Location Technique based on Pattern Recognition of Radio Signal Strength using Active RFID

Romeo Mark A. Mateo, Insook Yoon and Jaewan Lee

School of Electronic and Information Engineering, Kunsan National University
68 Miryong-dong, Kunsan, Chonbuk 573-701, South Korea

Abstract. RFID technology is used by various application areas to implement smart data processing and ubiquitous system. In the recent research of parking system, implementing efficient and accurate location technique using active RFIDs are not considered. This paper proposes a location technique based on pattern recognition of radio signal strength using active RFID. Active RFID is used by cars for identification by sending signals to receiving sensors. The proposed pattern recognition based on multilayer perceptron (MLP) uses the pattern of radio signal to process accurate location technique. The procedure provides a training model for received signal strength (RSS) patterns in able to classify the signals and determine the exact slot. A parking simulator platform is used and compared the proposed method to other algorithms and found that MLP is more accurate classifier and faster in building the classification model.

1 Introduction

The current research studies in parking management system have realized the usefulness of ubiquitous technologies to automate car monitoring and provide smart processing of information in wireless environment. Most researches implement wireless sensor devices in sensing presence of car and monitoring location of cars [1, 2]. Relevant services in parking system like locator system for parked cars rely on monitored events and updated databases for data retrieval. However, issues of integrating radio frequency identification (RFID) with the wireless sensor networks (WSN) are not well studied. An example of integration issue is how to associate sensor devices to identification of cars (RFID tags) where the system can detect the presence of the car by WSN but cannot tell exactly the identification of car that parked on the slot [3]. This can be solved by location techniques using active signals [4] with the WSN's interactions. However, the interaction of the WSN and RFID must be efficiently designed.

Positioning techniques are important for monitoring the position of a mobile object. There are varieties of positioning techniques like global positioning system [5] which have accurate method of locating mobile or immobile objects. The GPS technology

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is limited on outdoor measurements of objects and not indoors. In this case, a location technique that can be used inside buildings is necessary. Some techniques like time of arrival (TOA), angle of arrival (AOA), and received signal strength (RSS) are used in indoors. Both TOA and AOA are more complex and costly compare to RSS. RSS is simple because it only needs to measure signal strength from the source and then calculate the position based on multilateration [6]. These do not require complex design and additional hardware. Active signals [7] are currently used for location system.

This paper proposes a location technique based on pattern recognition of radio signals applied in the ubiquitous parking management system (UPMS) by locating the specific parking slot using active RFID. The UPMS is consisted of a car active RFID (CARFID), wireless sensor modules and an access point computer with the pattern recognizer agent that interact in implementing automated and efficient parking system. A CARFID is used to send signal to sensor nodes in the parking area. The pattern recognizer agent (PRA), based on multilayer perceptron, trains the received signal strength from CARFID. After the training, the system classifies the location of the car using the current input RSS from the CARFID. The proposed method is implemented in the parking system simulator. The result of experiments shows that using the PRA acquires accurate location technique by correct classification of current radio signals.

2 Related Works

2.1 Automated Parking Systems

The current contributions of studies in parking system are providing smart monitoring by using WSN. Wireless sensor devices are used for automatic vehicle car parking [8] where wireless sensors and infrareds are used for the positioning to enhance the accuracy of positioning. A parking monitoring system using WSN is proposed [9]. The status of the parking field detected by sensor nodes is reported periodically to a database via the deployed wireless sensor network and its gateway. The database can be accessed by the upper layer management system to perform various management functions, such as finding vacant parking lots, auto-toll, security management, and statistic report. In [2], describes a simulation where reports from wireless sensor nodes are passed from car-to-car in order to achieve scalable dissemination of information regarding parking spaces. An analysis of link characteristics in the car-park scenario is studied [1]. The experiments shows unexpected reliability patterns which have a strong influence on MAC and routing protocol design. It concludes that the presence of the cars being sensed can cause significant interference and degradation in communication performance and link quality has a high temporal correlation but a low spatial correlation. A comparison of data from different sensors for improvements to WSN in car parking system is presented [10]. An RFID-based car parking system is proposed which is improved by designing a middleware [3]. Using RFID technology to identify each car entering the parking area is also useful information and consideration by researches. However, the issue of simultaneous parking of cars and associate the identification to the correct slot location is not discussed by the previous researches. The previous system can only detect the car presence by WSN to monitor free spaces but cannot tell exactly the identification of car if other cars are within the range of the RFID reader. There are alternative methods like assigning cars on a specific slot before entering the parking area but one of the draw backs is that a car owner cannot choose the parking slot he liked. This can be solved by location techniques using active signals with the help of WSN's interaction.

2.2 Location Technique based on Received Signal Strength

There are lots of localization and positioning methods that uses active signals. Active badge location system [4] is the first location system designed and built for simple, portable devices within buildings. It uses infrared as transmission medium and exploits the natural limitation of infrared waves by walls as delimiter for its location granularity. An ultrasound-based location system [11] is used to send ultrasound to the receivers. Moreover, properties of these methods are also needed to be considered. In the proposed method, the location technique uses received signal strengths (RSS). The calculation is presented in Equation 1, where P_{tx} is the transmission power, α is the path loss model, P_{rcvd} is the signal strength is used to solve the r or distance.

$$P_{rcd} = c\frac{cP_{tx}}{r^{\alpha}}, r = \alpha\sqrt{\frac{cP_{tx}}{P_{rcd}}} \tag{1}$$

The distance value from Equation 1 is used in location estimation procedure in calculating the lateration of the node that send the signal where at least three receiver nodes are needed. Pattern recognition of signal also provides a convenient way of implementing the location schemes which doesn't need sophisticated devices [12]. A study using nearest neighbour technique, statistical approach for signal pattern recognition are proposed [13]. Assume that RSS in any training location (x_i, y_i) is a random variable p with a density function f [p/(x_i, y_i)] drawn from the samples of measurements performed at that location. Then, for a new measurement, RSS=P at an unknown location (x, y), the probability of having that measurement taken in the specific training points (x_i, y_i) is in Equation 2. The actual estimate of the unknown location (x_i, y_i) is the statistical average over all measured training locations in Equation 3

$$p_i = f[p/(x_i, y_i)] \tag{2}$$

$$(x, y) = \sum_{i=1}^{N} p_i(x_i, y_i) \tag{3}$$

It is proved that statistical approaches are more accurate than the nearest neighbor approach. However, most of statistical methods are computation costly and because of the unknown path loss model from RSS, it is not assured that accuracy of the model is achieved. Approaches using non-linear methods like neural-networks can be efficient and convenient in pattern recognition of signals. This approach uses the power of learning from training patterns and does not need sophisticated computation.

3 Framework of the Ubiquitous Parking Management System

The architecture of the proposed ubiquitous parking management system is shown in Figure 1. The architecture consists of three layers: ubiquitous network, middleware and application services layers. In the ubiquitous network, represents the physical networks of different sensor devices and computers communicating in the wireless environment. The components in the middleware layer are transparently executing for the efficiency on managing data from the ubiquitous network layer. Interaction of clients and application services are also handled by the middleware layer. Users and administrators do not need to know the configuration on how to find, where to find and how to manage the resources but transparently executes the services. The application service layer is consisted of services for parking management system. This paper proposes a location technique in the ubiquitous network layers of the parking management system. The efficiency of the ubiquitous network relies on the reliable communication and well-designed distribution of tasks in wireless environment.

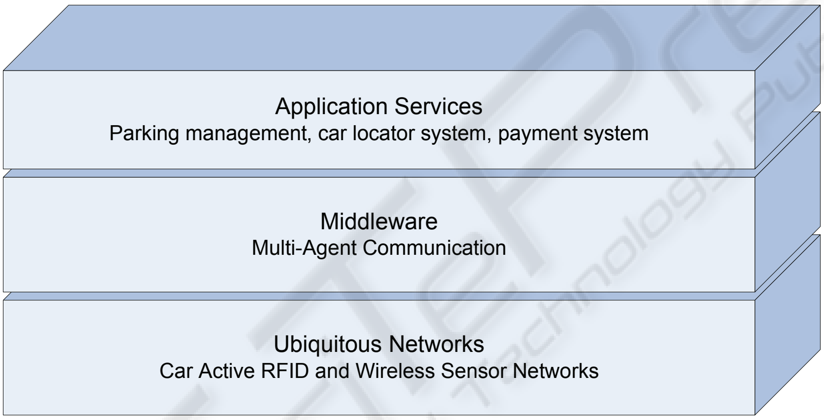


Fig. 1. Framework for the ubiquitous parking management system consisting of three layers; application services, middleware and ubiquitous network.

The proposed framework uses multi-agent approach to provide an intelligent distribution of task within the system. The pattern recognizer agent (PRA) is the focused of this paper. Also, a car monitoring agent that monitors cars parked which interacts with RRA. This paper focuses on improving the functions of the ubiquitous network layer by proposing a location technique using signal pattern recognition method. Unlike other location method, the proposed design is not complex and cost-effective by only using wireless sensors to locate the object.

4 Signal Pattern Recognition based on Multilayer Perceptron

A car is assigned with an active RFID. Every time a car parked, the active RFID sends data to all wireless sensors in the parking area. The sending of message occurs until a period of time. Each wireless sensor determines the received signal strength (RSS) from the active RFID and then sends the value to the sink node. In this proposal, RSSs are used for the recognition method from the trained structured of the neural networks.

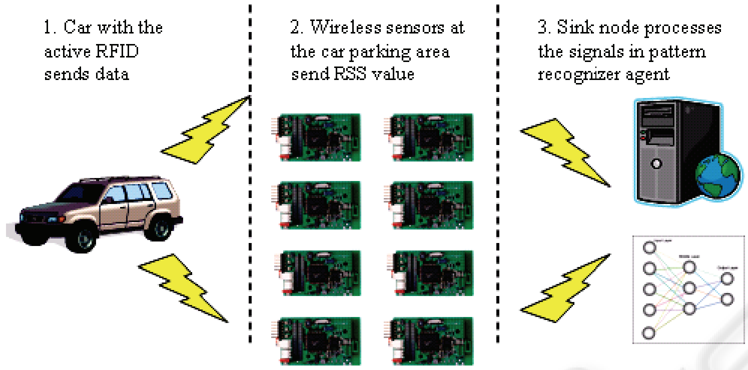


Fig. 2. The procedure of gathering and processing the received signal strength (RSS).

The proposed pattern recognizer agent in the sink node gathers all RSSs and determines the slot location of the car. Figure 2 shows the procedure of gathering the RSS to each wireless sensor; (1) sending the data by the active RFID; (2) each wireless sensor determines RSS from the active RFID then send to the sink node; and (3) processing the RSSs to the pattern recognizer agent based on MLP.

4.1 Training MLP with RSS Pattern

Each RSS pattern is used for the training of multilayer perceptron (MLP) of the proposed pattern recognizer agent. MLP is consisted of three layers of processing nodes an input layer which accepts the input variables used in the classification procedure, one hidden layers, and an output layer with one node per class. Equation 4 shows the over all calculation of the MLP. RSS data are presented as input x and weight value of the connection as w. The z_k refers to the output is value from calculating the activation function from input to hidden and hidden to output nodes.

$$z_k = f\left(\sum_{j=1}^{nH} w_{kj} f\left(\sum_{i=1}^{d} w_{ji} x_i + w_{j0}\right) + w_{k0}\right) \quad (4)$$

The back-propagation algorithm is a gradient descent optimization procedure which minimizes the mean square error between the network's output and the desired output for all input patterns P. The outputs are compared to the target values and determine the differences. The error is minimized by a function when the network output match the desired outputs where the weights are changed. The least mean square (LMS) for two layer nets is shown in Equation 5, where t and z are the target and the network output vectors of length c and w represents all the weights in the network.

$$J(w)=\frac{1}{2}\sum_{k=1}^{c}(t_k-z_k)2=\frac{1}{2}\|t-z\|^2 \quad (5)$$

4.2 Managing Misclassified Patterns

After the training, the structure of the MLP is used to recognize the pattern of signals to detect the car identification and verifies the location of the car. First, the RSS patterns from the new arrived car are processed at the MLP and produce the output. The output is compared to the WSN which detects the presence of the car. If the output and the WSN ID is the same then it reports to the monitoring program the location of the car. Else if it not the same, the input patterns are again processed in the training.

4.3 WSN and RFID Interaction

The interaction of the wireless sensors, car active RFID (CARFID), car monitoring agent and the pattern recognizer agent (PRA) is designed to implement the efficient ubiquitous network of parking management system. The car monitoring agent is used by other application services which are dependent on the function of the PRA. The WSN and CARFID interaction is implemented to acquire efficient car presence detection by processing the inputs in wireless sensors and accurate car location based on RSS pattern recognition of the proposed PRA.

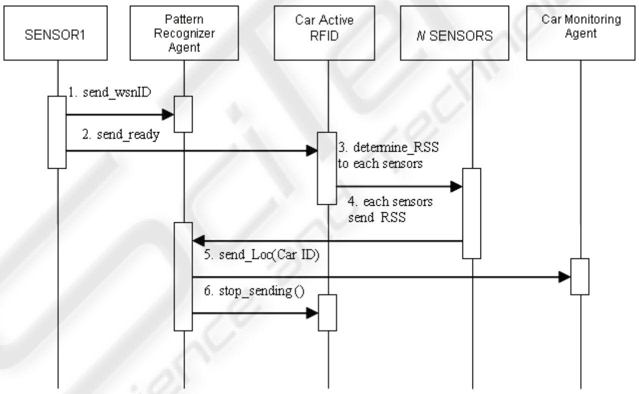


Fig. 3. The Event Trace Diagram (ETD) of the CARFID and WSN Interactions.

The procedures of the CARFID and WSN interaction on the Event Trace Diagram in Figure 3 are explained in the following:

1. The wireless sensors processes the input values to determine the car presence. This procedure sends the address of the slot location (send_wsnID) where presence of the car was detected to the PRA to be used in RSS pattern classification in step 4.
2. After the sensor detects the presence of the car, it sends message send_ready to

the CARFID to initialize the sending message of CARFID to all sensors.

3. The CARFID start sending determine_RSS to each sensor in the parking area and the sensors determine the received signal strength.
4. After each sensor determines the RSS by receiving the message of CARFID, it sends the RSS values to the PRA.
5. The RSS values that were sent by sensors are processed in the MLP of PRA. After the output is determined then the current signal pattern is associated with the slot location of the car and then informs the car monitoring agent by the command send_Loc(CarID).
6. The PRA sends a stop message to the CARFID.

The proposed interaction considers the reliable communication within the wireless environment. The misclassification of the PRA is managed by processing again the RSS patterns on the MLP.

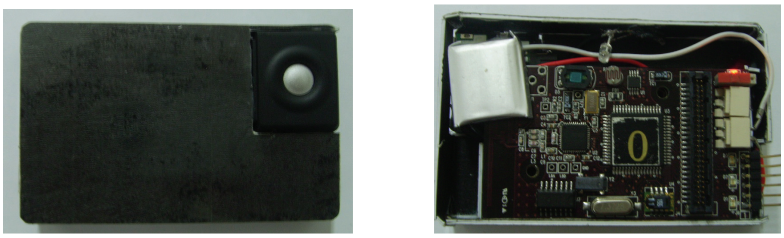
5 Implementation and Evaluation

5.1 Implementation in UPMS

Our design of the ubiquitous parking management system (UPMS) used wireless sensor motes which is a 2.4 GHz IEEE 802.15.4 compliant RF transceiver. The active RFID is put on the top of the car model shown in Figure 4. Every time the wireless sensor detects the presence of the car, it sends a message to the active RFID.

Fig. 4. The active RFID is placed on the top of the car model.

The proposed location technique based on pattern recognition of RSS is implemented in the ubiquitous parking management system simulator. The program for the active RFID is coded and designed in nesC, which a programming for sensors, and the pattern recognizer agent based on MLP is programmed in Java. Each ID is encoded in a wireless sensor mote to simulate the active RFID.



(a) **(b)**

Fig. 5. The front side (a) and back side without cover (b) of the CARFID.

The CARFID prototype is shown in Figure 5. The area of the CARFID is 8.5 cm by 5.5 cm which is equal to the size of an ATM card and the thickness is about 1 cm. We used the same frequency of the wireless sensor motes to the CARFID. In Figure 5a, CARFID has a command button to represent other functions like automated opening doors at the entrance of parking lot. Figure 5b shows the hardware inside of CARFID. It is provided with a small sized battery and like wireless sensor, the commands and interaction are programmed in nesC. CARFID is used for the proposed location technique based on pattern recognition of RSS. The program of the CARFID, to interact with the wireless sensors is coded and designed in nesC as well as the wireless sensors. PRA which is used to receive and process the RSS is programmed in Java. The IDs of each wireless sensor which is for the slot location and CARFID which is for the car identification were included in the program.

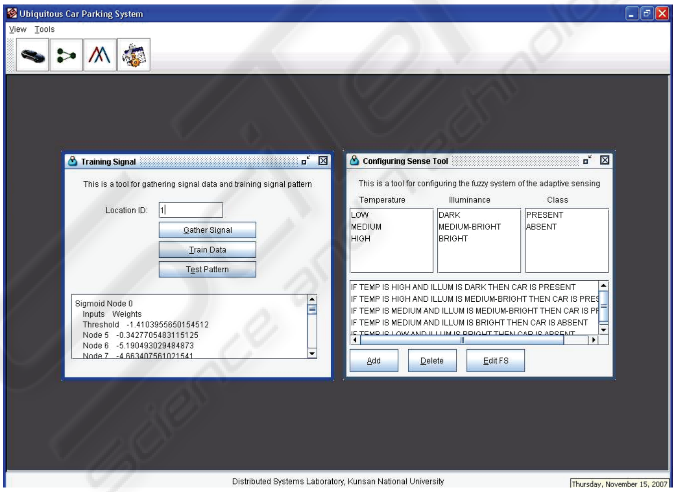


Fig. 6. The configuration of MLP training and wireless sensors are performed in the GUI program of ubiquitous parking management system.

Figure 6 presents the configuration of the training of RSS patterns in MLP and wireless sensors. A GUI program is developed to do these tasks and other services. On the parent window, the child window for training the MLP is shown at the left of Figure 6. The training of RSS is performed in three steps. First, gathering of RSS data by performing the parking event. This procedure includes parking the car in each parking slot and records the signals that are associated to the slot that is currently occupied. After RSS patterns were gathered, all patterns were used to train the MLP. The last step is a test of the trained MLP to classify the current RSS pattern.

Fig. 7. The ubiquitous parking management system simulator with wireless sensors nodes and car model.

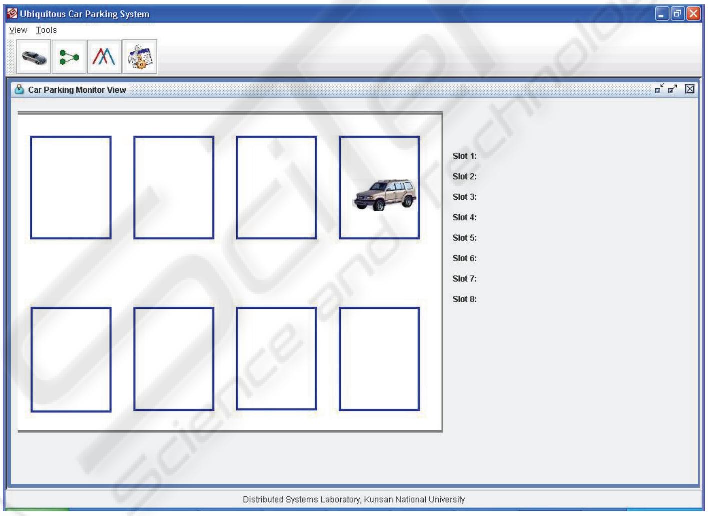


Fig. 8. The parking monitor program displays the output from the platform.

The interaction of the parking platform simulator is presented in Figure 7 and 8. The area of the parking simulator platform is 2.4 x 0.1 m and placed at inside of an office type room. Each slot area is 18 x 13 cm with a boundary of 3.5 cm between each slot and drive way of 36 cm. The parking platform is consisted of 8 slots embedded with wireless sensors. In Figure 7, a car parked in a single slot and at the same time in Figure 8 shows the output display from the parking platform simulator. The output display is updated every second and the values are stored in the database. Also at the same time, the active RFID from the car model sends data to all sensors. Each sensor determines the RSS from the active RFID and sends the values to the sink node with the pattern recognizer agent. The PRA gathers RSS data and associates the slot address where car presence is detected by the wireless sensor mote. After knowing the identification of the car, the information is stored in the database of the system.

5.2 Performance Evaluation

Several path loss models are considered in RSS location techniques [12] and our simulation environment considers the office space type. We used a maximum of 7 nodes for simulating the proposed location technique and a car model which is scaled 28 times smaller than the original size with the active RFID. In the simulation, each RSS readings from the nodes are recorded and stored in the database whenever a car is on the slot area. We selected 100 patterns containing five different locations classes with the RSS signals where each location class contains 20 patterns. Most of the studies measure the distance error, however, this study focuses more on the pattern recognition of radio signal where the accuracy of classifying the pattern from the current signals is observed. The cross-validation method is a popular classification test which uses the same training data in determining the number of misclassified patterns and is used for our evaluation. The nearest neighbor (NN) based on averaging the group of patterns and logistic regression which is a statistical model for probability modeling of patterns were compared.

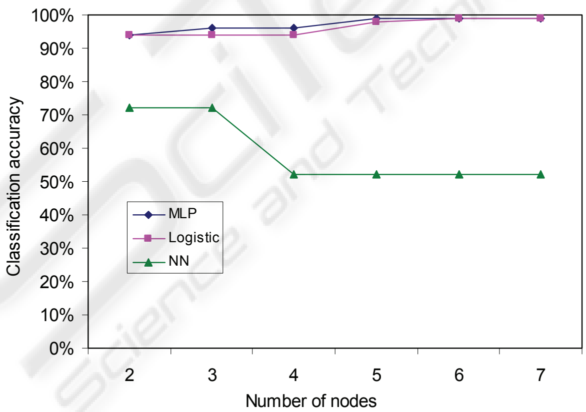


Fig. 9. Accuracy of the MLP, logistic and NN algorithms in classifying the patterns from RSS.

Figure 9 shows the MLP and logistics are more accurate in classifying the patterns compared to NN. Also, by increasing the number of nodes, MLP and logistic classification accuracy increases while the NN decreases. However, Figure 10 shows that MLP is efficient in processing time compared to logistic. Building the statistical model of logistic is computational costly and by adding another node between 2 to 6 in

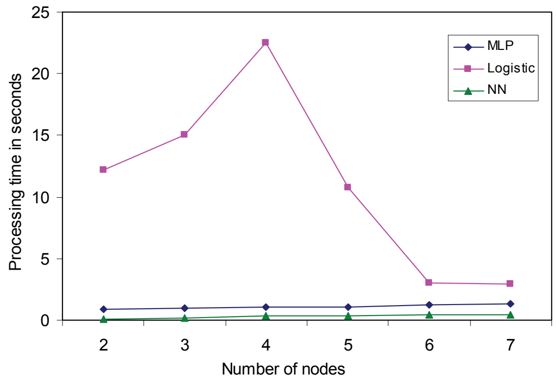


Fig. 10. Processing time to build the model of the MLP, logistic and NN algorithms.

creases the calculation time. MLP shows more efficient in time processing and adding a node has a minimal time processing. Even though MLP is not faster than NN, it has a big difference on the accuracy in Figure 9. In overall, the pattern recognizer agent has an average of 97% of accuracy which is more accurate in classifying RSS patterns and time efficient compared to nearest neighbor and logistic regression, respectively.

6 Conclusions

The use of active RFID provides flexibility to application in wireless environment. Moreover, the main challenges in wireless and mobile environments are to considered effective and cost-efficient location technique to implement in the system. This paper proposes a location technique based on pattern recognition of radio signals for the ubiquitous parking management system. To accurately locate the slot location of the car by using the received signal strength (RSS) from each sensor, the pattern recognizer agent (PRA), based on multilayer perceptron, is proposed. The proposed method is implemented in the ubiquitous parking management system simulator. The result of experiments showed that using the PRA acquires accurate classification of current signals to locate the slot of the car.

The future work will be the integration of the application services and middleware of the proposed framework for ubiquitous parking management system. Moreover, the proposed method will be configured and simulated in the real environment of the parking management system.

References

1. Benson, J. P., O'Donovan, T., O'Sullivan, P., Roedig, U., Sreenan, C.: Car Park Management using Wireless Sensors. In 31st IEEE Conference on Local Computer Networks (2006) 588-595

2. Miura, S., Zhan, Y., Kuroda, T.: Evaluation of Parking Search using Sensor Network. In 1st International Symposium on Wireless Pervasive Computing, (2006) 6
3. Cervantes, L. F., Lee, Y. S., Yang, H., Lee, J.: A Hybrid Middleware for RFID-based Parking Management System using Group Communication in Overlay Networks. In International Conference on Intelligent Pervasive Computing (2007) 521-526
4. Want, R., Hopper, A., Falao, V., Gibbons, J.: The Active Badge Location System. ACM transactions on information systems, 10 (1) (1992) 91-102
5. Hoffmann-Wellenhof, B., Lichtenegger H., Collins, J.: Global Positioning Systems, Theory and Practice. Springer-verlag, 5th Ed (2001)
6. Karl, H., Willig, A.: Protocols and Architectures for Wireless Sensor Networks, John Wiley & Sons Ltd. (2005) 231-288.
7. Jin, G. Y., Lu, X. Y., Park, M. S.: An Indoor Localization Mechanism using Active RFID In IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing 1, 40-43
8. Chou, L., Sheu, D. C. C., Chen, H. W.: Design and Prototype Implementation of a Novel Automatic Vehicle Parking System. International Journal of Smart Home, 1, (1), (2007) 11-16
9. Tang, V. W. S., Zheng, Y., Cao, J.: An Intelligent Car Park Management System based on Wireless Sensor Networks. In 1st International Symposium on Pervasive Computing and Applications (2006) 65-70
10. Kumar, R., Chilamkurti, N. K., Soh, B.: A Comparative Study of Different Sensors for Smart Car Park Management. In International Conference on Intelligent Pervasive Computing (2007) 499-502.
11. Ward, A., Jones, A., Hopper, A.: A New Location Technique for the Active Office. IEEE Personal Communication, 4, (5) (1997) 42-47
12. Pahlavan, K., Levesque, A. H.: Wireless Information Networks 2nd Edition, Wiley (2005) 607-37
13. Bahl, P., Padmanabhan, V. N.: RADAR: An In-Building RF-based User Location and Tracking System, In IEEE INFOCOM, 2 (2000) 775-784