

Sensor Fusion based Energy Efficient and Sustainable Smart Parking System

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Abstract— With the rapid increase in urban population and hence the automobiles, parking has emerged as a resource with fair amount of energy consumption, air pollution and traffic congestion in almost every major city around the globe. Therefore, its efficient management in terms of both energy and space is not only necessitated to save a lot of energy, but also plays a pivotal role to obtain environment friendly green cities. In this article, we proposed a smart energy efficient parking system, which integrates the image recognition techniques for license plate recognition, infrared sensor for group control and wireless sensor network (WSN) for intelligent light emitting diode (LED) lighting. The system offers better guidance to parking position, controls LED lights based on traffic distribution for maximum energy efficiency, and offers enhanced security as compared to its counterpart conventional system. The system is built on ZigBee based Wireless Mesh network (WMN) nodes equipped with image sensor and RF module. The vehicles in the parking lot are detected and recognized using the grid based algorithm and license plate image recognition. The concept of zoning or lighting group control algorithm is integrated with moving object tracking algorithm to control the array of lights to attain the maximum energy efficiency and reduced Greenhouse gases (GHG) emissions. In comparison to conventional parking and normal lighting, the proposed system presents the substantial amount of energy savings, less environmental pollution and enhanced surveillance. Moreover, the embedded advantage of improved reliability, reduced maintenance and low cost due to smart control suggests very satisfactory and optimistic results for future implementation of the system as an integrated part of smart cities.

Keywords— Energy Efficiency, Group control, Image recognition, Smart parking, LED Intelligent lighting, Wireless sensor, ZigBee

I. INTRODUCTION

The rapid emergence of information and communication technology (ICT) such as ubiquitous wireless sensors has introduced unlimited new and very existing applications in every walk of life. These applications either machine-to-machine (M2M) or person-to-machine (P2M) have not only enhanced the living standard, but also have added the advantages of reduced energy consumption, better security and more sustainable technology. In particular to the term smart cities, where cities integrate different applications and services rather than approaching them individually to maximize the benefits, wireless sensor network (WSN) is very evident in the current research and development literature. In the perspective

of public parking, it is considered among the important part of future smart cities with high stakes in saving considerable amount of energy, reducing the levels of polluting gases, even reducing pressure on urban land, when used efficiently.

In terms of energy usage and its associated pollutant gases, lighting accounts for 19% of global use sharing around 6% of environmental pollution in emitting hazards greenhouse gases (GHG) [1]. As an example, even less than half of energy savings in global lighting could significantly reduce environmental hazards i.e. a climate impact equivalent to eliminating 50% the emissions of all electricity and heat production in the EU, only [2]. Therefore, the smart management and control of parking lot lighting has not only the potential to offer considerable benefits in energy efficiency and to cut the energy bill, dramatically, but also helps to achieve highly sought environmental goals with additional benefits of better light quality and enhanced security. In this context, LED lights have had an impact by setting up new avenues, both in light efficiency and its associated electronic control. As an efficient and environmental conducive solid state light source, LED is predicted to dominate all lighting applications in the recent future [3]. LED lights, when integrated with smart control achieve multi-dimensional goals, i.e. not only to overcome the inherent disadvantages of inefficient and outdated lighting, but to be a part of future smart cities by utilizing the suitable communication technology.

II. RELATED WORKS

In most of the application related to smart or intelligent use of parking management, either for energy saving purposes or efficient guidance, wireless sensor network has been chosen with other sensor modalities like magnetic, ultrasonic and infrared. Wireless sensor network can be used efficiently to replace the expensive wired system in order to monitor the each parking space [4]. The proposed system in [5] is a wireless intelligent parking lot based on magnetic and ultrasonic sensor detection, however, it only provides the car count and detection statistics over different time slots. A prototype of an event driven WSN based system to control the different functions inside a parking lot is tested in [6]. SmartParking [7], outlines an intelligent and secure wireless sensors based parking management system. This system uses analytical model and simulations results to reserve the promotional based parking slots according to in-out vehicle flow and to generate the

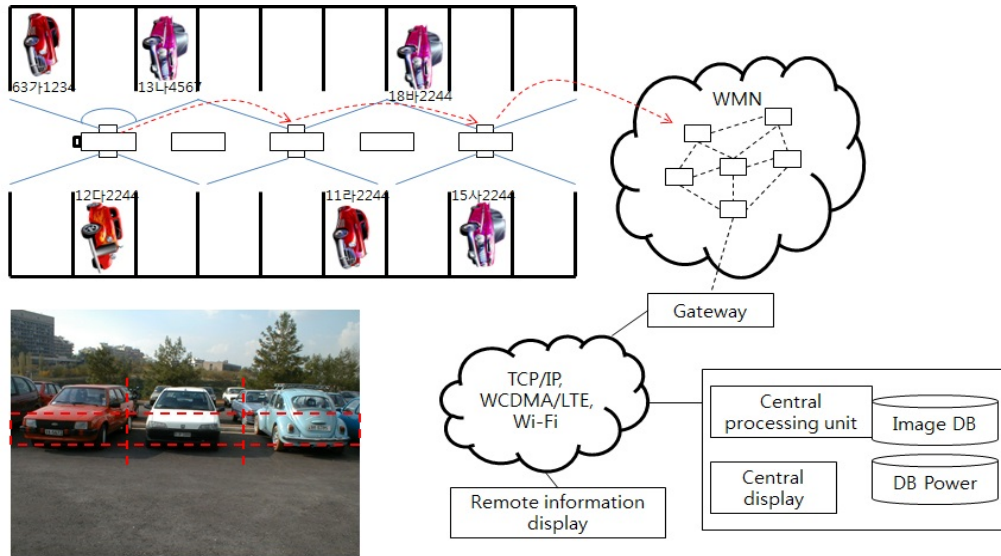


Figure 1. Smart Parking System Model

revenue out of intelligent parking management. The iParking frame work proposed in [8] using magnetic sensor, manages the efficient parking spaces by disseminating the data to drivers through social media. In [9],[10] ZigBee sensors based networks have been proposed to parking guidance management to reduce the time for vacant slot in order save the amount of energy and reduce emissions, respectively. However, in [9] navigation system needs to equip the vehicles with ZigBee nodes as well, while in [10] no results related to energy conservation and emissions are presented.

In our proposed system, ZigBee mesh network embedded with image sensor, infrared sensor and smart lighting control is deployed. The novel idea of controlling lights ON/OFF switching and dimming level based on object tracking algorithm and traffic distribution achieves the maximum energy efficiency and reduced emissions. Moreover, license plate image recognition provides efficient location guidance with more security and better surveillance.

The rest of the paper is structured as follows: Section III outlines the system overview. Section IV discusses the proposed algorithms and complete system flow. Section V presents the mathematical modelling and systems performance measurements. Finally the conclusions and future work is presented in Section VI to conclude the paper.

III. SYSTEM OVERVIEW

Since parking guidance and lighting control does not require very high data system, it appeals the use of ZigBee as a low cost, low data rate and easy to implement technology. Therefore, our proposed system depicted in fig. 1 is built on Wireless Mesh Network (WMN) of ZigBee nodes to monitor and control the smart application modernizing the old existing system. It uses image sensor and LED lights attributed as smart loads equipped with sensor/actuator and ZigBee nodes, controlled both locally and remotely. Local in the sense that personal area network

(PAN) consisted of wireless nodes equipped with cameras to capture the license plate time stamped images and smart lights are deployed in the parking lot. While, remote in the way that all the information is transmitted to remote station for data gathering and logging purposes through a wireless gateway. The smart load (LED lights) are operated based on traffic distribution during the different operating hours ranging from dusk to dawn. WMN is exploited for a more reliable system implementation. This not only provides demand based network expansion, but also offers more reliability in providing multiple paths for data packets to its destination, in contrast to point-to-point and point-to-multipoint topologies. Another important factor in choosing WMN over proprietary network is the interoperability based on open standards. Since the system monitoring application encompasses many services, open standards architecture is essential because it provides true interoperability between different vendors. In order to control the network remotely, transport control protocol/internet protocol (TCP/IP), Wi-Fi, or WCDMA can be used. A gateway node serves as a bridge performing protocol conversion offering interoperability between different networks.

IV. ALGORITHM AND SYSTEM FLOW

A. License Plate Recognition

The algorithm is based on the images captured from image sensor (CCTV camera) embedded with ZigBee RF module and LED lights for motion based dimming control. In the algorithm, the whole parking area is divided into the grids having a unique identity based on which the moving object i.e. both vehicles and human inside the parking area are recognized and tracked. The large grid and small grid size corresponds to vehicle and human, respectively. The changing position or the movement of the objects also corresponds to the changing grid value. The license plate of the parked vehicle is saved and forwarded to both, the

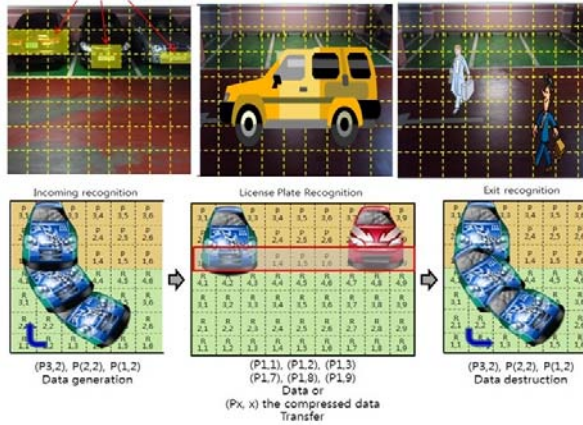


Fig. 2 Grid based license plate recognition and object tracking

local network for displaying and remote server for data logging. Figure. 2 shows the basic idea of license plate recognition and moving object tracking through data generation and data decimation based on grids location.

B. Lighting Group Control

In lighting control algorithm, the On/Off and dimming levels of the smart LED lights are control in the form of zone or group. The activity factor or area of operation selecting number of lights in a zone is determined with reference to a center light at (n_0, m_0) , which changes with the parameters (C_n, C_m) under the condition that $|n - n_0| \leq C_n$ and $|m - m_0| \leq C_m$. The changing of zone from old lighting group to new with moving object tracking is decided on the basis of same center light shifting. The values of the C_n and C_m parameters define the area of the zone, which finally decide the amount of conserved energy. That is, greater area coverage means less energy savings and more satisfaction to drivers and vice versa. However, the group size can efficiently be controlled on the basis of changing traffic flow for optimal results. Figure. 3 depicts the both concept, that is the selection of zone and its renewal with moving vehicles

C. System Operation Flow

The complete system flow is depicted in fig.4. It shows the operation flow for all three components i.e. license plate recognition, lighting control and displaying information over the In-premise display (IPD) for location guidance.

The flow starts with the motion detection in the parking premise in regular intervals to detect the motion to operate the LED lights with varying dimming levels and further processes. In case the vehicle or human presence is detected, the lights or dimming level is set to motion i.e. with full intensity or no dimming with the object tracking function to designate and update the area of motion and to control the corresponding lights group. In case, the parking area has no activity for a particular time, the smart loads are set to dimming or off, depending on the operation hours and traffic statistics. In order to save the activity for surveillance or future use the compressed video data is stored until the activity is finished.

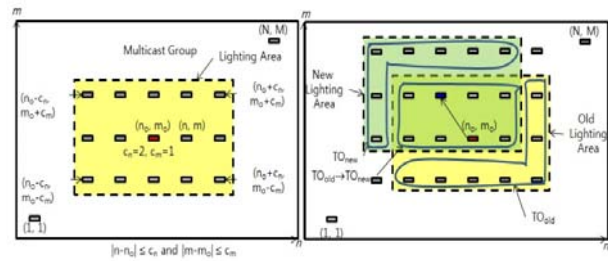


Fig. 3 Lighting group control and location update

In/Out or parking status followed by the license plate extraction is done to transfer the data to server and to IDP for updating the data base and also to display the guidance information on central LED/LCD display for driver assistance.

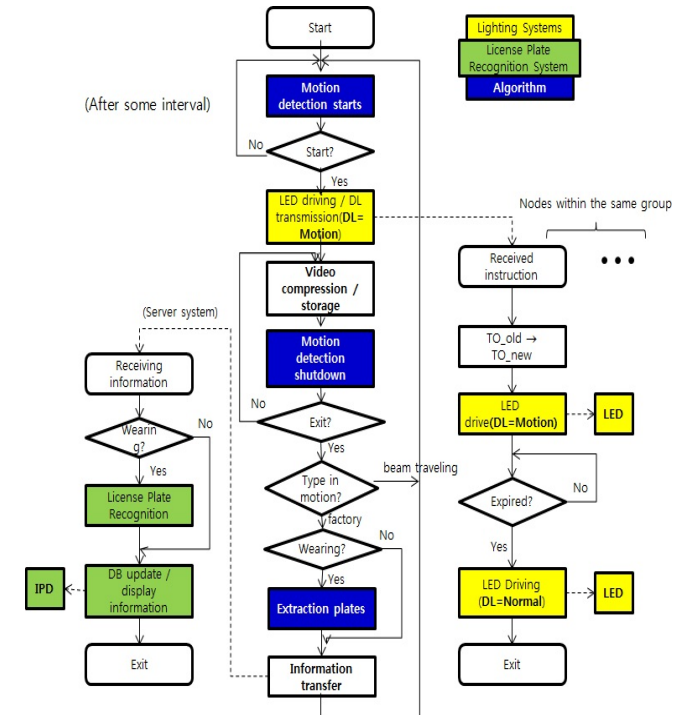


Fig. 4 System operation flow

V. MODELLING AND PERFORMANCE

In order to evaluate the performance of proposed smart parking application, it needs to have an appropriate model to account for the parameters corresponding to different processes involved in system design. This section addresses both the mathematical model, its validity and system performance based on it.

A. Queuing Based Traffic Model

Vehicle traffic in this system is primary process involved in lighting control, image capturing and data base management, eventually defining the amount of energy savings and reduced emissions. Therefore, the underlying model should not only

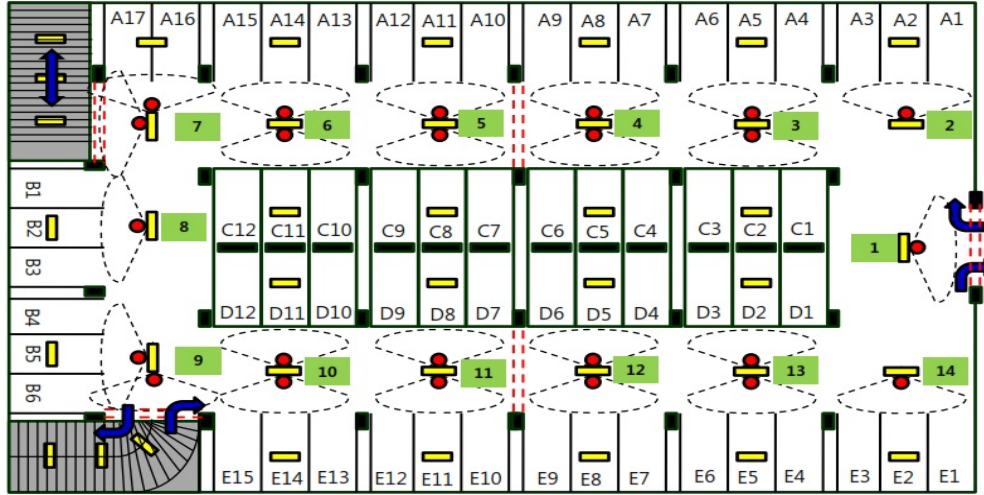


Fig. 5 Parking Layout showing sensor nodes equipped with camera with their operating angles and infrared sensors for group control.

account for arrival pattern, but also for departure characteristics with average spent time. In case of traffic arrival patterns, it can assume to be uniform i.e. successive vehicles entering the parking with equal time intervals; however, this is not true in real scenario. Similarly, the model also requires the assumption regarding the departure characteristics, specially the distribution of time a vehicles stays in the system. Another important aspect or parameter is number of slots available in the parking.

Considering all the parameters, that is, average random arrival (λ), average departure rate (μ) with N number parking slots available, an M/M/N queuing model is proposed to design and evaluate the system. In the model “M” represents the exponentially distributed times derived from the assumptions of Poisson-distributed for arrival and departure, and “N” represents the number of parking slots available in a designated area for vehicles to be parked. Given the average time of arrivals and departure and associated traffic intensity (ρ), the model can effectively be used to calculate the probability of empty parking or traffic free time over the different time slots. The given below equation describes the operational characteristics of M/M/N queuing model.

$$P_0 = \frac{1}{\sum_{n_s=0}^{N-1} \frac{\rho^{n_s}}{n_s!} + \frac{\rho^N}{N!(1-\rho/N)}}$$

In above equation, P_0 shows the probability of no vehicle having N number of parking slots and $\rho = \frac{\lambda}{\mu}$ traffic intensity i.e. the ratio of vehicle's mean arrival and departure rate

B. Energy Savings and Emission Reduction Analysis

Fig. 5 shows the layout of the parking lot to analyse the most important and targeted outcome of proposed smart lighting i.e. energy savings, eventually reducing the amount of hazardous gases, too. The whole parking area is distributed into four

groups with sixty parking slots, each. Figure also shows the infrared sensor to separate the lighting groups from each other and smart lamp coverage angle. The size of each lighting group can also be varied in accordance with time varying traffic for optimal energy savings.

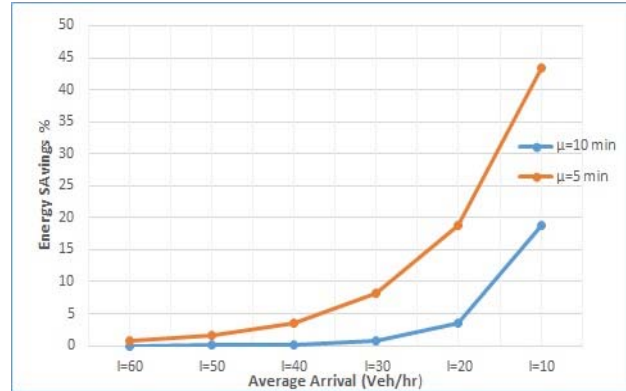


Fig. 6 Amount of percentage energy savings for different arrival and departure or occupancy rate.

In order to save the energy and to reduce the emission using occupancy based smart lighting control time varying average arrival rate and average occupancy or departure rate is analysed to control ON/OFF switching and dimming level of smart LED lights. Fig. 6 shows the probability of empty parking slots, for the varying arrival rate (λ) in correlation to average parking time (μ) for which the space is occupied. Therefore, during those time slots, smart lights can be switched off completely or can be set to minimum illumination with maximum dimming for optimal amount of energy savings.

Referring to graph, it is obvious that percentage amount of energy savings increase with decreasing arrival rates and increased average occupancy time. Using the above results, it can be concluded LED lighting is more energy efficient and cost savings comparing to conventional lighting. In the similar

lighting conditions and operating hours, LED system consumes 50% less energy than its counterpart, directly cutting the half of energy bill and reducing same amount of harmful gases.

TABLE. 1 Comparison of conventional and smart LED system (Single day)

	Conventional Lighting	Smart LED Lighting ($\mu=10$ min)	Smart LED Lighting ($\mu=5$ min)
Ratings	150 W	75 W	75 W
Total operating hours	12 Hrs	12 Hrs	12 Hrs
Consumed Energy	135 kWh	64.88 kWh	58.93 kWh
CO ₂ Emissions	70.58 KgCO _{2e}	33.91 KgCO _{2e}	30.80 KgCO _{2e}
Energy Savings/GHG Reduction	Nil	53%	58%

Moreover, adding the smart lighting control in ON/OFF switching and dimming control based on wireless sensor networking and traffic queuing model can save significant amount of energy with same amount of reduction in greenhouse gases (GHG). Table .1 shows the maximum amount of energy savings and correlated reduced greenhouse gases emissions [12] for varying average arrival rate (λ) and occupancy time (μ) for five and ten minutes depending on time varying traffic.

VI. CONCLUSIONS AND FUTURE WORK

In lighting applications, substantial amount of energy consumption and hazardous gases have necessitated the use of advanced technologies to make them more energy efficient and green. South Korea being the part of top ten emitting countries contribution two-thirds of world CO₂ emissions has also implemented a new scheme to reduce its emissions up to 30% by 2020 [13]. This fusion based smart LED lighting solution can be considered as a step towards the same direction in proposing the energy efficient and less emissions system to meet the set goals of not only cutting energy consumption, but also providing environmental friendly sustainable solutions.

As a future work, we are aiming to install the hardware of the system in a local parking area integrating the group lights control changing its size with time varying traffic accordingly for maximum amount of energy savings and minimum emissions.

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