PARKING GUIDE AND MANAGEMENT SYSTEM WITH RFID AND WIRELESS SENSOR NETWORK

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ABSTRACT: In apartment type of housing, if resident's vehicle is registered in central control office and RFID TAG is issued, identification can be recognized from the time of entrance into parking lot and intelligent parking guide system can be activated based on the residents' profile. Parking Guide System leads a vehicle to the available parking space which is closest to the entrance gate of the vehicle's owner. And when residents forget where they parked their cars, they can query to the Parking Guide and Management System and get responses about the location. For the correct operation of this system, it is necessary to find out where the residents' cars have parked in real time and which lot is available for parking of other cars. RFID is very fancy solution for this system. RFID reader gathers the ID information in RFID TAGs in parked cars and updates the DB up to date. But, when non-residents' cars are parked inside apartment, RFID reader cannot identify them nor know the exact empty/occupied status of parking spaces because they don't react to RFID reader's query. So for the exact detection of empty/occupied status, we suggest the combined use of ultrasonic sensors and RFID. We designed a tree topology with intermediate data aggregators. The depth of tree is normally more than 3 from root (central office) to leaves (individual parking lots). The depth of 2 in tree topology brings about the bottleneck in communication and maintenance. We also designed the information fields used in RFID networks and Sensor Networks.

Keywords: Parking Guide System; Parking Management System; RFID; Wireless Sensor Network

1. INTRODUCTION

RFID (Radio Frequency Identification) is a technology to identify objects using RF signals. The application area with RFID is very wide. Passport identification, automotive toll debiting in high way, product tracking and animation identification are some examples.

There have been many researches to provide convenient parking environment using RFID. G. Ostojic, et al. used RFID to decrease the time that people have to spend on waiting in line to buy the ticket in on-street parking and to reduce the time of tariff collection and computation in garage parking [1]. Smart parking system by Z. Pala and N. INANC was to calculate total parking fee by keeping records of check-in/check-out time around parking lots in a city into central DB [2]. GPS can be used to provide shortest (best) routes for a moving vehicle. But it shows malfunction in the downtown with very tall buildings, underground parking and the inside of buildings. In 2008, K. Kang and J. Kim suggested to use RFID in real-time path finding to overcome GPS limitation [3]. As transport and land use evolves, new paradigm in parking management is necessary. Todd Litman showed new strategies, evaluation and planning in parking management in Canada [4].

Although there have been many researches and products to use RFID in parking management system [5-9], it requires the precondition that all the vehicles have to attach RFID TAG for these technologies to be operated correctly in a real world.

This paper proposes PGMS (Parking Guide and Management System, or PGM System) to be used in apartment type of housing in which many families live together as neighbors. PGMS provides vehicles with efficient guides towards vacant parking lot which is closest to the entrance gate of the vehicle's owner. And it manages parking space by monitoring and maintaining the status of each parking lot's empty/taken state. When residents forget where they parked their cars, they can query to the Parking Guide and Management System and get responses about the location. For the correct operation of this system, it is necessary to find out where the residents' cars have parked in real time and which space is available for parking of other cars.

Residents' information is registered in centralized control center and RFID TAG is issued to each vehicle. RFID reader in parking area can infer owner's profile from the RFID TAG in vehicle and find out the parked location of each vehicle. PGM System becomes to know the park-in/park-out time of each vehicle with the report of aggregator nodes' messages. But visitors' vehicles don't have globally standardized RFID TAG and RFID reader fails to detect the parking space' status of empty/occupied. This results in misguide of available parking space.

Proposed PGMS uses not only RFID system but also ultrasonic wireless sensor system. Ultrasonic sensor detects the emptiness of parking spaces and compensates the deficiency of RFID capability in parking management system. We designed the tree topology for PGMS and defined necessary message formats.

In section 2, we described the construction regulations for parking lots in apartment. In section 3, we defined the role of data aggregator and explained the RFID system and wireless sensor system. We showed overall topology of PGMS in section 4. After defining information fields in section 5, we concluded in section 6.

For the clarity of terms, *parking lot*, *parking space* and *parking area* is used in this paper as shown in Figure 1.

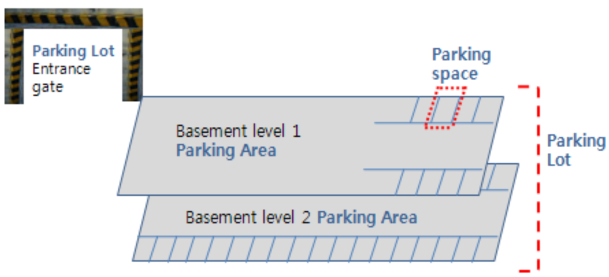

Figure 1: Terms: Parking Lot, Parking Space, Parking Area

2. REGULATIONS ABOUT PARKING LOT CAPACITY IN KOREA

2.1 Parking Space for One Vehicle

Korean Regulation for the parking space per vehicle is shown in Figure 2.

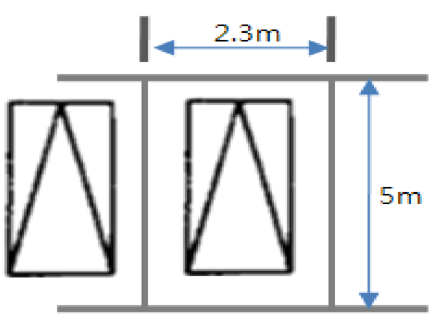

Figure 2: Parking Space per Vehicle

The parking types are depicted in Figure 3. There are 5 parking types: parallel parking, orthogonal parking, 45 degrees parking, 60 degrees parking and intersecting parking. The regulation resolves the required moving in/out path between parking spaces as in table 1.

Table 1. Path Width (B)

Parking Type	Path Width (B)	
	In case of two gates	In case of one gate
Parallel Parking	3.3m	5.0m
Orthogonal Parking	6.0m	6.0m
60 degrees Parking	4.5m	5.5m
45 degrees Parking	3.5m	5.0m
Intersecting Parking	3.5m	5.0m

In usual apartment type of houses in Korea, it is a trend not to make parking spaces over ground and hide parking spaces underground. In underground parking space, orthogonal parking type is the general trend. And secondly, parallel parking type is the tendency.

2.2 In Reality: Parking Capacity for an Apartment

Here, we took the apartment which is recently open for installment sale as an example. Its overall plot plan is shown in Figure 4. The total number of building is 18 and the total number of house (for one family) is 548. The allotted parking space per house is 51.4414m^2. It corresponds to 4.47 vehicles per house when we take into account 11.5m^2 of per-vehicle-parking-space (2.3m X 5m in orthogonal parking type). We assumed some numbers as in table 2. This assumption is to meet the total number of houses in this apartment; that is 548.

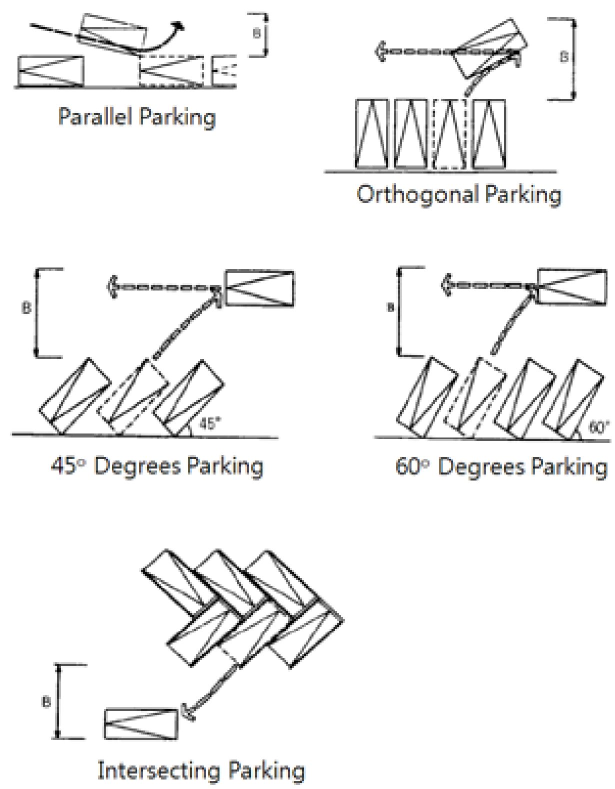

Figure 3: Parking Types

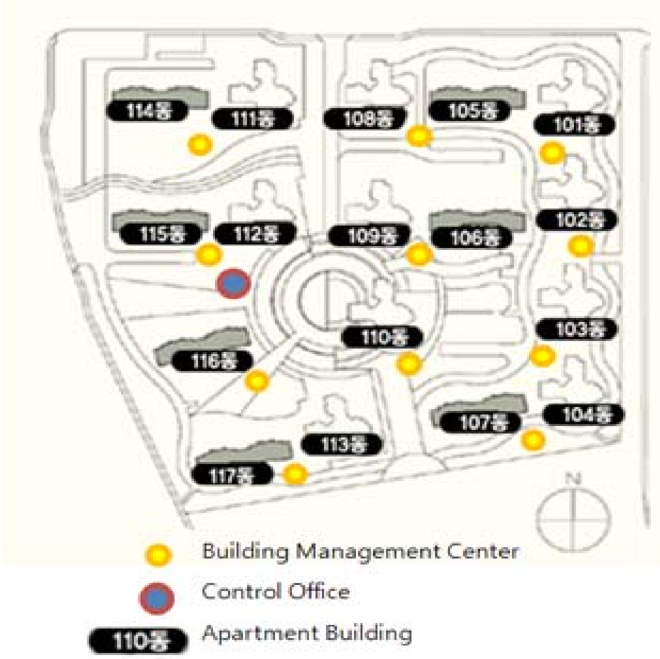

Figure 4: A Plot Plan of an Apartment

Table 2. Some Simple Assumptions

	1^{st} ~ 13^{th} building	14^{th} ~ 17^{th} building	Description
# of houses	32	33	Total # of houses = 548
Required # of parking spaces per building	143.14	147.61	Min. 148 parking spaces are assumed.

3. Data Aggregator for RFID and Wireless Sensors

3.1 Active RFID Reading

The readable distance of passive RFID TAG is a few feet at most. This is too short to apply to communication with moving vehicles. With passive RFID TAG, vehicle must stop to put the TAG within readable distance from RFID reader which leads inconvenience. Further, PGM System requires regular information gathering whether the parking lots are occupied or empty, and which car occupied. When cars are parked on the parking lot, to get the RFID information from the vehicle attached with passive RFID tag, RFID reader has to either move to the vehicle closely enough, or be installed so densely.

Thus, our PGM System considers using active RFID TAG with readable distance of up to 100m. But, we don't consider the maximum available transmission distance. Merely, we assume the transmission range of active RF to be 10m. Within a circle whose diameter 10m, only one reader is required. This reader gathers all the RFID tags' information within its boundary. RFID reader is installed on the ceiling as depicted in Figure 5.

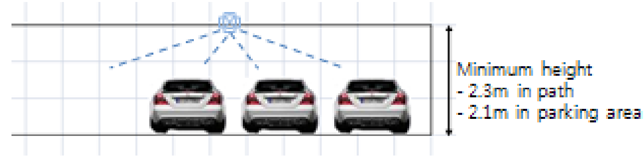

Figure 5: RFID Reader on Ceiling

As shown in subsection 2.1, the parking space regulation for one vehicle is 2.3m X 5m. So, with assumption of 10m transmission range for active RFID, the coverage of one RFID reader is 8 parking spaces. This is shown in Figure 6.

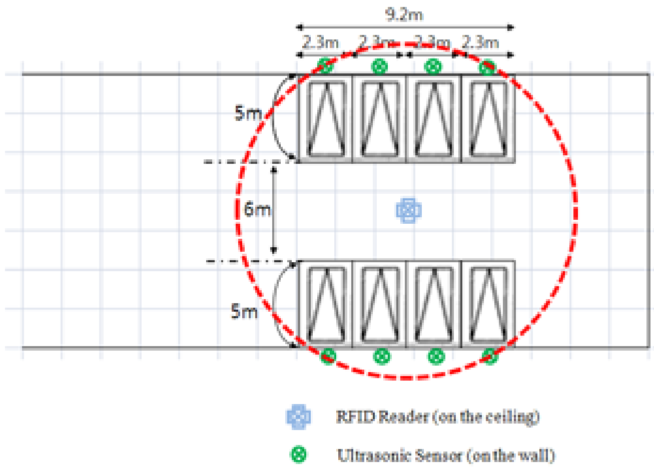

Figure 6: Placement of RFID Reader and Ultrasonic Sensor Reader

3.2 Sensor Data Reading

An ultrasonic sensor can be used to detect the distance from the object by measuring the time the signal returns. In our PGM System, we use this ultrasonic sensing to discover whether a parking lot is currently empty or occupied. Sensor readers are installed on walls for each parking space per vehicle as in Figure 7.

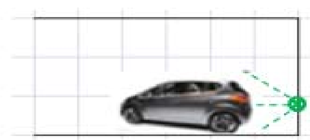

Figure 7: Ultrasonic Sensor Reading on Walls

3.3 Data Aggregator

Data from RFID reading and sensor reading has to be collected and forwarded to the PGM System server regularly. There exist many RFID readers and sensing readers on one story of parking areas. In pure star topology, these each readings would be forwarded to next upper level component (collector) directly. But, in our PGM System, we use the data aggregator concept in topology formation. At each level of data collecting, data are gathered and manipulated in intermediate node, and then forwarded to the next level's aggregator. Contents compression and/or merging techniques are further study. Sensor nodes usually have very limited memory and CPU

Table 3. EPC Identifier Format

EPC Type	Header Size	First Bits	EPC Manager ID	Object Class	Serial Number	Total
64 bit Type I	2	01	21	17	24	64
64 bit Type II	2	10	15	13	34	64
64 bit Type III	2	11	26	13	23	64
96 bit and more	8	00	28	24	36	96

capability. So, we didn't consider making use of sensor nodes as aggregator in PGMS.

4. GDMS Topology

4.1 Tree Topology with Aggregators

For the topology of GDMS, we adopted centralized manner, not distributed manner. When the size of apartment is very huge and the data from one building is very bulky, distributed management can be another option. Centralized server resides in central control office in apartment. Every intermediate node in a tree can be data aggregator. Figure 7 is a tree topology applied in Figure 4.

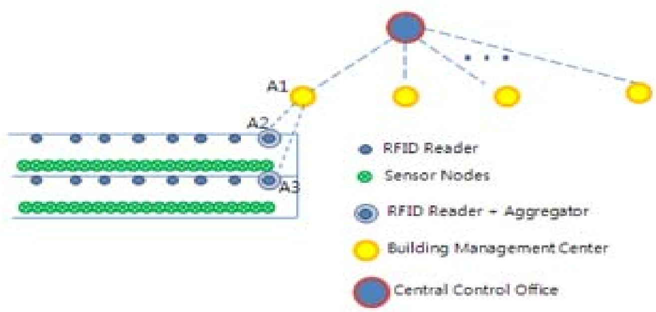

Figure 8: Tree Topology in GDMS

In Figure 4, Each Building Management Center is assumed to be responsible for one or two apartment buildings. Each building has two-storied basement parking lot. The depth of tree is normally more than 3 from root (central office) to leaves (individual parking spaces). The depth of 2 in tree topology brings about the bottleneck of communication and maintenance in central server. The relationship of aggregators A2 and A3 in Figure 6 can be parent-child (that is, A1 – A2 – A3) or sibling (A1 – A2, A2 – A3).

4.2 Deployment in Apartment

Figure 6 shows a placement of RFID reader and ultrasonic sensor readers. In table 2, we assumed that this apartment constructs parking lot only under-ground with 2-stories structure. With this assumption, 1-story parking area has to have capacity of at least 74 vehicles. For the 1st ~ 13th building, the minimum capacity of each story should be 71. But, for simplicity, we use the minimum value of 74 unanimously. Then, the total number of required RFID readers on ceiling in one parking area is 74/8≈10, and the total number of required ultra sensors on walls in one parking area is 74.

5. Information Fields

5.1 RFID TAG Information

Table 3 shows an EPC (Electronic Produce Code) Identifier Format. We adopted the 4th row format (96 bit and more) to provide long serial number to express various information.

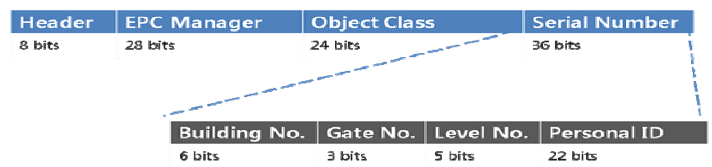

Figure 9: RFID TAG information

Figure 9 shows information stored in RFID TAG. As shown in figure 9, we divided *serial number* field into 4 information sub-fields.

- *Building Number* : 6 bits (0 ~ 63)
- *Gate Number* : 3 bits (0 ~ 7)
- *Level Number* : 5 bits (0 ~ 32)
- *Personal ID* : 22 bits

Gate number sub-field is for the entrance gate number to go to the resident's house in a building. It is not the entrance gate number of parking lots. This RFID TAG information is transmitted to RFID reader from TAG.

5.2 RFID Reader Information

Figure 10 shows information fields constructed in RFID Reader after reception the RFID TAG information from the vehicles. The first field, *ID info* (36 bits), is same with *Serial Number* in Figure 9.

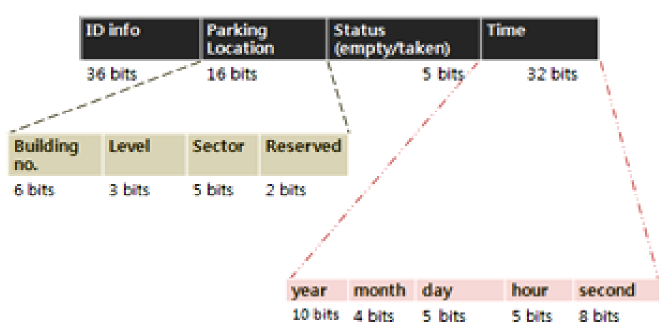

Figure 10: RFID Reader Information

A RFID reader is responsible for 8 vehicles in its sector as shown in Figure 6. So the possible granularity of parking location is sector unit, not parking space unit.

Parking location field has 4 sub-fields.

- *Building Number* : 6 bits (0 ~ 63)
- *Level* : 3 bits (basement level 1 or 2)
- *Sector* : 5 bits (0 ~ 32)
- *Reserved* : 2 bits (for later use)

Time field is the information when this data is collected. It consists of 5 sub-fields: *year, month, day, hour* and *second*.

5.3 Ultrasonic Sensor Information

Contrary to subsection 5.2, the possible granularity of parking location in ultrasonic sensor node is parking space unit, because one sensor is responsible for one vehicle's parking space.

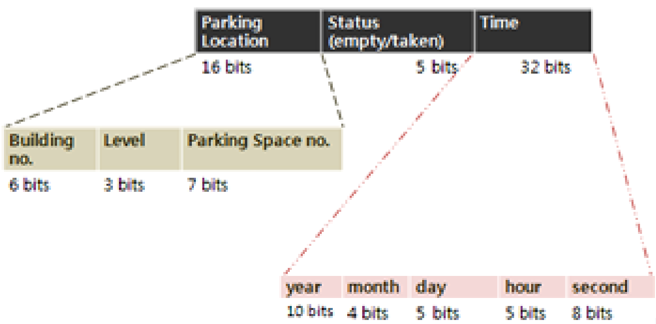

Figure 11: Ultrasonic Sensor Node Information

Field length is same with RFID Reader information as in Figure 10. But the *sector* field (5bits) and *reserved* field (2bits) are changed to *Parking Space number* (7bits). Its range is 0~127. For the future usage, this field can be defined with longer length. But currently, it is sufficient for 74 parking spaces.

6. CONCLUSIONS

Existing RFID-based parking management solutions has several limitations. In case that some vehicles don't have RFID TAG, parking guidance system cannot detect vehicles' existence in the parking area and thus gives the wrong information to vehicle which searches for vacant slot. We proposed combined use of RFID system with ultrasonic sensor network system. In proposed system, PGMS, sensor nodes detect the existence of non-RFID-attached-vehicles, and thus overcome the limitation of RFID-only system. We used centrally controlled mode in topology and defined information formats generated in each component: RFID TAG, RFID Reader and sensor node.

The optimization of merging and compression in data aggregator must be studied and defined further. With the globally full standardization of personal information and its popularization will change the current systems. Before that point, combined technologies will be used to compensate the lack of individual systems.

ACKNOWLEDGEMENT

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