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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 8 (2): 138-146, 2009
ISSN 1812-5638

Parking Guidance System Utilizing Wireless Sensor Network and Ultrasonic Sensor

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Abstract: This study introduces a new approach of parking system by using Wireless Sensor Network (WSN) technology equipped with ultrasonic sensors. The system also implements shortest path algorithm to calculate the shortest distance from the parking berth to the nearest preferred entrance. The system operates by monitoring the availability of the vehicle berth and making the information collected available for patrons and car-park operator. The information gained from the detection sensor and calculation from the shortest path algorithm is used to guide patrons to parking berth. The car-park operators use the sensors' information to aid in overall management and planning. WSN is chosen since it enables reliable information gathering and measurement to be transmitted through wireless channel without having to install new cabling for network and electricity to reach each sensing device.

Key words: Smart parking systems, A-Star algorithm, WSN, ultrasonic sensor

INTRODUCTION

With the significant increase in the number of new registered vehicles shown clearly in the statistics provided by the Malaysian Ministry of Transportation, 458, 293 new vehicles was registered in the year 2006 compared to the year 1999 where 296, 716 new vehicles was registered. This makes a drastic increase of approximately 54.5% increase in span of 7 years (MMOT, 2007). Driven by the frustration of the scarcity of parking space in most major cities, an organized and effective car park system is important to ensure smooth flow of traffic and mitigate problems on the road.

Roads in Asia are significantly narrower compared to the West which leads to more problems including traffic congestion (Inaba *et al*., 2001). A smart parking management system would help in solving such difficulties when patrons take less time to find parking when they reach a parking lot. This also greatly reduces the fuel consumption and reduces the combustion emission (Smith and Roth, 2003).

The emergence of Wireless Sensor Network (WSN) which consists of spatially distributed autonomous devices using sensors has contributed to a wide variety of applications. The ability to provide wireless localized measurement with low power consumption has driven the authors to propose a smart parking system which employ WSN technology. WSN technology will be used to detect parking occupancy and provide information to the proposed system which implements shortest path route calculation. The system will guide patrons to the nearest parking berth to the entrance. Information from the sensor also can be used for performing more complex tasks like statistical sampling.

This study, present current smart parking technology. Then, the proposed system methodology is presented to show how WSN technology, ultrasonic sensors and shortest path algorithm can be integrated to form a smart parking system.

SMART PARKING SYSTEM

There are five categories of smart parking system which are in common use which consist of parking guidance and information system, transit based information system, smart payment system, E-parking and automated system (Shaheen *et al*., 2005).

Parking Guidance and Information System (PGI) is a system that uses Variable Message Display (VMS) and other methods including radios and phones to provide information to patrons. These systems can be implemented city wide or restricted within a specific car park and it can provide the patrons with the information about the parking lot or information about the traffic (Sakai *et al*., 1995). Having similar function like the PGI system, transit based information system provides patrons with information about the traffic as well. The main difference between these two systems is that the transit based information system directs patrons to car park nearest to a public transport ride lots. The main goal

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of such system is to encourage the public in using public transport by providing them a place to park their vehicle and switch to public transport (Chinrungrueng *et al.*, 2007).

Another type of smart parking system is the smart payment system which uses various types of technologies such as RFID transponder and mobile technology. E-parking is a system whereby information of car park occupancy can be retrieved and parking space reservation can be done via mobile phone, PDA and internet. The automated parking utilizes computer control mechanisms which normally include heavy machines to automatically places vehicle into parking space in according order to save space (Shaheen *et al.*, 2005).

PARKING GUIDANCE SYSTEM

Here, the researchers will present the proposed system design. This study is a continuation project of parking guidance system described by Idris *et al.* (2005, 2006, 2007, 2008) which guides patrons to the nearest empty parking space. Wireless sensor network technology is employed in the latter implementation. The system can be divided by various components or segments as shown in Fig. 1. The system starts with an interface for patrons to select their general preferred entrance to the building (e.g., level, wings etc.). The selection user interface is presented when the patrons vehicle approach car park barrier. Based on the selected destination, the system will calculate the nearest empty parking berth nearest to the entrance chosen using shortest path searching algorithm. This is done assuming patrons will prefer to park nearest to the building entrance since less walking distance is needed.

Searching algorithm plays a crucial role in deciding the efficiency of the entire system. A heuristic algorithm is much preferred as immediate result is needed and since the shortest path needs to be calculated repeatedly (Fu *et al.*, 2006). Delay could not be tolerated because this will definitely slows down the traffic at the entrance and defeats the purpose of the system. Various evaluations have been conducted on different algorithm in the search for the most appropriate algorithm that is able to deliver the performance desired. In this system, the shortest path calculation is done using A* (A-star) shortest path algorithm. A-star is a bidirectional heuristic search algorithm which makes it preferred to be used in the system. It is a best-first, graph search algorithm that finds the least-cost path from a given initial node to one goal node out of one or more possible goals.

Following the calculation, the calculated empty parking berth is reserved with a unique ID embedded in a Radio Frequency Identification (RFID) tag. Then, the unique ID and reserved parking berth is updated in database. The patrons will be presented with the RFID tag via a ticket dispenser and the solution route to their reserved parking berth via touch screen monitor as shown in Fig. 2. In the case the reserved parking space is not

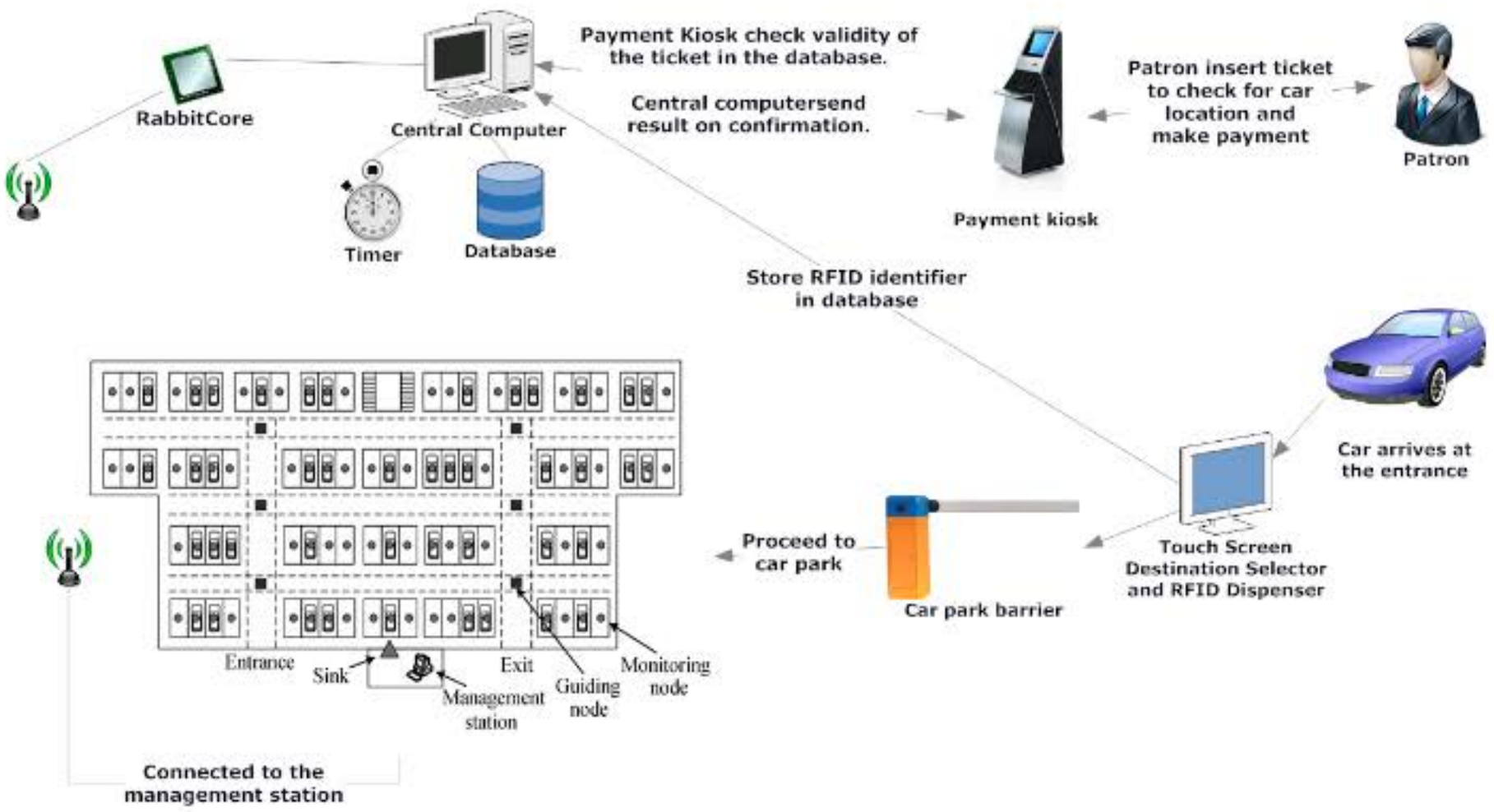

Fig. 1: WSN parking guidance system using ultrasonic sensor overall components and segments

Fig. 2: Shortest distance path from entrance to parking berth

Fig. 3: Shortest distance path from payment kiosk to parking berth

utilized, the reservation will expires after 10 min. The system calculates the time of reservation of every parking berth and reset the status of the parking berth to available when the time is due. The system will assume the patron parked the car at other parking berth.

The RFID tag is used for timing audit to calculate the parking duration and fee that should be paid by the patrons. It is also used to guide patrons to their parked vehicle. Patrons are able to make payment conveniently by the aid of payment kiosk. As shown in Fig. 3, the path to the parking berth which is firstly assigned to the patron will be displayed on the payment kiosk screen when patrons insert their RFID tag. This component is useful to aid patrons who did not remember where they have parked their vehicle after spending time in the building. As soon as the car leaves the berth, the database will then set the status of the berth back to available triggered by the information provided by the ultrasonic sensors.

The system is developed with a strong feature which allows the car park operator to customize the layout of the parking lot map for each level of parking lot. The car park operator can add, move and remove a parking berth, entrance to the parking lot and entrance to the building from the parking lot. Figure 4 is the customization page for the car park layout. This feature greatly increases the usability of the system as it can be used in most building and even outdoor parking lot. The car park operator can edit the layout of the parking lot from time to time if any modification were made to the parking lot. The reusability of the system reduces the overall cost of the parking lot.

Fig. 4: Customization page of the car park layout

CAR PARK OCCUPANCY DETECTION

Various types of sensor systems are used in smart parking system as the system relies heavily on the car park occupancy information. The crucial part in implementing the smart parking system is the step where proper detection system is chosen. With various sensors available, the significant challenge in selecting a suitable sensor system for smart parking system has to be taken into account. The various factors are cost, sensitivity to the environment changes, size, reliability robustness and the integration into a global system design (Masaki, 1998). Generally there are 2 categories of sensors technology which is the intrusive sensors and the non intrusive sensors (Scheeling, 2002).

Inductive loops, magnetometers, pneumatic tubes, piezoelectric cables and weigh-in-motion sensors are categorized as intrusive sensors. Intrusive sensors are installed in holes on the road surface which requires tunneling under the road surfaces or by anchoring the sensors on the surface of the road which leads to an invasive installation procedure (Scheeling, 2002). Non-intrusive sensors are sensors that require simpler installation compared to intrusive sensors by mounting the sensors on the ground or the ceiling. Examples of non-intrusive sensors include video image processing, microwave radar, passive infrared, ultrasonic, laser radar and passive acoustic array sensors (Mimbela and Klein, 2007).

In this study, ultrasonic sensor has been chosen to detect empty parking space. Ultrasonic sensors transmit sound energy waves or emit pulses of waveform between 25 to 50 kHz. The transmitted energy is reflected by an object will then received by transducer. The reflected energies are used to analyze the occupancy of the parking berth by the signal processor (Mimbela and Klein, 2007).

Ultrasonic sensors are able to provide vehicle count, presence of a vehicle and the occupancy information of the parking berth. Using ultrasonic sensor can cut down the overall development cost since ultrasonic sensors are inexpensive and require minimal maintenance (Kim *et al.*, 1998). Besides that, ultrasonic sensors are capable to detect overweight vehicle. However, ultrasonic sensors' performance is affected by temperature change and extreme turbulence. Figure 5 is a schematic diagram for ultrasonic sensor detection and Table 1 is the list of components used in the diagram.

Table 1: Component of ultrasonic sensor detection circuit

Resistor	Capacitor	Integrated circuit	Transistor
R1 = 160K	C1 = 0.001	IC1 = GL3274	Q1 = 9012
R2 = 1K	C2 = 047/50v	IC2 = 4093	Q2 = C458
R3 = 2K	C3 = 047/50v	IC3 = 4093	Q3 = C458
R4 = 390K	C4 = 0.1	IC4 =7809	
R5 = 5K	C5 = 1/16v		
R6 = 1K	C6 = 4.7/16v		
R7 = 10K	C7 = 0.001		
R8 = 2.2M	C8 = 100/16v		
R9 = 1K	C9 = 100/16v		
R10 = 1K			
R11 = 10K			
R12 = 1K			
R13 = 56K			
R14 = 10K			
R15 = 1K			
R16 = 20			
Variable resistor	**Diode**	**Relay**	
VR1 = 10K	DI-D4 = 4001	RY1 = Relay	
VR2 = 100K	D5-D8 = 4148	12V	

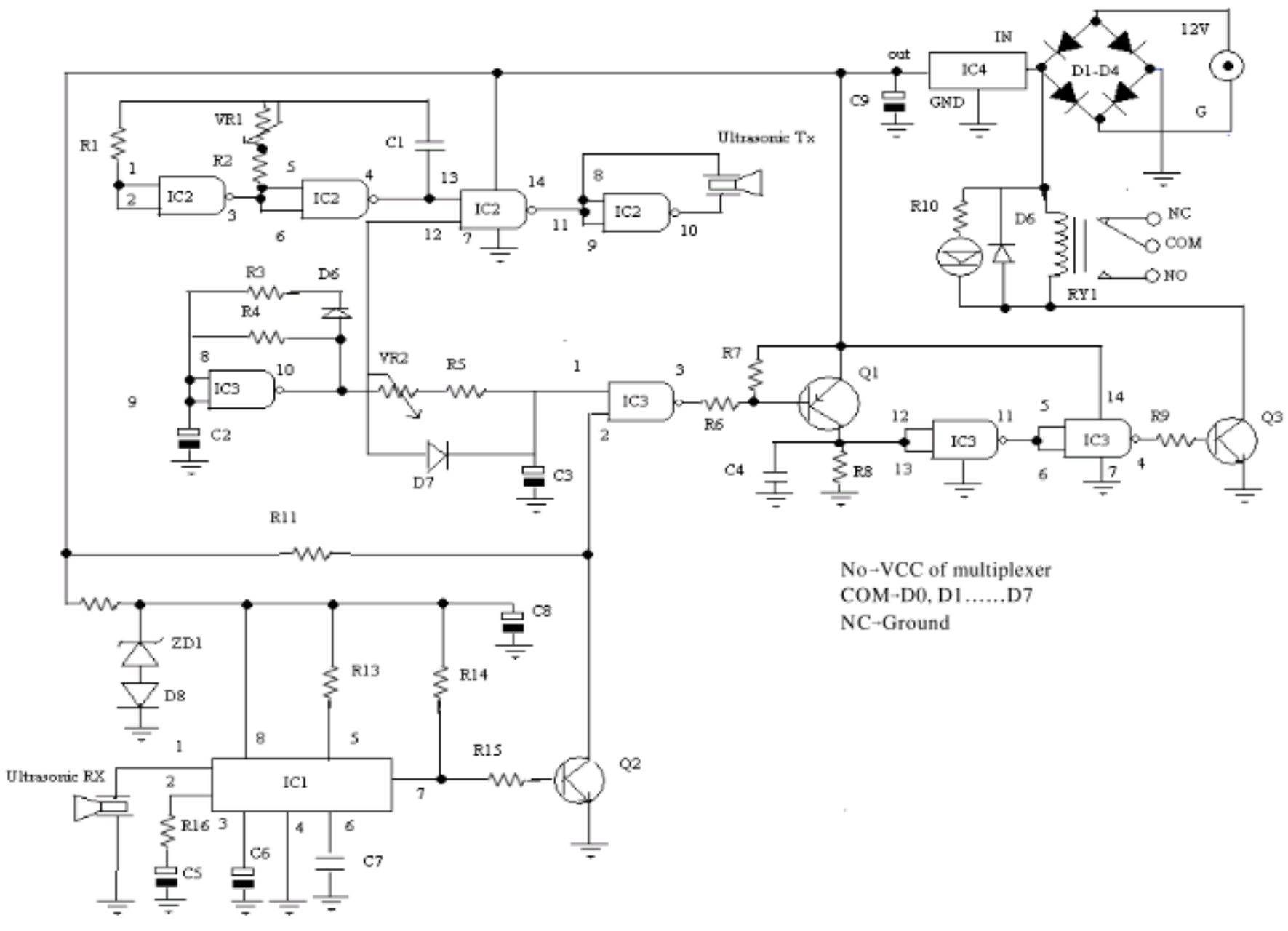

Fig. 5: Schematic diagram for ultrasonic sensor detection

MULTIPLEXING ULTRASONIC SENSORS

In this system, ultrasonic sensors appear as nodes in WSN environment. Since many, ultrasonic sensors are used, it is not cost effective to use many microcontrollers and wireless transmission module to activate the database. An electronic multiplexer makes it possible for several ultrasonic sensors input signals to share expensive microcontroller device and outputs it into a single line. These multiplexers are controlled by RabbitCore® microcontroller module which selects ultrasonic signals in round robin. RabbitCore® Module sends repeating signal to the selector of the multiplexer to allow input from the ultrasonic sensor. Figure 6 shows the connection between RabbitCore® module, ultrasonic sensors and ZigBee® wireless module. In this example, nine 74HC151 8-input multiplexer is used to select 64 ultrasonic sensor signals or 64 parking berths. The selection is controlled by three RabbitCore® microcontroller outputs from port A (i.e., A_1, A_2, A_3) and three output from port B (i.e., B_1, B_2, B_3) as shown in Table 2. Port B selects which multiplexer to choose from the eight multiplexer (i.e., mux1, mux2…mux8) and Port A selects the parking berth (i.e., 1FG1, 1FG2, 1FG3…1FG64). A schematic example is shown in Fig. 7 where relay is used as switch to trigger the multiplexer. The number of nodes that a single RabbitCore® Module can handle is mainly depends on how many pins the RabbitCore® Module possesses.

Table 2: Selective data input of multiplexer controlled by RabbitCore® module

		Port A data select			Port B data select		
MUX	Parking berth to be detected	A_1	A_2	A_3	B_1	B_2	B_3
MUX1	1FG1	L	L	L	L	L	L
MUX1	1FG2	L	L	L	L	L	H
MUX1	1FG3	L	L	L	L	H	L
MUX1	1FG4	L	L	L	L	H	H
MUX1	1FG5	L	L	L	H	H	L
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
MUX8	1FG62	H	H	H	H	L	H
MUX8	1FG63	H	H	H	H	H	L
MUX8	1FG64	H	H	H	H	H	H

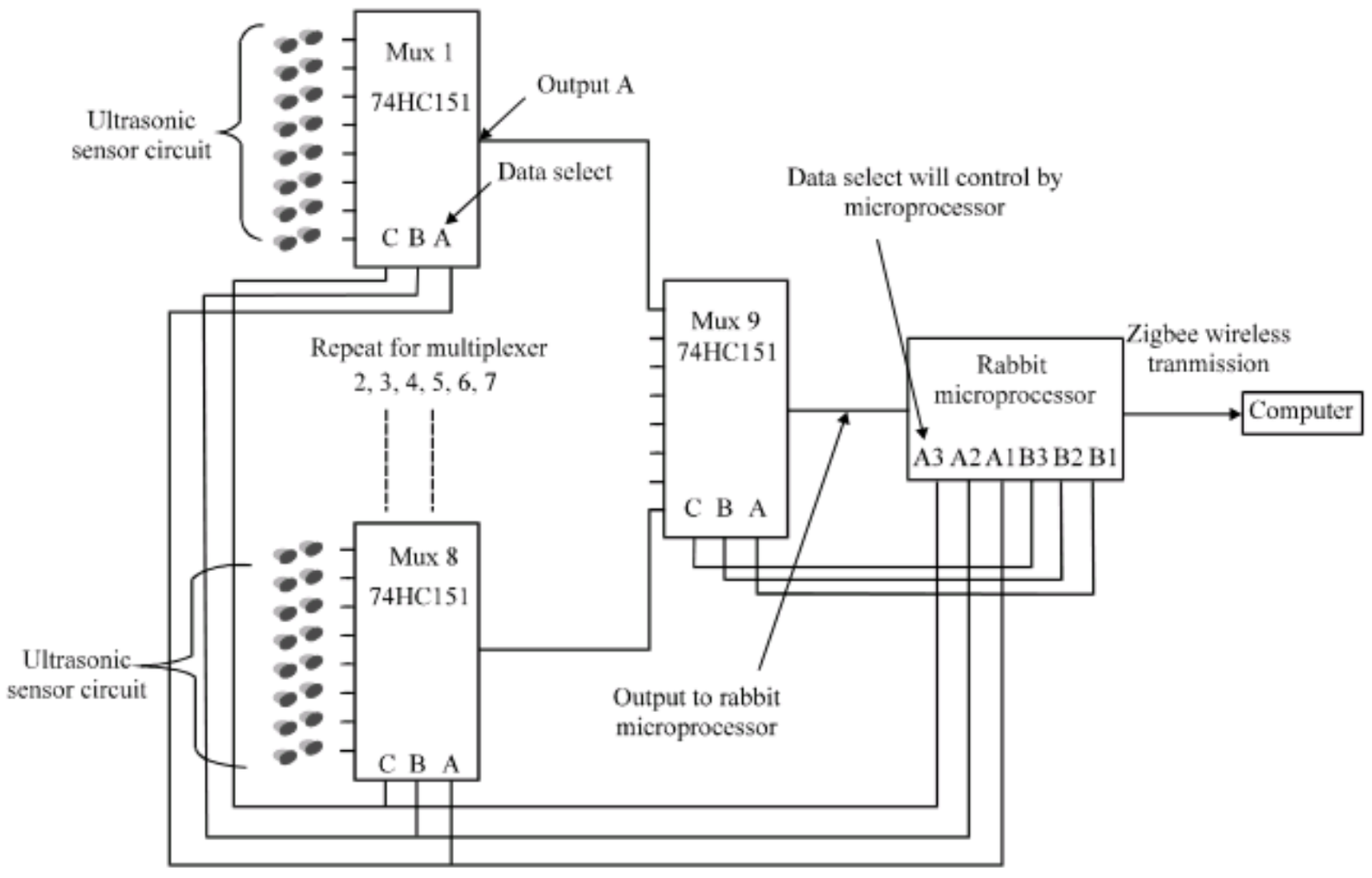

Fig. 6: Logic Connection within the entire WSN segment

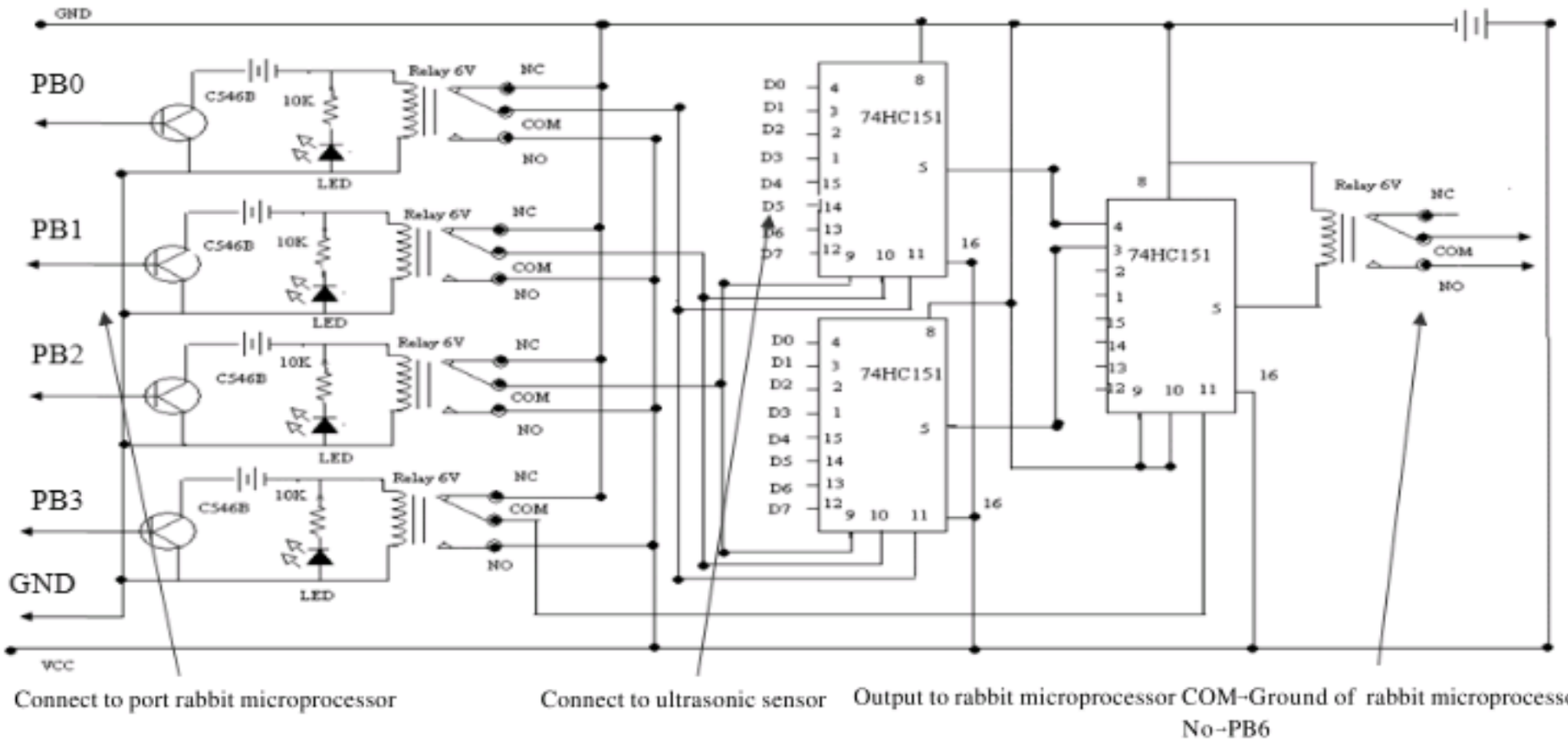

Fig. 7: Schematic diagrams for multiplexer

WIRELESS SENSOR NETWORK PARKING SYSTEM ARCHITECTURE

Parking lots are usually wide and spacious. Installing cables and wires for data transmission is very difficult and challenging. In addition, wires and cables require frequent maintenance and cost more compared to a wireless environment. ZigBee® is a low cost, low power, wireless mesh networking standard. The low cost allows the technology to be deployed at various spot in the parking lot to ensure a reliable data transmission. The low power usage allows longer life of operation even with a small size battery which also reduces the size of the device. Mesh networking provides high reliability and wider range as data can be routed between transmitters.

The proposed parking system consist of various types of hardware components where each of them are connected together to form segments hence build up the whole system. The segments includes multiplexer, the RabbitCore® Module, ZigBee® and the ultrasonic sensors. Figure 8 exhibits the topology of the system architecture. Ultrasonic sensor detection circuit detects the presence of the vehicle on the parking berth and sends the data to multiplexer. RabbitCore® module collects the data and sent it through wireless environment using wireless ZigBee® transmitter. At the management segment, wireless ZigBee® coordinator (i.e., Digi® USB) will receive the signal sent from the sensor segment and update the database with the latest status of respective parking berth. Central computer can command these nodes to perform time synchronizing, debugging and working status reporting.

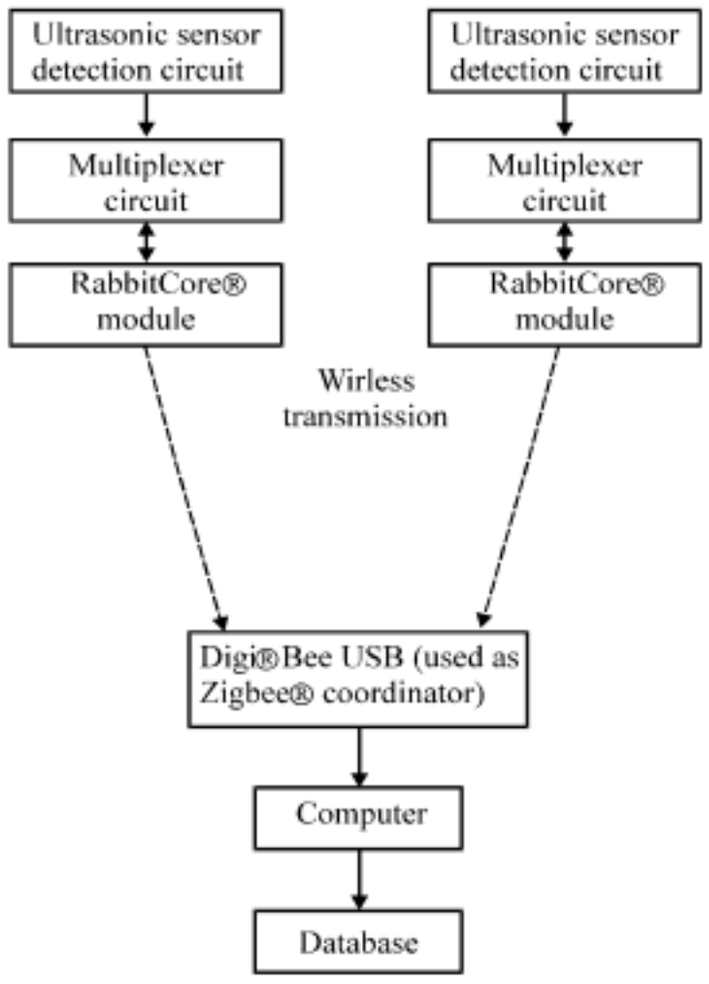

Fig. 8: System architecture

The status of the parking bay is segmented into three as below:

FSKTM - RabbitId = 0 -00…….0010011

Accesss key Rabbit Id Status of 64 parking lot

FSKTM is the access key for quick access to the database. RabbitID is the unique ID of the RabbitCore® Module. The unique ID is used to identify

more than one RabbitCore® Module where each module detects 64 parking berths. At the end of the segment, status of the 64 parking berth is shown. The convention used for the parking berth status is: 1 occupied and 0 empty. This data is sent via ZigBee® transmitter to the Digi® USB located at central computer. The data is received as a serial data as shown in Fig. 9.

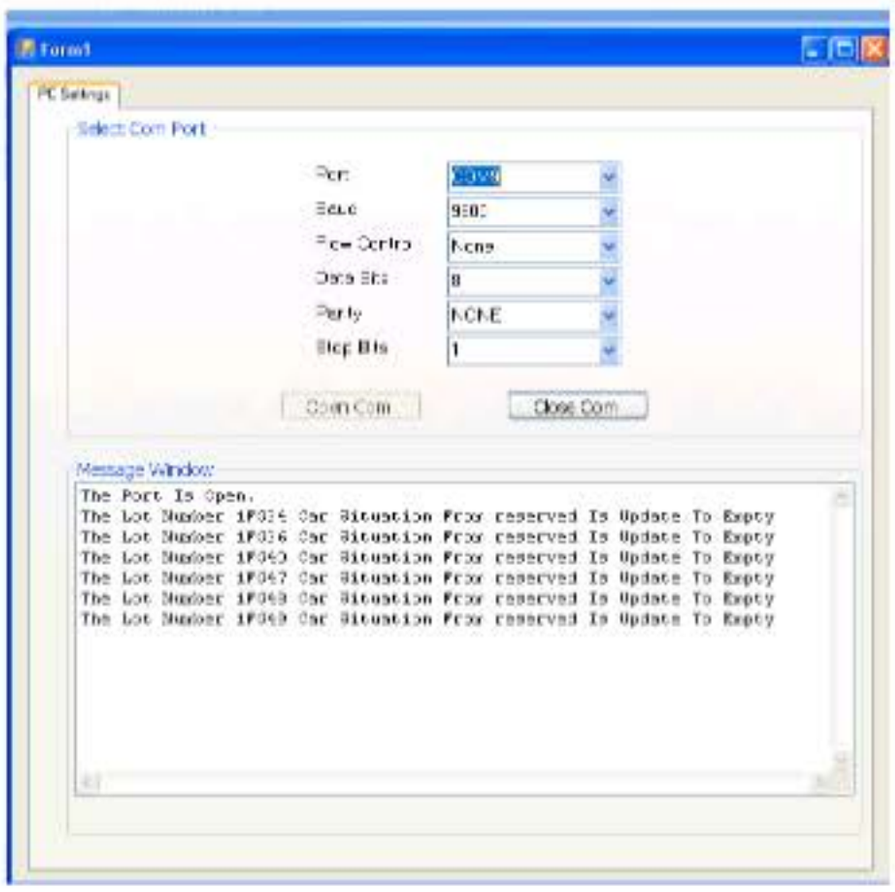

Fig. 9: Data received at central computer via ZigBee®

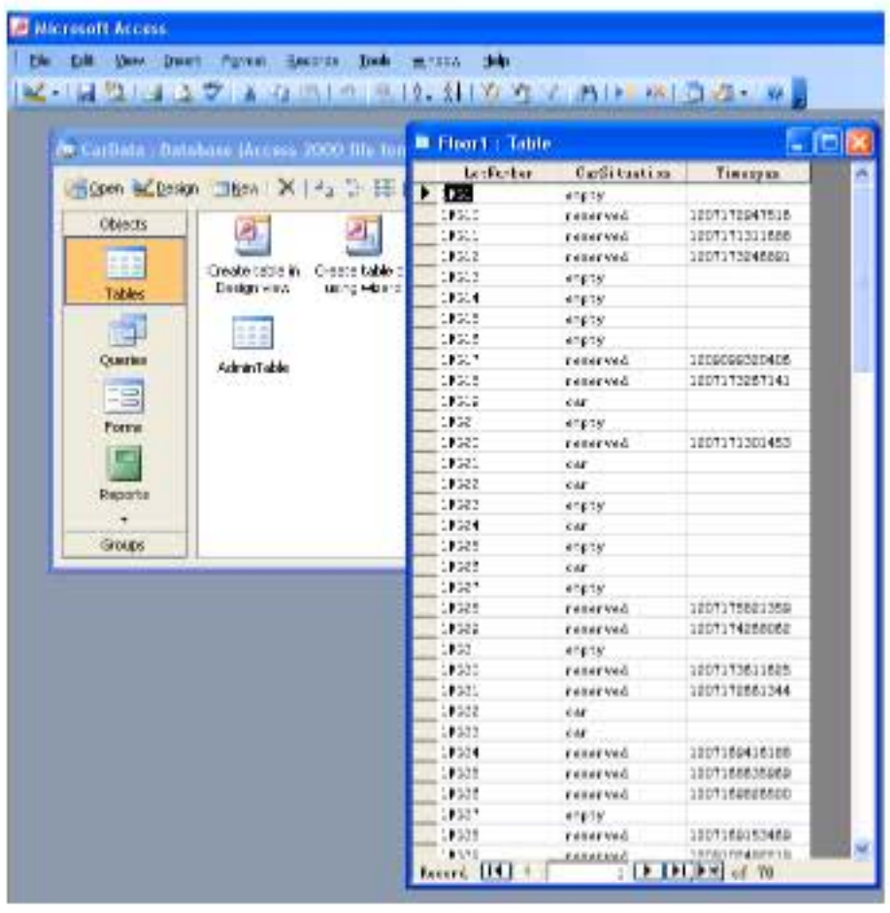

Fig. 10: Database showing the status of parking berths

Based on the data received, the database is updated and displayed at the user interface as in the earlier Fig. 2. Total availability and route to the reserved parking berth is shown. The database that activate the user interface is shown in Fig. 10 where LotNumber is the unique car park lot number (Primary Key), CarSituation is the parking berth status and Timespan is the time when the status is triggered.

SYSTEM EVALUATION

This study proposed parking guidance system utilizing Wireless Sensor Network is used for patrons convenient. The system aid by reserving an empty parking berth and guide the patrons to the reserved space. Instead of waiting for vehicle to exit, the system will calculate the nearest available parking space from the patrons preferred entrance to save searching time.

The system also helps patrons to locate their parked vehicle. Since, most of the car parks are large and have many exits, it is common problem that patrons often fail to remember where they have parked. Furthermore, a different view from other exits might confuse the patrons in locating their vehicle. Therefore, the RFID reader (available at payment kiosk) will help the patrons by providing the way to their vehicle. When the patrons insert the RFID tag into the RFID reader, the ID which is embedded in the tag will be used to search the central computer database. Shortest path algorithm used the database information to calculate and show the route from the payment kiosk to the parked vehicle ID.

In this system, wireless transmission technology is proposed. Using wireless transmission technology, less wiring is needed hence maintenance is easier to be conducted and overall costing will be reduced. Zigbee® wireless transmission is employed in the system to transmit the parking berths status to a single management node at the central computer. The availability status of each parking berth relies on ultrasonic sensor nodes which is located at each parking lot. Synchronized with the database, availability of each parking berth is kept up to date.

The implementation of WSN in parking system is extremely beneficial for the car park operators as they are able to utilize the data in the system to predict future parking patterns and therefore helps them in developing and improve pricing strategies. The system also able to increase the utilization of the parking lot hence increases the revenue. Furthermore, illegal parking can be reduced since parking spaces are easily available.

Although the system has various benefits, there are also limitation and constrains. There are chances that the patrons disobey the direction given and chose another parking berth instead of the one assigned. As a result, the parking lot which the system reserved for the drivers become unavailable until the reservation time is over. This illegal parking is minimized by the implementation of shortest path algorithm which guides patrons to their reserved slot. The shortest distance would give the patron advantage to be the first one to park. Another approach to alleviate this problem is by imposing kind notice or even a penalty ticket to patrons who disobey the instructions.

FUTURE ENHANCEMENT

There are many rooms for improvement to ensure the reliability of the system. Problems faced such as data loses in between ZigBee® transmitter and receiver needs to be solved. Possibilities such as integration with the legacy system used by the parking management should be considered. Other consideration that would be beneficial is the proper manner of displaying the information to drivers.

A potential approach of enhancing the system is to implement image processing technique to detect vehicle presence. Surveillance CCTV camera can be used as the image receiver and a RabbitCore® Module is used to analyze the vacant parking berth by comparing image captured from time to time. Apart from surveillance, the advantage of using image sensor is that it can detect multiple parking berths within its view.

CONCLUSION

In this study, solution for handling high demand parking space has been introduced. Ultrasonic sensors are used as the main component to detect parking vacancies. Then, the sensors' information signal is transmitted via Wireless Sensor Network (WSN) using Zigbee protocol and updated in the central database. The information is then used by the central computer to assign and reserve a parking space for the patrons through A-star shortest path route calculation. RFID technologies are also utilized to calculate parking fees and to guide the patrons to their parked vehicle. Research and experiments are conducted to refine the algorithm and the method used. It is believed that by the implementation of the system, problems such as insufficient of parking space, difficulties of finding available parking berth and the difficulties of finding the parked vehicle will be reduced. Both car park operator and patrons will benefit from the system as parking spaces are easily acquired and parking space wastage is reduced.

ACKNOWLEDGMENT

The authors would like to thank Mr. Goh Hong Long for his help and University of Malaya for funding this project (Grant No.: SF035-2007A and FS255/2008B).

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