Smart Parking System using Wireless Sensor Networks

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***Abstract*—Reliable communication is imperative for realising a vision of "Ambient Intelligence" where different devices gather and process information from different sources to exert control over the physical environment. Wireless Sensor Networks (WSN) have been employed to fulfil the necessity of reliable energy efficient communication between these devices. These networks consist of individual motes that are able to sense and control the environment with the help of sensors and actuators. In this paper, we describe the implementation of an energy and cost efficient smart parking system for multi-floor parking facility using WSN. The system monitors the availability of free parking slots and guides the vehicle to the nearest free slot. Additional information such as the amount of time the vehicle has been parked is also monitored for billing purposes along with the status of each mote. Cost is minimized by keeping the number of sensors lower without sacrificing the reliability. Energy consumption of each mote is kept in check by allowing the systems to sleep periodically and by reducing their communication range.**

***Index Terms*—smart environment; energy efficiency; wireless sensor networks; sensor mote; light-dependent sensors.**

I. Introduction

In recent years, there has been tremendous amount of research in the field of wireless sensor networks. These networks are typically ad-hoc in nature consisting of large number of sensing motes communicating with a Central Supervisory Station (CSS). The sensor mote is a battery operated device with limited computation and communication capabilities. The mote can be interfaced with several types of sensors to measure different environmental parameters. The wireless sensor networks have varied advantages like flexibility, inherent intelligence, low cost, rapid deployment and more sensing point, especially in area that cannot be wired. It is because of these advantages that they found their way in diverse application domains such as facility management, health care, environment monitoring, intelligent buildings, disaster relief applications etc. In this work, we have developed a smart parking management system that can track available parking slots economically and reliably and in turn contribute considerably to fuel and time conservation. An emerging trend in wireless sensor networks is its use in parking facility management. Typical car parking management systems monitor the number of cars passing the entry and exit points for estimating the free slots available. This result is then displayed at strategic locations for assisting the user.

A number of WSN systems have been developed to address the car facility management. In [1], the system is developed using the DSYS25z [2], mote with magnetic sensors. The system described in [1] concentrates on issues such as connectivity, sensing and network performance. In [3], [4] and [5], a WSN based car parking system are proposed, where each of these papers explore the possibility of using different kinds of sensors. They also propose different routing mechanisms for transferring the data from the source to the sink. Most of the existing systems have discussed a scheme in which the data collected from the multiple sensor motes is analysed by a central station and is displayed at strategic points to assist the user.

In this paper, we propose and implement a car parking management system using wireless sensor networks such that overall efficiency and flexibility of the facility management system is improved. The system is highly cost-effective as each mote is equipped with only one passive

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ambient light sensor, to detect the presence or absence of a car. Apart from detecting the car the sensor mote also provides additional information like the amount of time the car has been parked and also its health status. The system designed is also energy efficient, since the radio module at the mote is allowed to "sleep" at regular intervals. In addition the power consumed by the radio module is reduced by the use of repeaters. The proposed system is completely automated and does not require the presence of a human at the entry or exit point. The system not only displays the availability status at strategic locations but also sends the information such as slot allotted, time parked, billing information and directional details to the user's mobile phone via SMS (Short Message Service). By introducing the SMS feature we are basically targeting everyone as the number of mobile subscribers in the world are very high, which is expected to increase further tremendously. Furthermore, including the SMS feature helps us avoid the usage of paper or plastic cards that are currently used for the purpose of parking/billing.

This paper is organized as follows: Section II decribes the system architecture and its operation. Section III discusses about the implementation details of the system. Section IV describes the experimental setup. Sections V and VI present the future work and conclusion.

II. System Architecture

The block diagram of the system is shown in Figure 1 and the CSS comprises of components as shown in Figure 2. The operation of the system is as follows:

- A user enters the parking facility. At the entrance, there will be a keypad and a display as shown is Figure 9. The driver enters his mobile phone number using the keypad.
- On successful entry of the phone number, ID of the nearest empty parking slot, time of entry and route direction information will be displayed on the monitor. The same information will also be sent to the user's mobile phone via SMS.
- In order to incorporate the SMS feature, a GSM modem is connected to the CSS. A java based SMS gateway at the CSS provides the essential functionality using AT commands to the send the SMS.
- When the driver parks the car in the designated slot, a timer is started in the mote present in that slot. The mote will inform the CSS that the slot has been currently occupied.
- The CSS will update the database of the motes with the occupancy information along with the corresponding user mobile phone number. This is done to uniquely identify the parking slot with the vehicle.
- When the driver leaves the parking slot area, immediately the timer in that slot's mote stops. The timer data is communicated to the CSS.
- The CSS consults its database, extracts the mobile phone number field corresponding to the mote ID it received, and sends an SMS to the user. The SMS will contain information of how long the vehicle was parked and the

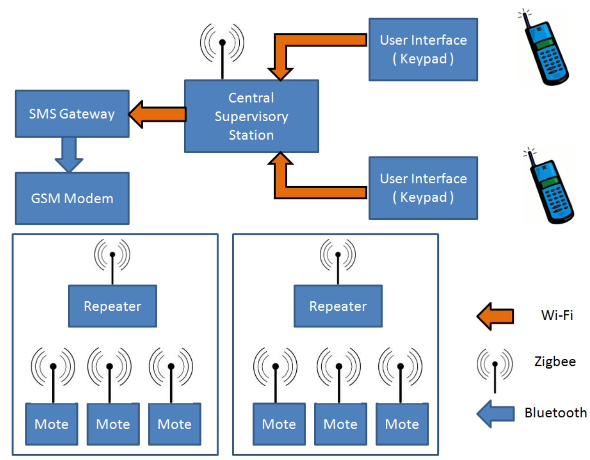

Figure 1. System Architecture

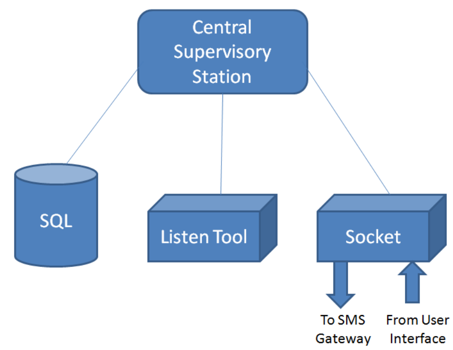

Figure 2. Central Supervisory Station Components

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billing amount.

- By the time the driver reaches the exit of the parking facility, he/she would have received the SMS containing the billing information.

Each parking slot will be equipped with an MIB510 Iris sensor [6] mote running TinyOS [7] operating system and MDA100 ambient light sensor to detect the presence/absence of a vehicle. The mote keeps track of how long the vehicle has been parked and sends this timing information to a repeater, which in turn sends it to the CSS. The IEEE 802.15.4 (Zigbee Protocol) [8] is the protocol used for communication between the motes. The CSS calculates the billing information based on the data received from the sensor motes. The mote also sends the availability status to the CSS which is displayed on a suitable GUI as shown in Figure 10. The CSS monitors the status of mote health.

To overcome the energy problems encountered in multi-hop routing strategy, in the proposed system, the motes forward their data to a repeater mote placed at a convenient distance from both the CSS as well as the individual motes in the parking area. The repeater simply retransmits the data it receives from the motes to the CSS. The repeater is powered from the AC mains.

III. Implementation Details

The entire working flow of the system at CSS and the sensor mote are shown in Figure 5 and Figure 6, respectively.

A. Parking bay occupancy detection and Data packet creation

The method employs measurement of the amount of ambient light captured by the light sensor to detect the presence/absence of the vehicle over the parking slot. The sensor mote is placed at the center of the parking slot few inches below the ground level with a suitable physical casing to ensure only light incident in normal direction is used for evaluation purpose. The principle behind detection is that, when a vehicle occupies a slot, there is a significant dip in the light intensity. By comparing this light intensity with a suitable threshold a decision on the occupancy status is taken. The threshold set is adaptive in nature based on the present lighting conditions.

Each sensor mote creates a data packet of 14 bytes with the following fields; mote id, timing information and slot availability status. Each field occupies two bytes. The packet header is as shown in Figure 3:

Misc Field
Mote ID (2 Bytes)
Slot Availability Status (2 Bytes)
Timing Information (2 Bytes)

Figure 3. Occupancy Status Packet Header

This packet generated by the mote is transmitted to the CSS. At the CSS, a java based packet sniffer program is used to detect the packets sent to the CSS. This java program has been modified to not only detect the packets but also parse the packet to obtain just the last 6 bytes of data from the packet. These last 6 bytes having the Mote ID, the slot status and the timing information is then stored at the CSS.

B. Dead or Alive (DoA) signalling

The mote periodically transmits DoA signal to the CSS, which enables the CSS to keep track of the health of the motes. The sensor mote sends the DoA signal typically every five seconds. The DoA signal is nothing but a data packet containing only mote id as the payload. The CSS maintains a table with all the mote IDs as its entries. Whenever a DoA signal is received, a count corresponding to that mote is incremented. Then, a decision as to whether a mote is dead/alive is taken after averaging over three consecutive readings from all the motes for experimental purpose. The number of consecutive readings can be increased to obtain a higher probablity of assurance, whether a mote is dead or alive, but at the cost of increase in decision taking time. The packet header here is of 10 bytes and is shown in Figure 4:

Misc Field
Mote ID (2 Bytes)

Figure 4. DOA Packet Header

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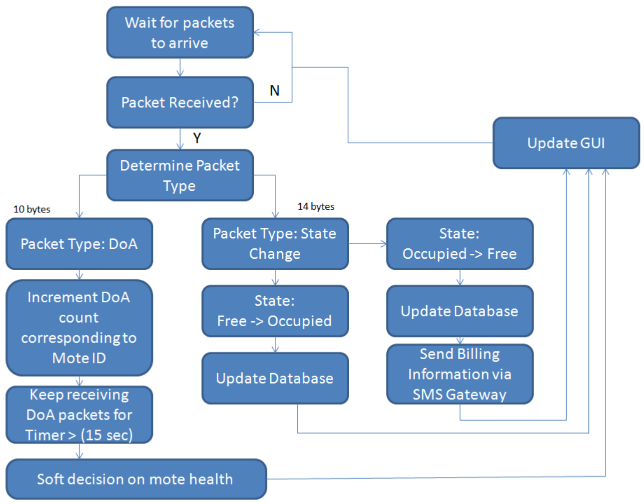

Figure 5. Flow Diagram at CSS

C. Data Packet Transmission Optimization

Radio Transmission consumes a lot of battery power. In order to reduce the battery drain due to repeated transmissions of data packet, the data packet indicating the slot status is transmitted only when there is a state transition. The state transition happens when the vehicle arrives at or leaves the parking bay. Activating the radio module to communicate information only during these transitions reduces the power consumption to a great extent.

However, to further reduce the power consumption by the mote, it can be put to sleep state. Since the DoA signal is sent every 5 seconds by the motes, according to the calculation it takes approximately 40 microseconds to transmit the 10 bytes long DoA signal at speed of 250Kbps. After the DoA packet is sent, the mote's transceiver module is put to sleep state. The mote is then awakened after every 5th second or if there is a state transition.

It has been found that the radio module of the mote in active state draws 12mA. On the other hand, during the sleep state, it draws only 1µA. This shows that by putting the mote to sleep state considerable power savings can be achieved.

D. Adaptive Thresholding

The lighting conditions do not remain constant at all times. In order to adapt to the ever changing lighting conditions, an adaptive thresholding algorithm has been implemented. The present lighting conditions are monitored and readings are captured periodically for a fixed interval of time. These values are averaged out and after comparing it with the previous threshold, the new threshold is set. Hence the system is made intelligent to adapt itself automatically to varying light conditions.

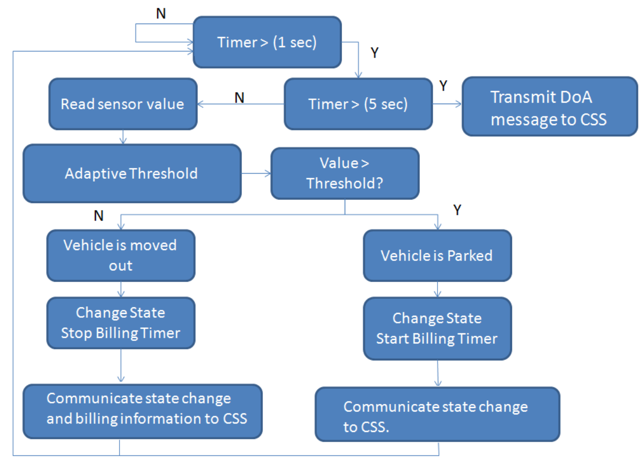

Figure 6. Flow Diagram at Sensor Mote

IV. Experimental setup

The project uses Crossbow IRIS – XM210 mote with MDA100CB sensor board. The MDA100CB sensor board is equipped with a CdSe photocell which acts as a light sensor. When there is light, the nominal circuit output is near VCC or full-scale, and when it is dark the nominal output is near GND or zero. This is used in the decision making process. Each mote runs on two AA batteries. The CSS mote is connected to the pc via USB cable for monitoring and display purposes. Figure 10 shows the display running at the CSS.

The adaptive threshold for the sensor mote was tested at an indoor parking facility at a mall. The communication range of the radio module was tested in the outdoor parking lot. The health status of the batteries in the motes is also monitored for maintenance purposes. According to therotical calculations, the battery life is estimated to be 1.58 years without considering the power consumed by the processor in idle state. The deployment of the sensor mote for the experiment is as shown in Figure 7 and Figure 8 shows a closer view of the same. In order to avoid the mote being over run by a car, the mote could be placed few

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inches below the ground surface during the actual deployment at the parking bay.

Attribute	IRIS - XM120
Program Flash Memory	128K bytes
Serial Flash	512K bytes
RAM	8K bytes
Serial Communication	UART
Analog to Digital Convertor	10 bit ADC, 8 Channel, 0-3V input
Current Drawn (Processor)	8mA (Active), 8uA (Sleep)
Frequency Band	2405 MHz – 2480 MHz
Transmit Data Rate	250 kbps
Outdoor Range	>300m
Indoor Range	>50m
Current Drawn (Radio module)	16mA (Rx mode), 10mA (Tx mode)
Battery	2 AA batteries

Table I
HARDWARE SPECIFICATIONS

Device	Software/Operating System
IRIS - XM120	TinyOS 2.1.1
Base Station - PC with Intel processor	Ubuntu 10.04
	Listen tool, GUI using JDK 1.6
	SMS gateway using JDK 1.6
	Socket Programming using JDK 1.6
	MySQL Database

Table II
SOFTWARE SPECIFICATIONS

Figure 7. Deployment

Figure 8. Deployment Under Car

Figure 9. End User UI

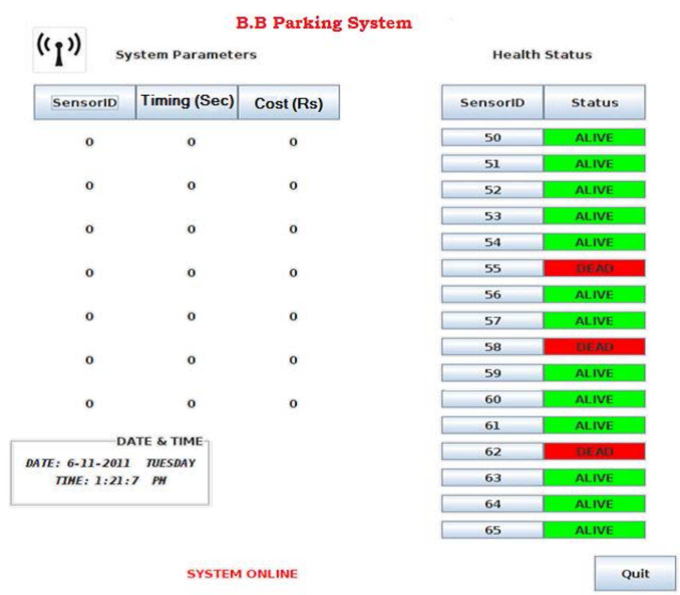

Figure 10. Central Supervisory Station UI

V. FUTURE WORK

In the future work, we plan to use additional sensors which will allow usage of the system in outdoors environment, albeit at increased cost. An active sensor may be added to validate the light sensor information. Cost may be further reduced by using a low cost processor mote such as custom built mote using the 8051 micro-controller. The system can be further extended to include the IMS network by providing information on SIP enabled devices. Another possible extension would be to provide location based services via mobile apps.

VI. CONCLUSION

The project successfully demonstrated the possibility of using WSN for multi floor parking

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facility. The system developed is fully automated, highly energy efficient and cost effective as only one sensor is utilized. The utilization of only one light sensor with the adaptive threshold algorithm was reliable in detecting the presence/absence of the car. As the application does not demand any complex routing mechanisms, our system implements the broadcast technique to communicate to the CSS. This is both simple in implementation and power efficient as opposed to unicast transmission which has a higher power profile due to the additional overhead to the packets. Finally, the system also proposed a novel approach of associating the slot, timing, direction and billing information with the users mobile number via SMS.

References

[1] J. Benson, "Car-Park Management using Wireless Sensor Networks," tech. rep., University College Cork (UCC), Cork, Ireland, November 2006.

[2] Andre Barroso, Jonathan Benson, Tina Murphy, Utz Roedig, Cormac Sreenan, John Barton, Stephen Bellis, Brendan Flynn, and Kieran Delaney, "The DSYS25 Sensor Platform," tech. rep., University College, Cork, Ireland and National Microelectronic Research Center, Cork, Ireland, 2004.

[3] Vanessa W.S Tang, Yuan Zheng, and Jiannong Cao, "An Intelligent Car Park Management System based on Wireless Sensor Networks," tech. rep., Internet and Mobile Computing Lab, Department of Computing, The Hong Kong Polytechnic University, P.R.China, August 2006.

[4] Seong-eun Yoo, Poh Kit Chong, Taehong Kim, Jonggu Kang, and Daeyoung Kim, "PGS: Parking Guidance System based on Wireless Sensor Network," tech. rep., Information and Communications University Daejeon, Korea, May 2008.

[5] B. Yan Zhong, S. Li Min, Z. Hong Song, Y. Ting Xin, and L. Zheng Jun, "A Parking Management System Based on Wireless Sensor Network," tech. rep., Institute of Software, Graduate School of Chinese Academy of Sciences, Beijing, November 2006.

[6] Sangwon Lee, Dukhee Yoona, and Amitabha Ghosh, "Intelligent Parking Lot Application Using Wireless Sensor Networks," tech. rep., Autonomous Networks Research Group, Ming Hsieh Department of Electrical Engineering, University of Southern California, Los Angeles, May 2008.

[7] Itziar Marin, Eduardo Arceredillo, Aitzol Zuloaga, and Jagoba Arias, "Wireless Sensor Networks: A Survey on Ultra-Low Power-Aware Design," tech. rep., World Academy of Science, Engineering and Technology, August 2005.

[8] ZigBee/IEEE 802.15.4 Summary, "Sinem Coleri Ergen," tech. rep., EECS Berkely, September 2004.

[9] David Gay and Philp Levis, *The nesC Language: A Holistic Approach to Network Embedded System*.

[10] David Gay and Philp Levis, *Software Design Patterns for TinyOS*.

[11] David Gay and Philp Levis, *nesC 1.1 Language Reference Manual*.

[12] Wikipedia The Free Encyclopedia, "Tiny OS Documentation Wiki." http://docs.tinyos.net/, August 2011. Accessed: 25/6/2012.

[13] "Tiny OS 2.0.2 Documentation." http://www.tinyos.net/tinyos-2.x/doc/, July 2007. Accessed: 25/6/2012.

[14] "Data Sheet for Memsic IRIS Motes." http://www.memsic.com/products/wireless-sensor-networks/wireless-modules.html. Accessed: 28/7/2012.