

EXHIBIT 1009

Smart Parking: an Application of optical Wireless Sensor Network

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Abstract

Parking problems are commonplace in most major cities. The limited availability of parking results in traffic congestion, air pollution as well as driver frustration. The price for parking expansion is usually prohibitive or extremely high. Recently researchers turned to applying technologies for efficient parking management. In our previous work, we have developed an optical wireless sensor network (WSN) for traffic monitoring. We have demonstrated our system to the public in several exhibitions. It is realized that this simple invention could be applied to monitor vehicles in a parking garage. The system can then inform drivers of the number of available parking spaces and in which area should they be directed to. This kind of system should avoid driver's frustration in trying endlessly to find a parking space in a crowded parking garage. This paper describes our work to modify our original WSN and applies it to parking garages. Problems associated to applying our original WSN to parking garage are explained, and solutions are proposed.

Keywords: Smart Parking, Traffic Monitoring, WSN

1. Introduction

Parking problems are commonplace in most major cities. The limited availability of parking results in traffic congestion, air pollution, as well as driver frustration. The price for parking expansion is usually prohibitive or extremely high. Smart parking is a parking garage that utilizes various technologies to efficiently manage the garage. Since early 1970s, smart parking have been implemented throughout Europe, the United Kingdom and Japan. Early systems displayed to drivers parking information such as the avail-

ability status and/or the number of available spaces. This system is still widely used today and becomes a necessary part of new parking garages in major cities. More complex smart parking incorporates more advanced technologies to serve customers of different needs [3]. For example, parking garages in large shopping complexes can direct customers to available spaces close to where they want to shop. While at the same time some parking garages can employ security measures such as collecting vehicle's license plate and verifying it when checking out. Smart payment systems such as smart meters, smart cards, mobile communications and e-parking may also be incorporated. Park and ride facilities may also display real time information on the departure and arrival time of the next bus or train, in addition to parking availability. Such system will encourage high-way commuters exploiting public transportation. In a broadest and simplest sense, smart parking permits an optimization of existing parking spaces in order to best satisfy the customers' needs. To name a few, these include minimizing the time that customers spend on trying to find a parking space, provide real-time information on parking spaces, and provide smart payment options.

Obviously, an indispensable element of smart parking is vehicle detectors. Inductive loop is the most widely used detector today. New parking garages will at least install them at the entrances and exits. It yields an accurate vehicle count. The major drawbacks, however, include difficulties in installation and maintenance processes that involve road surface excavation [2]. This installation and maintenance can prevent normal operation within under-operation parking garages. Other detectors include video cameras, ultrasonic sensors, and doppler radars. To avoid installation and maintenance difficulties, we proposed an optical wireless sensor network (WSN) to monitor vehicular traffic [1]. It was a simple WSN that based on a star-topology as shown

in Figure 1. The network consisted of a server node and a number of sensor nodes. The server node served as the central point for collecting traffic data from all sensor nodes installed at various monitored points. The sensor node was equipped with an optical sensor to detect passing vehicles. The use of optical sensor yielded very accurate count as well as position of vehicles. The design of our polling MAC protocol allowed an efficient-power mode of operation. Several tests and demonstrations at various exhibitions showed that our WSN was reliable and robust in counting vehicles and in relaying data to the central server.

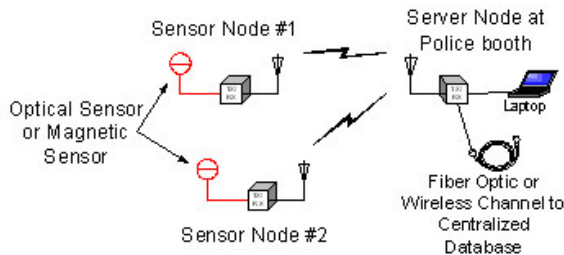


Figure 1. WSN with a star-based topology.

In this work, we propose to apply our optical WSN as the vehicle counting system in smart parking garage. The sensor nodes can be easily installed as they require no excavation and signal wiring. We install these sensor nodes at all entrances, exits and other key locations for counting vehicles passing those points throughout the parking garage. The system collects these data with a server node installed at nearby control station and calculate occupied and available parking spaces. Then the system displays the number of available parking spaces or even directed drivers to closest available parking areas. We review existing smart parking systems in Section 2. We then propose how our WSN may be employed in these systems. In section 3 we describe our problem setting in applying WSN to monitoring parking garages. Problems inherent to parking garage application that were not important issues in our original WSN will be explained. Then we explore the modification of our original design of WSN in order to apply it to parking system. Finally, we conclude this work in section 4.

2. A Review of Smart Parking Systems

Europe, the United Kingdom and Japan were among the first countries to implement smart parking systems. Today we can find several smart parking facilities in most major cities. Smart parking technology benefits the customer and the parking operator in the following ways:

- The customer can readily determine space availability prior to entering the garage and/or parking level.

- The customer can plan for their transit to public transportation with such smart parking systems employed at Park and Rides
- The parking operator can use the system data to develop or improve pricing strategies.
- The parking operator can use this system data to predict future parking patterns and trends.
- The parking operator can use this system data to prevent vehicle thefts.
- The parking operator can reduce the staffing requirements for traffic control within the facility.
- The system significantly reduces traffic—and the resulting vehicle emissions—by decreasing the time required for customers to locate open spaces.

Smart parking systems were categorized into 5 systems as following summarized [3]:

2.1 Parking Guidance Information Systems (PGI)

PGI is a parking technology that guides and provides information about the availability of parking spaces located in major cities. Vehicle detectors are installed at entrances, exits and/or individual parking space to collect and calculate the number of occupied and available spaces. Common detectors include loop detectors, machine vision, ultrasonic, infrared, microwave and lasers. Information, ranged from "empty" or "full" lot, to the number of availability, or to the exact location of available spaces, are displayed at various spots so that drivers can make better decision.

2.2 Transit-Based Information Systems

This system specifically provides parking space information and public transportation schedules in Park and Ride facilities. The system's main purpose is to encourage commuters to park their vehicles and use buses or trains for their transit. This in turn will reduce traffic congestion, pollution, and fuel consumption. Vehicle detectors are employed similar to PGI. Messages are then displayed on variable message signs along highways leading to park and ride lots.

2.3 Smart Payment Systems

Smart payment systems employ advanced technologies to implement payment systems in place of conventional parking meters. The systems allow fast and convenience payment, improving collection rates for fine, and reducing

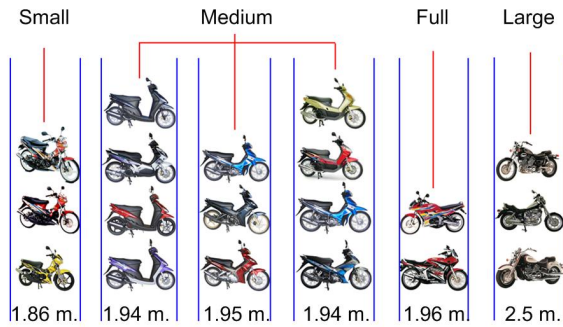


Figure 3. Motorcycles of various sizes range from 1.8 to 2.5 meters.

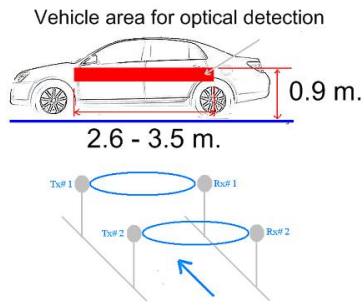


Figure 4. Appropriate placement of two sensor heads to distinguish pedestrian from vehicle and to determine vehicle direction.

the garage. Figure 3 shows our parking garage's WSN state diagram. The diagram starts at State A where an unidentified object (pedestrian or vehicle) is not detected by sensor 1 and sensor 2. The system detects a vehicle if it completes full cycle of the state diagram in either clockwise or counter-clockwise direction. We define variable v to be the state variable in order to identify if a full cycle is completed. Variable v is set to 0 when exiting State A – identifying that an object is detected by either sensor. The value of variable v either increases or decreases depending on direction that state diagram cycle through. If state diagram cycles counter-clockwise through States B, C and D back to State A, variable v increases to 4. Similarly, if state diagram cycles clockwise through States D, C, and B back to State A, variable v decreases to -4. The value of v can be verified when State A is entered for the vehicle direction. For example, $v = 4$ corresponds to vehicle entering, while $v = -4$ corresponds to vehicle exiting. Values of v other than 4 and -4 represent false positives.

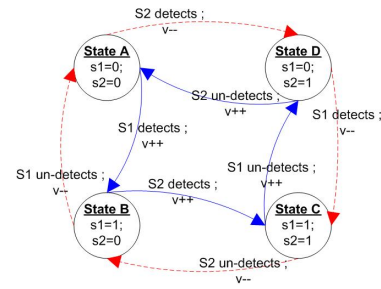


Figure 5. WSN State Diagram.

4. Conclusions

Smart parking systems employ advanced technologies to permit efficient use of parking lots. Smart parking ranges from simple systems that show the number of available spaces to complex ones that can guide customers to a free spot. In addition, smart parking may incorporate transit-based information, smart payment, and auto-parking to best serve customers' various needs. In most smart parking, vehicle detectors are an indispensable component. We proposed to employ optical sensor in WSN to replace commonly used loop detectors. Optical WSN allowed for easy installation and maintenance with the same or better accuracy. Our original WSN was modified to include two optical sensor heads. With two sensor heads, vehicles can be distinguished from pedestrians as well as motorcycles. The vehicle direction information can also be obtained with two sensor heads. We plan to implement this optical WSN at our main parking lot and test for its workability.

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