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A Study on Improvement of Parking Guidance System to Low-Power Operation for Green Building

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요 약

주차정보시스템은 주차 대기시간을 줄이고 운전자의 편의를 증진시킬 수 있지만, 다수의 검지기, 표출장치, 제어장치 등을 포함하는 특성에 기인하여 항구적인 전력을 소비하는 특징을 갖는다. 근래에 국내외에서 환경 친화적 그린 빌딩을 위한 저 전력 소비 형 주차정보시스템의 요구가 증대되고 있다. 본 논문에서는 가상 빌딩의 주차장을 대상으로, 소비전력 저감을 특징으로 하는 주차정보시스템을 설계하였다. 본 설계를 위한 주차검지기로는 기 상용화된 배터리방식 주차검지기인 무선루프식검지기와 지자기방식 검지기를 적용하고, 시스템 구성 및 통신 네트워크, 운전자 정보서비스 시나리오, 배터리 수명 평준화 등에 대한 설계를 진행하였다. 이어서, 설계된 주차정보시스템의 운영 소비전력을 추정하고 이를 종래의 일반적인 초음파방식 시스템의 동작 소비전력과 비교 하였다. 또한, 주기적 배터리 교체비용을 고려한 전력 유지비용을 환산하여 비교하였다. 7년의 배터리 교체주기를 기준으로 하였을 때, 설계된 시스템의 운영 소비전력은 기존 초음파센서 기반 시스템의 13% 수준으로, 전력 운영비용 환산 값은 기존시스템과 유사한 수준인 94.9%로 추정되었다. 본 연구의 시스템은 소비전력의 괄목할 만 한 경감에 따라, CO2발생의 저감을 기대할 수 있다.

Abstract

The parking guidance system can increase driver's convenience with detailed parking information service, but it continuously consumes electrical energy with large amount of sensors, displays and control modules. With the increase of the demand for green and sustainable building design, it becomes a meaningful issue for parking guidance system to reduce operating power. This paper presents the preliminary design and estimated results of a parking guidance system which is optimized to reduce the power consumption mainly on detectors and displays. The system design is based on commercial wireless parking detectors, wireless-loop-detector and earth-magnetic-detector. We have performed system architecture design, communication network design, parking information service scenario planning, battery life regulation and at last operating power estimation. With the 7 years of battery replace cycle, the estimated result for power consumption of designed system was 0.33W/slot, which is 13% of the traditional system's estimation result. The estimated annual maintain cost was similar to the traditional ultrasonic sensor based system's. The low power operable designed system can be expected to reduce CO2 emission.

Key words : Green building, parking guidance system, low power, wireless loop detector, parkdisk

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Ⅰ. Introduction

Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle[1]. The efficient energy use is one of the important issues for green building to reduce the overall impact of the built environment which affects on human health and the natural environment. The parking guidance system can increase driver's convenience and reduce searching time for free parking space with detailed parking information service in the parking lot. At the same time, parking guidance system consumes non-negligible electrical energy with large amount of sensors, displays and control modules. With the increase in the demand for green and sustainable building design, it becomes a meaningful issue for parking guidance system to reduce operating power, especially for advanced tall buildings with large scaled parking lot. This paper presents a design of parking guidance system which can be operated with reduced energy. The designed system is based on the commercial wireless parking detectors, wireless-loop-detector and earth-magnetic-detector. The designed system has 4,000 parking space detectors, 1,200 section displays, 1,200 car location guidance terminals and 16 vehicle count detectors. We have performed system architecture design, communication network design, parking information service scenario planning, battery life regulation and at last operating power estimation.

Ⅱ. Related Works

In this section we review on existing and proposed parking lot applications based on vehicle detector and communication network. A. Marma and M. Zilys developed and install a parking guidance system and showed that the system can decrease parking time up to 65%[2]. P. Vijay Kumar and Siddarth T.S implemented a prototype model of parking information system based on wireless sensor network, and demonstrated that it can effectively satisfy the need for an automated, cost-effective, real-time and easy-to-use system for car parking[3].

Energy efficient communication for sensor network is highly required for wireless parking information systems, too. Byung-boo Kim and Seung-Hyong Rhee proposed an energy-efficient MAC protocol of mobile device in cognitive radio equipment and proved the improvement[4]. Hong-Hyul Shin and Hyuk-Joon Lee proposed an IEEE 802.15.4-based simple but efficient routing protocol for a VAWS(Vehicle Approach Warning System). The protocol creates and maintains routing tables based on the network topology organized by the topology control protocol, transports data packets generated from the sensor nodes to the base station with high level performance in terms of both energy efficiency and throughput simultaneously[5].

Ⅲ. System Design

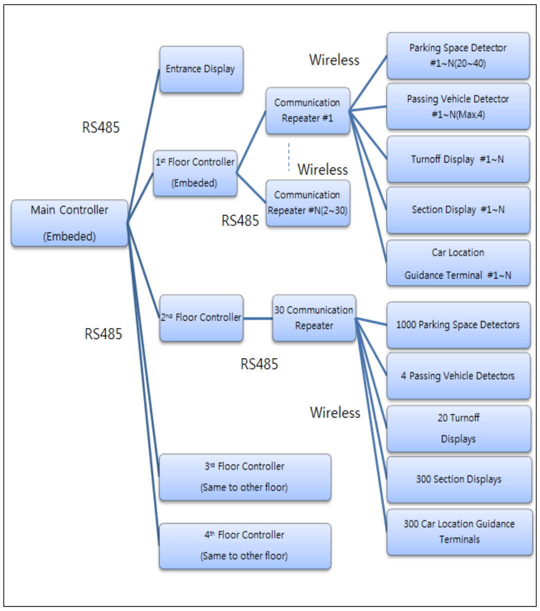
1. System Architecture

We have designed parking guidance system for virtual parking lot of tall building. We assume it has total 4,000 parking spaces with 4 parking lot stories, and it has total 80 turnoffs.

2. System Components

1) Parking Space Detector

The parking space detector senses the status of parking space and sends the data to communication repeater with RF channel. As a detector for design the system we selected two commercial wireless parking detectors as alternative. One is ParkDisk and the other



〈Fig. 1〉 System Architecture

is ANTS T-sensor. ParkDisk is a wireless parking detector with inductive loop vehicle detect technology by MORU Industrial Systems Co., Ltd. and ANTS T-sensor is another wireless parking detector with earth-magnetic detect technology by SNR Co., Ltd.

ParkDisk and ANTS T-sensor are work with 1-st order Lithium battery. The battery life of ParkDisk is announced as 7 years and ANTS T-sensor is announced as 2 years.

2) Passing Vehicle Detector

The passing vehicle detector is to detect and count the vehicles at the main pathway of the parking lot. Passing vehicle count detectors are located mainly on floor to floor pathway. The passing vehicle count detectors are for wake-up the parking guidance display devices of next floor, and for estimate the volume of vehicles which is parked on out of space in each floor. As a passing vehicle count detector we applied dual ParkDisk for each vehicle path, with wired DC power supply.

3) Entrance Display Device

The entrance display device is located at the main entrance of the parking lot, and displays the capacity of remained parking spaces of each floor. The entrance display device has dimming control function to reduce operating power during night time.

4) Turnoff Display Device

The turnoff display device is located at every turnoff point of the parking lot, and displays the capacity of remained parking spaces of each direction. The turnoff display device can service various free messages. Turnoff display device has dimming control function, too.

5) Section Display Device

The section display device is located mainly on the pillar of the parking lot and displays the parking capability information for the small section. The section display device has dual way for display the information, one is LED based lighting method and the other is flip plate based reflection method. When the moving vehicle is in the floor, the LED display function of the section display device can be activated until timeout. The reflection plate of the section display device can give message to driver or pedestrian at any time with zero power.

6) Car Location Guidance Terminal

The car location guidance terminal has keypad and LCD display. The driver can resister and look up the parking section number with one's phone number or vehicle license plate number. The car location guidance terminal consumes power only when someone operating the terminal, otherwise it goes to long term power save mode. With this operating characteristics, the car location guidance terminal has the good condition for battery operation.

7) Other Devices

Communication repeater is for repeat the wireless data communication within each device of the system. Almost all of the devices use RF channel for data communication, and the channel can be selected within sub-1Ghz and 2.4Ghz band. Control units manage the function of the system. The control units have embedded architecture for reduce power consumption.

Control units have multi serial port and LAN port for interface with other systems, for example intelligent building system. We located 1 control unit for total system, and total 4 control unit for floor control.

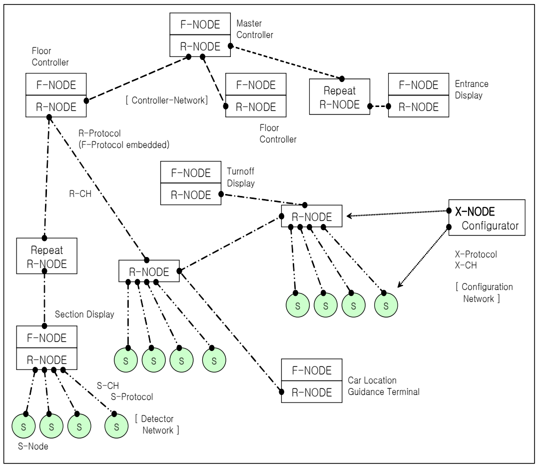
3. Communication Network

For design wireless communication network, we assigned the naming and proper operating method of each communication node. Detector has huge volume in system, and directly effects on system power consumption. For reduce the system operating power, the detector must have long wakeup period and must have function of event based communication.

〈Table 1〉 Communication node definition

Node	Device	Comment
S-NODE	Detector	Event based data send.
R-NODE	Repeater	Periodic RSSI check for detector data receive.
X-NODE	(Configuration Device)	Portable configuration device. Use only when configuration.

The designed communication network has S-NODE for detector, R-NODE for sensor data collection and general repeat, X-NODE for configuration and F-NODE for function devices. R-NODE periodically wakeup and check the radio signal strength and sleep again when there is no RF signal, and can wakeup the F-NODE and send the data for F-NODE with serial interface when data destination ID matches. R-NODE and F-NODE can be in a single enclosure.



〈Fig. 2〉 Communication Network

4. Battery Life Regulation

Recently, in accordance with operating power reduction effort for parking detectors, some detectors can be operated with battery.

$$I_{avg} = \frac{I_{rfc} \cdot T_{srfc} \cdot C_{rfc} + I_{det} \cdot T_{sdet} \cdot C_{det} + I_{slp} \cdot T_{slp}}{24 \cdot 3600 \cdot 1000} + I_{bdc}$$

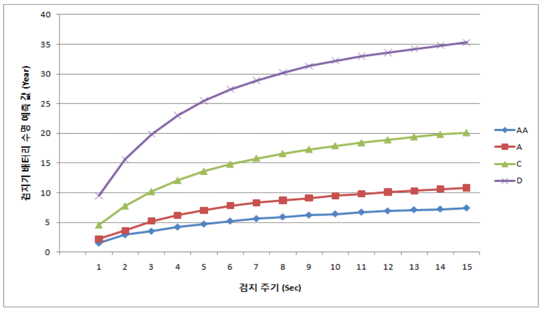
I_{rfc} : Wireless comm. current (mA)
T_{srfc} : Wrirless comm. duration for each time (mS)
C_{rfc} : Wireless comm. event count (event/day)
I_{det} : Detect current (mA)
T_{sdet} : Detect duration for each time (mS)
C_{det} : Detect operation count (event/day)
I_{slp} : Sleep current (mA)
T_{slp} : Acumulated sleep time (mS/day)
I_{bdc} : Average self discharge current of battery (mA)

(1)

Using the battery for operating the devices has the merit of easy and cost effective install, but on the other hand it makes the overhead for periodic battery replacement. The battery powered parking detectors works with the power consumption characteristic of equation (1).

The average operating current of ParkDisk in typical condition is calculated as 79uA, and the typical battery life is anounced as 7 years.

The ParkDisk, as a passing vehicle detector, is under the condition of 100ms wakeup interval and 20,000 vehicles are passing in a day, average operating current calculated as 18.2mA(3.6V), and we decided to operate it with wired DC connection.



〈Fig. 3〉 Battery life estimation of parking space detector (ParkDisk, 10veh./day)

The car location guidance terminal is under the condition of average working current, 10mA, average operating duration, 30sec, 10 times work per day, average current is calculated as 34uA, and the typical battery life with A cell Lithium battery(3.6V-3650mAh) is estimated as over 7 years. Parking space detector and location guidance terminal are selected for operate with battery.

The battery replace cycle for stable operation with ParkDisk as a parking space detector and location guidance terminal are defined as common 7 years. The battery replace cycle of ANTS T-sensor is defined under the recommendation of producing company.

5. Information Service Scenario

The information service scenario of designed low power parking guidance system is almost same as traditional systems. When a car is arrived at the parking lot, the designed parking guidance system can show the overall parking lot status information with the entrance display device. When a car is approaching to each parking floor and final empty parking space, the system can show the directional parking space information with turnoff display device, and show the detailed section status information with section display device with full activated display mode. When no car is approaching for the parking floor, all the display devices can work with power save mode until a new approaching car is detected by the passing vehicle detector. If a driver wants to register and search his parking position with the system, the system can meet the needs with car location guidance terminals. The processed parking information can be served for intelligent building systems or intelligent transportation systems. The intelligent building system can use the data for light dimming control of the parking lot to reduce lightening energy.

Ⅳ. Operating Power and Cost Estimation

1. Power Consumption Estimation

The estimated result of total power consumption of the system was 1.3 Kw, and parking space averaged power consumption was 0.33 watts. We assume that the battery of each device is all worn out during replace cycles. And we assumed that the section display can work with 5V-50mA average power, including DC-DC converting loss.

〈Table 2〉 Power Consumption of Designed System (battery replace cycle:7 years)

	Device Name	Count (Set)	Average Power Consumption		
			Power Feed	Watts/ Device	Total (W)
1	Parking Space Detector	4,000	Bat. (A)	206uW	0.824
2	Passing	16	Wired	66mW	1.06

	Vehicle Detector		DC		
3	Entrance Display	1	Wired AC	50	50
4	Turnoff Display	80	Wired AC	10	800
5	Section Display	1,200	Wired DC	250mW	300
6	Location Guidance Terminal	1,200	Bat. (AA)	115uW	0.138
7	Repeater	120	Wired DC	0.25	30
8	Floor Controller	4	Wired AC	25	100
9	Main Controller	1	Wired AC	35	35
*	Total	-	-	-	1,317
*	W/slot	-	-	-	0.33

〈Table 3〉 Power Consumption of magnetic sensor based application (battery replace cycle:2 years)

	Device Name	Count (Set)	Average Power Consumption		
			Power Feed	Watts/ Device	Total (W)
1	Parking Space Detector	4,000	Bat. (A)	720uW	2.88
2	Passing Vehicle Detector	16	Wired DC	66mW	1.06
3	Entrance Display	1	Wired AC	50	50
4	Turnoff Display	80	Wired AC	10	800
5	Section Display	1,200	Wired DC	250mW	300
6	Location Guidance Terminal	1,200	Bat. (AA)	405uW	0.49
7	Repeater	120	Wired DC	2.5	300
8	Floor Controller	4	Wired AC	25	100
9	Main Controller	1	Wired AC	35	35
*	Total	-	-	-	1,589
*	W/slot	-	-	-	0.397

With the similar manner, we estimated the power consumption for earth magnetic sensor(ANTS T-sensor) based, and ultrasonic sensor based traditional parking guidance system.

While the estimated result of total power consumption of the ultrasonic sensor based system was 9.9 Kw, parking space averaged value was 2.4 watts. For traditional ultrasonic sensor based system, we assumed that the communication repeater can drive 32 sensors with RS485 interface.

〈Table 4〉 Power consumption of ultrasonic detector based system

	Device Name	Count (Set)	Average Power Consumption		
			Power Feed	Watts/ Device	Sub. Total
1	Parking Space Detector	4,000	Wired DC	1.2	4,800
2	Passing Vehicle Detector	16	Wired DC	1.2	19.2
3	Entrance Display	1	Wired AC	50	50
4	Turnoff Display	80	Wired AC	20	1,600
5	Section Display	1,200	Wired DC	1.5	1,800
6	Location Guidance Terminal	1,200	Wired DC	1.0	1,200
7	Repeater	125	Wired DC	2.5	312.5
8	Floor Controller	4	Wired AC	25	100
9	Main Controller	1	Wired AC	35	35
*	Total	-	-	-	9,917
*	W/slot	-	-	-	2.48

The cost converted estimation result shows that if the battery life is 7 years or over, the designed system can be operated with the similar(94.9%) or reduced annual power cost to the traditional ultrasonic based non-wireless system.

We assumed the battery cost of Lithium cell as 4,000won, labor cost for replace the battery of each device as 3,500won, and electrical charges as 83won[6] per Kwh.

〈Table 5〉 Annual Maintenance Cost for Power Supply

Item		Anual Cost(x1,000 Kr. Won.)			
		Phy-sical	Labor	Sub. Total	Total (%)
Designed System	Batt.	3,142	2,750	5,892	6,848 (94.9)
	Wired	956	-	956	
Magnetic sensor based system	Batt.	11,000	9,625	20,625	21,778 (302)
	Wired	1,153	-	1,153	
Ultrasonic sensor based system	Wired	7,210	-	7,210	7,210 (100)

Ⅴ. Conclusion

We designed a parking guidance system which can be operated with reduced energy, for meet the needs of green building. The design is based on commercial wireless parking detectors, ParkDisk and ANTS T-sensor. The designed system has 4,000 parking space detectors, 1,200 section displays, 1,200 car location guidance terminals and 16 vehicle count detectors. We have performed architecture design of the system, communication network design, information service scenario planning, battery life regulation and at last operating power and annual energy cost estimation. The estimated operating power of the designed system with 7-years of battery replace cycle was 0.33W/slot, which is 13% of the estimated result of traditional ultrasonic detector based system. The estimated annual maintain cost for power was similar(94.9%) to traditional system, with 7 years of battery replace cycle. The low power operable designed system can be expected to low CO2 emission.

Further research on energy efficient display devices for parking information system is planned.

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