Smart Parking System using IoT Technology

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Abstract—*A simple and easy task such as parking is thought as a tedious and time-consuming process due to mismanagement of parking system. Current parking systems involve huge manpower for management and requires user to search for parking space floor by floor. Such conventional systems utilize more power, along with user's valuable time. This paper presents a Smart Parking & Energy Management solution for a structured environment such as a multi-storied office parking area. The system proposes implementation of state-of-the-art Internet of Things (IoT) technology to mold with advanced Honeywell sensors and controllers to obtain a systematic parking system for users. Unoccupied vehicle parking spaces are indicated using lamps and users are guided to an empty parking space, thus eliminating need for searching for a parking space. The occupied parking spaces are virtually stored to the cloud to be accessed by central system and direct the upcoming cars to empty spaces. The automatically controlled light illuminance helps reduce energy usage, along with lighting up the parking space to the user whilst in the parking space. The entire system being fully automatic leads to reduced manpower involved and improves illuminance aesthetics of the parking area. This paper aims at improving user's time value and convenience in a parking system.*

Keywords — Car Parking, Sensor, WSN, Time saving, Internet layers.

I. INTRODUCTION

Large commercial areas such as malls, hospitals, city centers and residential societies demand extensive parking areas due to increasing quantity of vehicles. A commonly imposed solution for such a system is multi-storied parking system. Users utilizing the multi-storied parking need to search for an empty parking space, thus unnecessarily spending time around the parking lot instead of spending it productively. Users that have come to work in offices or for shopping in malls have to begin their day in the parking lot getting annoyed by loud car honks and breathing in the polluted air. Repetition of such user inconvenience leads to reduced quality of life. During peak times, the entire entry area is crowded. The rate of vehicles entering and exiting keeps on fluctuating, causing few of the parking spots to be left entirely vacant. Multi-storied parking spaces require commodities such as illumination, air ventilation and manpower for handling the traffic at all times. This raises the overall cost of electricity, along with the wastage of energy. The cost of parking space expansion is very high and is thus followed with high power consumption. In a multi-level parking system, lighting system consumes the most energy since illumination is required during all working hours. The demand for an intelligent parking service is increasing rapidly due to space constraints and growth in vehicle quantity. The smart parking system is a green solution that provides user time saving and energy conservation. The user is instructively guided to the empty parking space, without necessitating user to manually find for one. The smart parking & management system provides accurate positioning, monitoring and online control. This solution is highly cost effective and user convenient.

Wireless sensor network (WSN) involves clubbing of large number of sensors in the area of interest in a cost-effective manner. Such an establishment has been proven more effective against those involving technologies such as camera monitoring systems, pneumatic tubes, etc. [1]. Existing WSN used in parking system focus mainly on parking space booking & allocation [2] along with merging them with online payment portals [3] using IoT based platforms. The method proposed in this paper provides a solution for a much larger parking space, taking into account all the possible aspects up to a level of its implementation. Security is also a main concern in parking spaces which is considered in an IoT systems [4] by providing live feedback of state of the asset to be monitored; in this case, the user's vehicle. A similar system has been proposed for roadside parking [8] where separate area has not been allocated for the same purpose. Several paid parking systems are known to be equipped with hardware - software integrated payment gateways [7].

The distributed sensor network consists of Dual Technology Ultrasonic and PIR sensors for detecting the incoming vehicle and illuminates the aisle lights. The Parking Sensor detects human presence or vehicle presence in any given area. It operates on both Passive Infrared and Ultrasonic technology. It transmits the car/human occupancy data via an RJ25 interface to the Wireless Parking Controller. The Parking Sensor also has the capability to connect to an external dual-colour indicator light, through RJ25 interface, which can indicate parking slot vacancy status. The whole system is connected through a server by Zigbee [5]. Zigbee is a wireless technology that provides secured data transfer between a controller & a gateway. It operates on 2.4GHz ISM band and has data rate up to 250kb/s in the range from 10 to 70m.

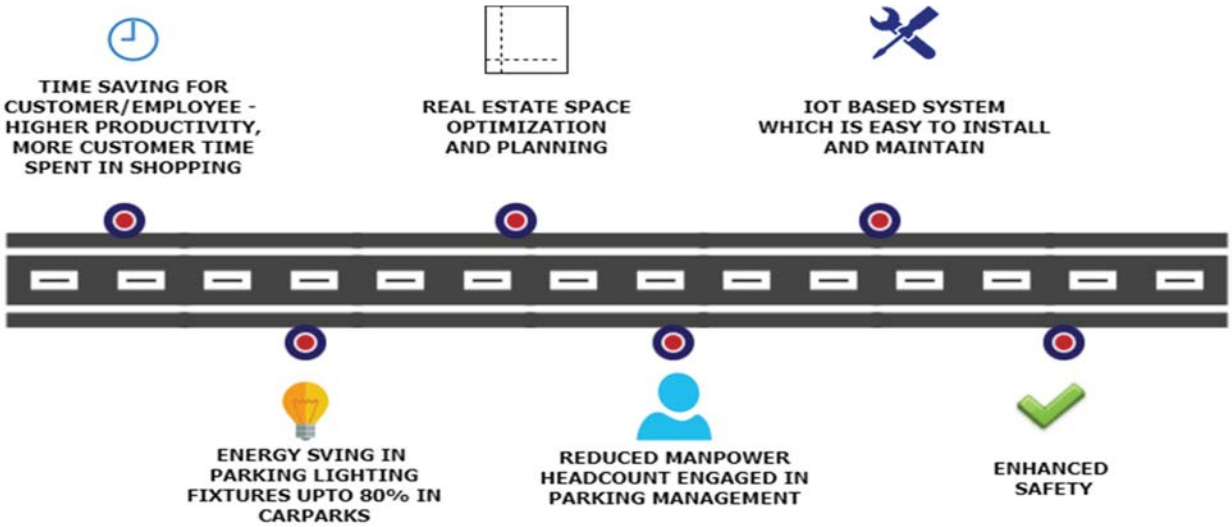

Figure 1: Benefits of smart parking system using IoT Technology

A. Sensor

The Parking Sensor detects human presence or vehicle presence in any given area. It operates on both Passive Infrared and Ultrasonic technology. It transmits the car/human occupancy data via an RJ25 interface to the Wireless Parking Controller. The Parking Sensor also has the capability to connect to an external dual-colour indicator light, through RJ25 interface, which can indicate parking slot vacancy status. The connected components are diagrammatically expressed in Figure 1.

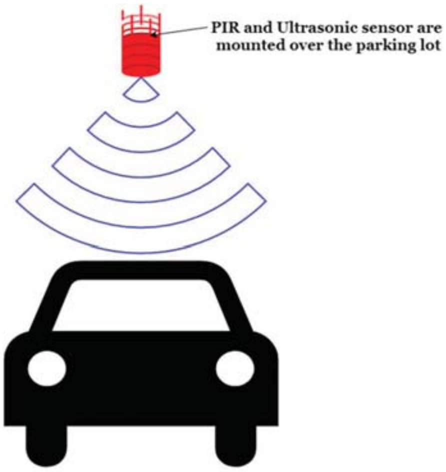

Figure 2: Wall mounted sensor

Methodology: As the user starts parking in the space, the parking space lights are activated. The controller sends signal to the server through gateway system and the respective space is marked as 'Occupied' in the system GUI. The Dual Technology sensors continuously detect motion of person/s and leave the lights ON. When there is no human presence detected, sensors send the data to controller indicating absence of personal in the parking space. The controller reduces illuminance of the aisle and parking lights after a pre-specified period of time, thus saving on the energy consumption.

Whenever the user returns to retrieve his/her vehicle from the parking lot and enters the sensor zone, controller activates the normal illuminance of aisle and parking light. The lights remain on as long as user is in the parking space. As soon as the user leaves with the vehicle, the space is assigned as empty and light illuminance is set back to dim state.

The parking occupancy data is stored in levels in case of a multi-storied parking system. With help of a display mounted on each entrance, user can decide on which level to park. The display shows exactly how many spaces are available and on which level. This user convenience helps save time for search of parking space every time they need to park.

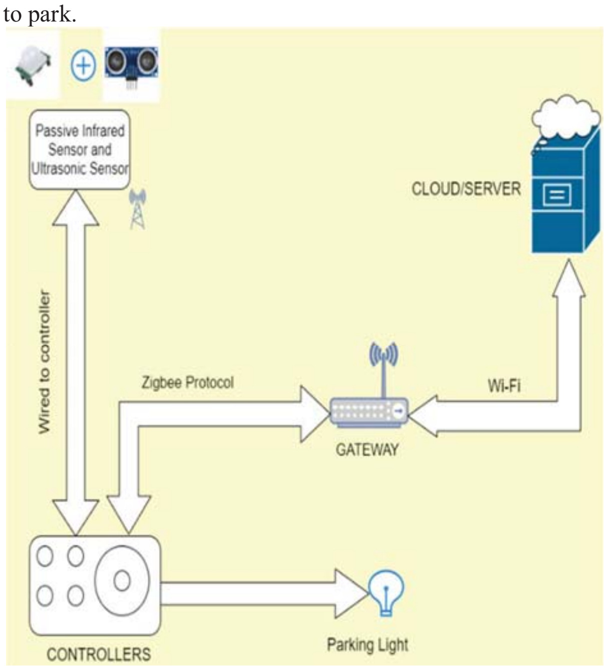

Figure 3: Schematic diagram of Wireless Parking.

II. Framework and Software Model for an IoT-Based Energy Management System

IoT-Based Architecture with Intelligent Edge Computing Figure shows the IoT-based energy management architecture with edge computing based on a DRL network. The architecture consists of three main components: energy devices, energy edge servers, and energy cloud servers.

A. Energy Device

The energy device can be any entity, device, or user that can supply and require energy in the network. The devices can detect/collect/generate the energy data according to their types.

B. Energy Edge Server

The energy edge server can be deployed at the network gateway, base station, and so on for computing/caching/delivering energy data in a local area network. It connects to the energy devices by different communication technologies, for example, 5G, WiFi, and vehicular ad hoc network (VANET). The energy edge server can also decide the operations of a local energy network according to the analytical results.

C. Energy Cloud Server

The energy cloud server connects to the central controller for energy management. The responsibility of the energy cloud server is to not only provide real-time analysis and calculation to energy devices, but also satisfy the computation requirements from energy edge servers. In the proposed architecture, energy edge servers process the collected data and transmit the data to the cloud server through the core network. In both the cloud server and edge server, the DRL agents are deployed. Upon the energy device having a computation task, it will send the task to a nearby edge server in which the edge DRL agent is responsible for computing the task.

III. Software Model

In this subsection, we design a software model of an IoT-based energy management system with intelligent edge computing, as shown in Fig. 3. The proposed software model includes four layers: the sensing layer, network layer, cognition layer, and application layer.

A. Sensing Layer

In the sensing layer, the devices can generate or detect the energy information of the connected energy network. The energy edge server is responsible for managing connection among devices, that is, setting up reliable communication links for devices. Querying data is one of the basic features of the proposed software model required by intelligent edge computing services. Considering the heterogeneity of the energy data in smart cities, the edge server will queue and classify the collected energy data for hierarchical processing.

B. Network Layer

In the proposed IoT-based energy management system, data transmission is a crucial function for data transferring between energy devices and the energy edge server, and task offloading between the edge server and the cloud server. Different kinds of communication technologies, such as power line communications (PLC), 5G, LTE, and WiFi, can be used for data transmission. The data storage capacity in the energy cloud server, energy edge, and energy devices can be integrated as one source of network storage, and the energy data stored in such storage can generate a "data pool." By using a unified interface, heterogeneous data is able to be accessed from the data pool by any devices and servers. The virtual data pool can help energy managers in developing control policies by historical data analysis. The registry is used to record the dynamic entering/leaving of devices in the proposed IoT-based energy network. Since the devices may enter/leave the network frequently, the registry plays a significant role in supporting related network configuration.

C. Cognition Layer

In the proposed system structure, the cognition layer is a core layer that creates intelligent awareness of the energy environment. This layer contains three main functional modules: DRL processing, optimization, and configuration. DRL processing modules are deployed at the cloud server and edge server. The module records the demands and current states of associated users. Then, according to the results of the last executed action, the reward can be calculated by the DRL module. The DRL module can make decisions under the guidance of a powerful DNN that provides accurate estimation and prediction. Since the frequent usage of edge servers may cause unacceptable energy consumption, the optimization also can explore an optimal schedule of using edge servers for cost minimization. The configuration can be realized in the energy cloud server to configure the operations of edge servers or devices. Meanwhile, the configuration also can be operated in the edge server for nearby devices. Note that the configuration can be processed at the cloud server in a centralized manner or at each device/ edge server in a decentralized manner.

D. Application Layer

The application layer provides a set of functions and tools to post-process data coming from the underlying layers and figure out the network settings of the proposed IoT-based infrastructure. In particular, energy management is the core function to help the entities control and schedule the energy from every angle of the system without knowing the underlying layer conditions. Topology control is used to make the decision for devices leaving/entering the network. Web-based application (e.g., online dashboard for visual management) and mobility application (e.g., mobile applications on smartphones for facility managers) benefiting the interoperability among different devices and technologies is enabled in the proposed IoT-based energy management system.

IV. Proposed Architecture for the Parking Management System

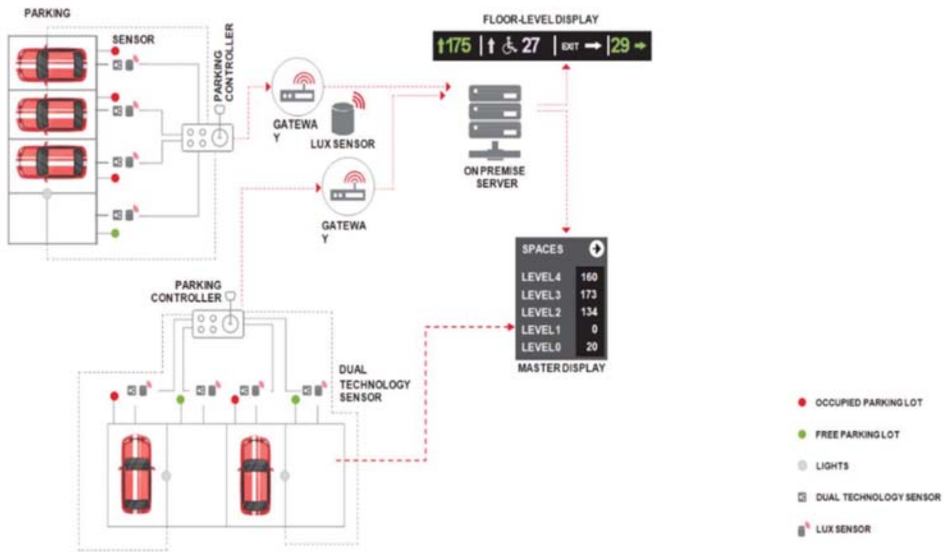

Figure 4: Architecture of proposed model

A. Timing Saving:

In the conventional parking system, the structure of layout is either unorganized or poorly maintained by workforce. The user has to spend unnecessary time looking for an empty parking space. By a probabilistic mathematical model, it is estimated that in peak hours, it takes about 24 minutes and in idle hours, 17 minutes. In the smart parking system, the parking space is well structured and user is provided with prior knowledge of empty parking spaces with help of head displays on every level and floor wings. The dual-colour indicator light indicates parking slot vacancy status. This helps user to find the empty parking space as quickly and conveniently as possible. For parking of a car in peak hours, it takes around 11 minutes and in idle hours, 9 minutes. The total percentage of user time saving is 54.16%. This time convenience reduces a common issue of user frustration of looking for a parking space. The time saved can be used productively for an office employee or in shopping for a mall parking lot. In a broad perspective, every 13 minutes of time saved per user, 585hours of collective time is saved for 2700 car parking users.

Equation (1) is based on the assumption that probability (P(E)) of getting an empty parking space linearly increases as user travels from ground to top floor of the multi-storied parking system.

$$\text{Time Saving} = \frac{\sum_{i=1}^{n} D_i P(E_i)}{S} \qquad (1)$$

S = Average speed of a car on each floor.
D = Distance covered by a car in a parking lot.
$P(E_i)$ = Probability of getting the free parking lot.
n = Number of floors

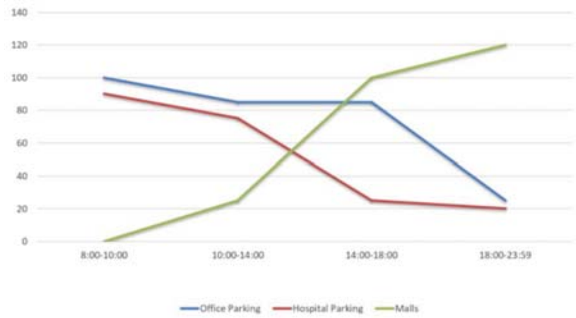

Figure 5: Density of cars in different parking lot.

B. Power Saving:

Typically, 36W LED lights are used in the aisles, whereas 18W LED lights in the parking space. In a conventional system, both, 36W and 18W LED lights are kept continuously on throughout the working hours. In the smart parking system, aisle and parking space lights are dimmed up to 40% of total wattage when user occupancy is not detected. Assuming that the user spends 10 minutes in total near the car and aisle lights are continuously on in the peak hours, the total percentage of saving in power consumption is 84%. This much amount of power saving significantly reduces the carbon footprint, helping bring up a green solution to the increasing global warming. The smart solution saves largely on the electricity bill, bringing down yearly bills from lakhs to merely a few thousands.

Energy consumed in conventional system = Energy of bulb(30W)* hours/1000 (100% illuminance) (2)

Energy consumed in smart system = Energy of bulb(30W)* hours*0.4/1000 (40% illuminance) (3)

A. Real Estate Space Saving:

In an unstructured parking layout, vehicles parked are unorganized due to absence of parking space markings. In such cases, users tend to follow the parking pattern of the following vehicles. Parallel parking in a parking lot utilizes the most parking space. Some users tend to park in an inclined manner such that one may consume parking space of 2. The users tend to follow the other users while parking instead of searching on each floor. For example, if few of the cars not within the visible range of the users exit the parking lot, that particular parking space remains vacant for rest of the period. Thus, it could be said that the ratio of rate of incoming and outgoing vehicles tend to deicide the actual utilization of total parking space. The proposed smart system provides a structured multistoried parking layout. The custom layout is provided with properly planned multiple wings per level of parking system. Each wing consists of marked perpendicular parking structure which has the highest efficiency of parking space utilization as compared to parallel and diagonal parking layouts. A structured layout not only saves cost of real estate, but also directly affects time required for user to park the vehicle. Due to indicator lights and display boards, users know exactly which space is unoccupied and where to park in a shortest amount of time. The total percentage of saving in real estate space is 18%, estimated as the specified ratio as supposed to an ideal case of 100% efficient parking in smart system.

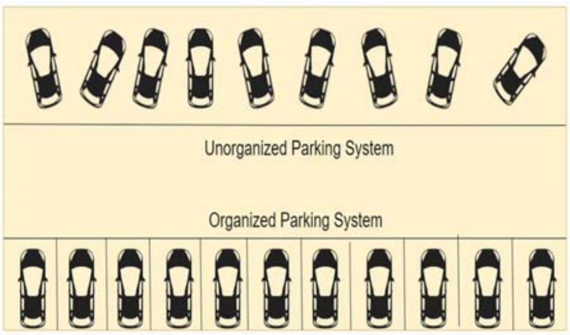

Figure 6: Unorganized and Organized Parking lot

B. Reduced Manpower:

In conventional system we require large manpower for managing the parking lot since the employment is done considering management of car owners in peak hours to manage the vehicle crowd. It is estimated that 4 employees are required per floor for guiding users to empty parking spaces. But in smart system only 4 employees are required in total for security and monitoring even in peak hours. There is a huge reduction in manpower required, which is around 63% as that compared to conventional parking system.

Smart Manpower(x) = (m + n) (4)
Conventional Manpower(y) = (m * b + n) (5)

m = Number of workers on each floor
n = Fixed number of workers
b = Number of floors in parking lot
Reduced Manpower = x – y/y

C. Return on Investment:

Every solution involves an investment cost which includes equipment, solution and construction cost. In the smart system, additional equipment such as Dual Technology sensors, indicator lights, controllers, gateways, etc. contribute a one-time investment cost with almost zero construction cost. But with a relatively small investment cost, the return on investment is substantial. Due to convenience of parking, there is a huge saving on total productivity of the users. Manpower required in the smart system is greatly reduced, and hence the saving on yearly salaries of individuals. There is an enormous power saving and LEDs' extended lifesaving due to dramatic drop in its usage in the parking spaces. All the factors put together, yearly return on investment is estimated to as high as 0.88.
ROI = Net Profit / Total Investment * 100 (6)

D. Predictive Maintenance:

The maintenance in a conventional system is done periodically, which involves checking of operation of lights, proper air circulation in closed parking spaces, water leakage checking, etc. Periodic maintenance ignores the fact that if few of the lights are damaged, users tend not to park in the area. This effectively reduces occupancy rate of the parking space. The smart parking system is equipped with strategically placed light sensors that predicts absence of sufficient light in the area and informs the maintenance team to check for the same. The system is equipped with programmable controllers capable of finding the fault in any sensor or wiring within the system in real time. This eliminates the fault-finding time for such a huge cluster of sensors and controllers.

E. Safety Enhancement:

While the smart parking system may seem like a relatively darker area of parking area, it always provides light to the user whenever he/she enters the respective area with help of motion detecting sensors. Presence of personnel in the vicinity lights up the respective parking lights, thus alerting the user in case of attempt to a possible theft. The parking area is retrofitted with CCTV cameras which are under surveillance by security.

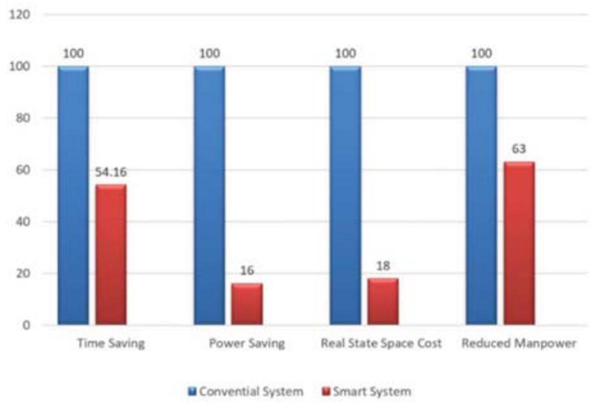

Figure 7: Comparison of conventional & IoT system

V.CONCLUSION

This paper tries to emphasize on IoT enabled smart parking system not only describes the architecture and connectivity of parking system but also improves the parking management. We have proposed a IoT framework in which sensor information easily transferred to the controller and it will act as on. Through these we can implement this into the hospitals, shopping malls and apartments. The purpose of this IoT based smart system this is to be reduce the challenges which are faced in conventional smart parking system such as real state space, time consuming, labour cost and productivity. However, the other benefits is gained privacy and security.

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