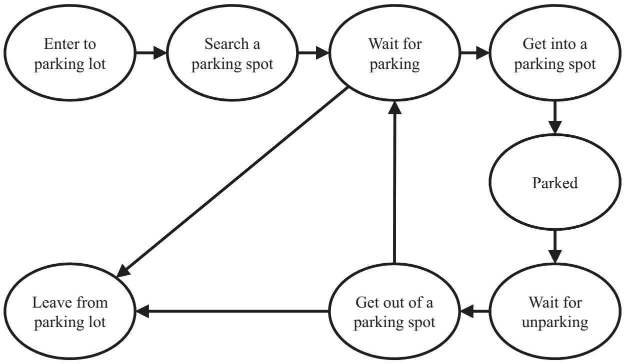

Fig. 5. State diagram of M2PARK

TABLE I
STATE TABLE TO RECOGNIZE USER STATUS CHANGE

Case	NO.	State	Before	After	Vehicle's position
Enter	1	Enter to parking lot	–	In	Entrance
	2	Search a parking lot	In	In	Entrance
Park	3	Waiting for parking	In	In	No spot
	4	Get into a parking spot	In	In	spot
	5	Parked	In	Out	spot
Unpark	6	Waiting for unparking	Out	In	spot
	7	Get out of a spot	In	In	spot
Leave	8	Leave from parking lot	In	In	Exit

related to the parking application, i.e., getting in a car and getting out of a car, as shown in Fig. 6. Our sensing data are trained for machine learning technologies to establish the activity detection mechanism.

Fig. 7 presents the accuracy of prediction results for the user status, i.e., getting In/Out a car, via CNN. Comparing with the other learning technologies such as SVM and MLP, CNN shows higher accuracy: 90.7% (SVM), 90% (MLP), and 96% (CNN). Based on accurate detection of the user activities on getting in/out a car, fine-grained location information of users could be exploited to recognize user status change according to Table I. For example, when a user does parking at a parking spot, the user will get OUT from the car. So, the parking system will register the spot place for the user, and it will inform the user the spot location. Also, the system will mark the parking spot is not available now, and it can trigger recommendation for guiding the user. The state diagram of Fig. 5 presents M2PARK operations for smart parking with localization, status sensing, and status change recognition.

IV. USER EXPERIENCE EXPERIMENTS

This section shows the proof-of-concept prototype to implement and evaluate the novel positioning mechanism and the new parking service paradigm. To implement M2PARK, this paper takes into account smart parking lot on the campus with eleven BLE beacons running the iBeacon protocol. Fig. 1 illustrates the testbed on the campus parking lot nearby a building. In terms of a edge computing system, Ubuntu, MySQL, and Django are set up on a desktop. The edge resources are utilized for content delivery by BLE beacon IDs and service management. A mobile application running the Android 6.0 is developed. For people sensing, the patterns and histories of BLE beacon and GPS signal reception and the sensing from sensors on the phone such as magnetometer and orientation sensors are analyzed. The experiments are fulfilled for positioning accuracy of our high resolution proximity estimation mechanism and the level of user experience for total experience time and complication of using system in parking situations as explained in Table I.

Fig. 8 illustrate average service utilization time for the parking lot service to see the service smartness. The legacy method means that combined service app unitization in the parking lot is based on an existing smartphone apps to search parking lot and the entrance of the building on the map, manual parking place search by walking around the parking lot, and the payment machine by a ticket while the developed app relying on the proposed framework is solely exploited for the parking service. The legacy approach shows much longer time of 15.6 times (530s) than the proposed methods (34s). Hence, by this total utilization time for whole parking service procedures, this paper could deliver that users should be experienced much faster and dedicated service provisioning. Fig. 9 shows the average communication cost for the smart parking lot service in comparison with the individual interaction manner by which individual interaction with each BLE beacon device every time to get proximal device detection as well as relevant content on the edge through on-hop broadcasting, the edge discovery by the ID of each beacon and individual request and

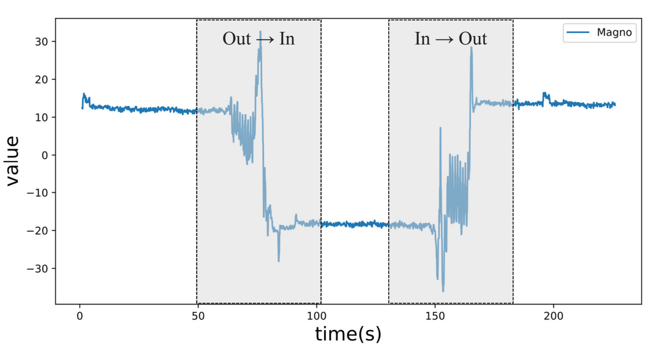

Fig. 6. Magnetometer sensing feature during in/out car

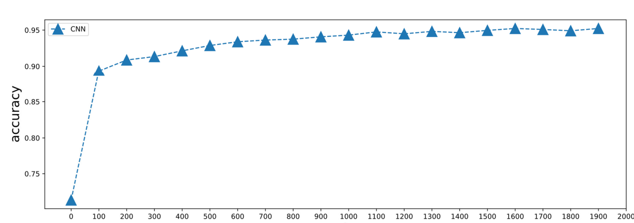

Fig. 7. Accuracy of CNN for in/out car

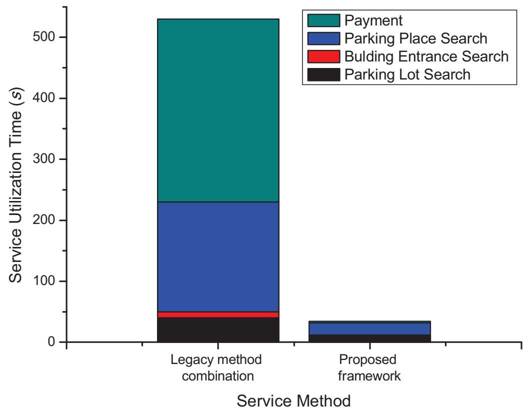

Fig. 8. Total time duration to use the parking lot service

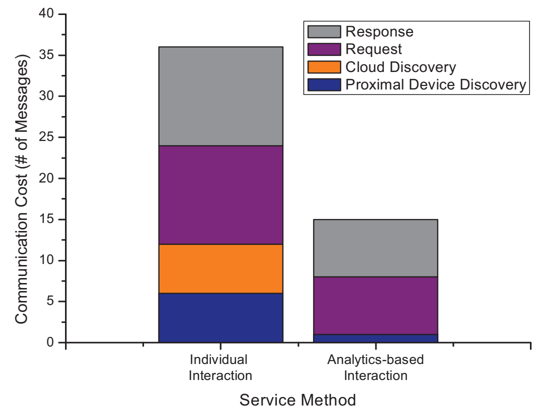

Fig. 9. Total communication cost

response message dissemination between the edge and the user smartphone. The communication cost is represented by the number of messages delivered. The analytics-based interaction of the proposed framework showed better performance than the individual interaction manner for 41.6%.

V. Conclusion and Future Work

This paper has proposed a user-dedicated smart parking scheme with the high resolution proximity estimation, user/vehicle status sensing and user intent based smart service. In this scheme, the first research of BLE beacon based outdoor localization with a parking spot scale have done. In addition, the data from sensors and wireless signals from smart mobile devices have been exploited to provide comprehensive user and vehicle status sensing mechanism. Based on the sensing, the edge-smart mobile device interaction is also implemented for user status change based smart service delivery to users in parking lots. The proof-of-concept shows implementation of this strategic system and provided experimental results to prove the system can improve the performance of parking service operations.

In future work, we will add dynamic occupancy ratio analytics to improve user experience about finding a right parking spot at right time. Also, social computing will be adopted on the cloud system for achieving better user preference understanding for more accurate user intent detection. In addition, all technologies will be experienced by practical users for real surveys of their experiences with fine-grained parking service utilization points.

References

[1] M. R. Palattella *et al.*, "Internet of Things in the 5G Era: Enablers, Architecture, and Business Models," *IEEE Journal on Selected Areas in Communications*, Vol. 34, No. 3, pp. 510-527, Mar. 2016.

[2] R. Lu, X. Lin, H. Zhu and X. Shen, "SPARK: A New VANET-Based Smart Parking Scheme for Large Parking Lots," in *Proc. of IEEE INFOCOM 2009*, Rio de Janeiro, 2009, pp. 1413-1421.

[3] Y. Geng and C. G. Cassandras, "New "Smart Parking" System Based on Resource Allocation and Reservations," *IEEE Transactions on Intelligent Transportation Systems*, Vol. 14, No. 3, pp. 1129-1139, Sep. 2013.

[4] A. O. Kotb, Y. C. Shen, X. Zhu and Y. Huang, "iParker-A New Smart Car-Parking System Based on Dynamic Resource Allocation and Pricing," *IEEE Transactions on Intelligent Transportation Systems*, Vol. 17, No. 9, pp. 2637-2647, Sep. 2016.

[5] C. Tang, X. Wei, C. Zhu, W. Chen and J. J. P. C. Rodrigues, "Towards Smart Parking Based on Fog Computing" *IEEE Access*, Vol. 6, pp. 70172-70185, 2018.

[6] C. Roman, R. Liao, P. Ball, S. Ou and M. de Heaver, "Detecting On-Street Parking Spaces in Smart Cities: Performance Evaluation of Fixed and Mobile Sensing Systems" *IEEE Transactions on Intelligent Transportation Systems*, Vol. 19, No. 7, pp. 2234-2245, Jul. 2018.

[7] G. Sun, J. Chen, W. Guo and K. J. R. Liu, "Signal processing techniques in network-aided positioning: a survey of state-of-the-art positioning designs," *IEEE Signal Processing Magazine*, Vol. 22, No. 4, pp. 12-23, Jul. 2005.

[8] R. Faragher and R. Harle, "SmartSLAM.An efficient smartphone indoor positioning system exploiting machine learning and opportunistic sensing," in *Proc. International Tech. Meet. Satell. Div. ION GNSS+*, Nashville, TN, USA, Sep. 2013, pp. 1006-1019.

[9] B. Ferris, D. Fox, and N. Lawrence, "WiFi-SLAM using Gaussian process latent variable models," in *Proc. 20th IJCAI*, San Francisco, CA, USA, 2007, pp. 2480-2485.

[10] R. Faragher and R. Harle, "Location Fingerprinting with Bluetooth Low Energy Beacons," *IEEE Journal on Selected Areas in Communications*, Vol.33, No.11, pp. 2418-2428, Nov. 2015.

[11] S. Saguna, A. Zaslavsky, and D. Chakraborty, "Complex activity recognition using context-driven activity theory and activity signatures," *ACM Trans. Comput.-Hum. Interact. (CHI)*, Vol. 20, No. 6, Article 32, Dec. 2013.

[12] S. Vigneshwaran, S. Sen, A. Misra, S. Chakraborti, and R.K. Balan, "Using Infrastructure-provided Context Filters for Efficient Fine-grained Activity Sensing," in *Proc. of IEEE International Conference on Pervasive Computing and Communications (PerCom '15)*, pp. 87-94, Mar. 2015.

[13] Vincent W. Zheng, Yu Zheng, Xing Xie, and Qiang Yang, "Collaborative location and activity recommendations with GPS history data," in *Proc. of the 19th ACM international conference on World wide web (WWW '10)*, New York, NY, USA, 1029-1038.

[14] Y. Fan, L. Xie, Y. Yin and S. Lu, "A Context Aware Energy-Saving Scheme for Smart Camera Phones Based on Activity Sensing," in *Proc. IEEE International Conference on Mobile Ad Hoc and Sensor Systems*, Dallas, TX, Oct. 2015, pp. 64-72.

[15] M. Collotta and G. Pau, "A Novel Energy Management Approach for Smart Homes Using Bluetooth Low Energy," *IEEE Journal on Selected Areas in Communications*, Vol. 33, No. 12, pp. 2988-2996, Dec. 2015.

[16] J. She, J. Crowcroft, H. Fu and P.-H. Ho, "Smart Signage: A Draggable Cyber-physical Broadcast/Multicast Media System," in *Proc. of IEEE International Conference on Green Computing and Communications*, Besancon, France, Nov. 2012, pp. 468-476.

[17] Z. He, B. Cui, W. Zhou, and S. Yokoi, "A Proposal of Interaction System between Visitor and Collection in Museum Hall by iBeacon," in *Proc. of International Conference on Computer Science and Education*, Jul. 2015, pp.427 - 430.