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Article *in* International Journal of Scientific & Technology Research · September 2019

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Low Cost Parking System For Smart Cities: A Vehicle Occupancy Sensing And Resource Optimization Technique Using IoT And Cloud PaaS

Ayaskanta Mishra, Abhijit Karmakar, Abhirup Ghatak, Subhranil Ghosh, Aayush Ojha, Kaustav Patra

Abstract: Modern smart city is facing numerous technological as well as administrative challenges in many fronts involving man and machines. One of these is the smart transportation system aided with cutting edge public transit modes like bus, monorail, metro and so on so forth. However needless to say only having an adequate public transport system will not suffice the need of end to end mode of transport. Hence an efficient and hassle free parking system is inevitable for any modern day smart city. With advancements of technologies like Internet of Things (IoT) and cloud platforms it is now technologically feasible to design and deploy systems to incorporate automation in traditional parking systems and hence making vehicle parking more organized and hassle-free and would require very less human interventions. In this paper, a Low cost IoT based vehicle parking system for smart cities is proposed using a cloud computing model: Platform-as-a-Service (PaaS). A HCSR-04 based ultrasonic sensor in used to detect the proximity of a car in a parking slot to detect the status of occupancy of a slot in the parking zone. An IR sensor in deployed at the Entry and Exit gate to sense the number of car in the parking zone. This prototype and proof of concept has been designed using Arduino UNO aided with an ESP-32 NodeMCU for sending the sensor data to a ThingSpeak™ cloud. A Blynk Android app PaaS is used to give user notification for the availability of parking online to users. A resource optimization technique is proposed based on the real time sensor data. This optimization technique would aid in a dynamic parking tariff and load balancing strategy for parking spaces in smart cities.

Index Terms: Vehicle Parking, Smart Cities, IoT, Vehicle Occupancy Sensing, Platform as a Service (PaaS), Cloud, Resource Optimization, Sensors, Cyber-Physical System, Dynamic Parking Tariff

1 Introduction

Internet of Things technologies have opened up new possibilities for smart systems in modern era. IoT with smarter algorithms provide Internet as a platform for connected sensors and actuators. This makes traditional systems more efficient using the model called connected-intelligence. The generic and pervasive nature of a global data network like Internet helps in achieving smarter technological solutions for any complex engineering problem. In the context of smart city an Internet enabled smart vehicle parking system is one of challenges in achieving a smart city in true sense. Section 1 of this paper is introduction to IoT based vehicle parking system and this includes related research work in the area. Section 2 is the literature review. Section 3 gives insight to the proposed system architecture and material and methods used to design the system. Section 4 shows the results obtained by implementation of the system and using designed prototype. In Section 5 we have done analysis of the results. Section 6 concludes the paper with future research direction.

2 Literature Review

There are some literatures of related works for IoT based smart parking systems. Al-Turjman et al. have given a study on various design aspects for a IoT based smart parking system in their survey work and recommended a conceptual hybrid-parking model.

- *Ayaskanta Mishra is currently working as Assistant Professor in School of Electronics Engineering, Kalinga Institute of Industrial Technology (KIIT) Deemed to be University, Bhubaneswar, India-751024*
  E-mail: ayaskanta.mishrafet@kiit.ac.in Phone: +91-9556991590
- *Abhijit Karmakar, Abhirup Ghatak, Subhranil Ghosh, Aayush Ojha and Kaustav Patra are currently pursuing Bachelor in Technology with specialization in Electronics & Telecommunication Engineering at Kalinga Institute of Industrial Technology (KIIT) Deemed to be University, Bhubaneswar, India-751024*

[1] Atif et al. has suggested a IoT cloud based intelligent parking system for smart cities by advertising parking lots on a shared cloud platform. They have proposed a multi-layered system of Parking Service Provider-business model through interdisciplinary research blocks. [2] Aydin et al. in their paper has proposed a genetic algorithm based reservation strategy for nearest available parking slot based on real-time sensor data acquisition using IoT technology. [3] Somani et al. have proposed a cost effective implementation of a smart parking system using a user-friendly app for the operations for finding and booking a parking space.[4] Kiliç et al. have implemented a smart parking system using android app for smart cities. [5] Kazi et al. have proposed a location based parking slot finding app for smart cities in their paper. In their work they have also emphasized on the digital payment methods for parking for a complete hassle free solution platform for users.[6] Sadhukhan has proposed in his paper a real-time detection of improper parking and automatic collection of parking charges. In her paper, a prototype of internet-of-thing based E-parking system is proposed with an integrated component called parking meter. [7] Al-Jabi et al. have proposed a whole you technique for parking system using Augmented Reality (AR) for more realistic and interactive user experience using AR-mobile application platform. [8] Kanteti et al. have proposed a Intelligent smart parking algorithm using the CMOS sensors for number plate identification, speed sensors for speed detection, ultrasonic sensors for vehicle detection they have used software for Optical character recognition (OCR), Arduino as a microcontroller and Raspberry Pi to interface all the components. This work focuses on the effective and efficient smart working methods along with guided user safety. [9] Grodi et al. have proposed a Parking occupancy monitoring and visualization system for smart cities using a Wireless Sensor Network (WSN) for real-time sensing of occupancy of parking slot and visualization using mobile app. [10] Vakula et al. have proposed a low cost IoT based parking online

reservation through portal. [11] Mahmood et al. have implemented and evaluated the performance of a rotary parking system. [12] Ebin et al. have proposed an android app based Smart Parking with efficient space management using number plate scanning technique.[13] There are numerous literature addressing various aspects and some of the prominent ones are: smart parking guidance algorithm [14], dynamic resource allocation [15], IoT enabled driver assistance [16], SParkSys-Framework [17], reduction of traffic congestion [18], utilization based parking space suggestion [19], GSM-RFID based parking system [20], wireless smart parking [21], OpenCV-MATLAB using Circle Hough Transform (CHT) based smart parking module [22] and binary search tree based hierarchical placement algorithm for IoT based smart parking [23]. This proposed work has a unique approach of utilizing the existing cloud platform by harnessing the PaaS model for automation in vehicle parking system for smart cities. This proposed system use neither camera/OCR nor AR hence don't require a very high computational requirements form the system (no power hungry algorithms like GA or CHT) which makes this proposed system more cost effective as well as low power. In addition to this smarter design aspects like real-time occupancy sensing and entry and exit boom barrier actuator controls makes this system highly efficient at the same time.

3 Materials and Methods

Traditional vehicle parking systems comprising of a closed spaces and in most of the cases in a office, shopping mall, cinema hall, Airport, railway station. All these parking system has one design element which is common that is it has multiple parking slots those are designated to park vehicles and the entry and exit to the parking space is guarded designated gates. In most of the traditional parking system are manned gates, where human intervention is required. The parking personnel would issue a entry ticket and the vehicle can enter the premises. There is a big challenge in getting a suitable place in a rush hour as there is no prior information to the user about the exact parking slot he need to park his vehicle in. The proposed IoT and cloud based vehicle parking system addresses all these challenges and making vehicle parking more organized and hassle-free. The key to achieve this is the real-time sensing of parking slots and the entry and exit of vehicle to the parking zone. This is possible by designing a system aided with sensors in each parking slots and sensing the status of occupancy of any vehicle in the designated slot. This sensor technology would enable finding whether a vehicle is parked in slot or empty and most importantly this information can be sent to the cloud server with very minimal network latency and in most of the system implementation the delay can be restricted up to few seconds only. The sound part of this system is an Infrared sensor based entry and exit monitoring of vehicles into the zone. The computer algorithm deployed for this smart parking system can increment or decrement the vehicle occupancy counter to route vehicles form one level parking to the next level in case of first level is full based on the slot occupancy status and number of vehicle inside the parking zone. This would be of tremendous help to the user to even get the definite parking slot pre booked and displayed on their smart phone application at the time of entering the parking zone. This will avoid the inconvenience of searching for an empty parking slot inside the jammed or difficult to maneuver parking zones. For an instance, if a car enters into a parking zone and the slots are already full in a traditional parking zone then the driver has to face a lot of difficulty to exit back from the parking level and finally unable to park the car in level or zone. In this scenario the IoT and cloud PaaS based Smart parking system would not even open the entry gate for that vehicle in that level of parking to avoid the inconvenience. In a nutshell implementation of the proposed smart vehicle parking system not only make parking more hassles-free but at the same time a proper resource management of time and space can be achieved.

3.1 Proposed System Architecture

The proposed low cost IoT based smart vehicle parking system is designed using a Arduino at the core. A NodeMCU ESP-32 based Wi-Fi (IEEE 802.11) based network adaptor is used to connect to internet using the TCP/IP protocol stack. A HTTP GET message is used to send sensor data to the ThingSpeak cloud using RESTful API over a TCP connection. NodeMCU and ESP library is used for programming the same using Arduino IDE. Sensors are the key for this parking system. There are two types' sensors those are used in this proposed system. First one being the HCSR04 Ultrasonic sensor and the second one is the Infrared (IR) Sensor. The HCSR04 sensor has a capability to detect a reflecting surface in close proximity. This characteristic of the sensor is utilized to find out the occupancy of vehicle in any parking slots. The Infrared sensors are basically a pair or IR transmitter coupled with an IR receiver. And this IR pairs are deployed at the gates. There will be two IR pair one at the entry gate and other pair at the exit gate. When any vehicle would cross the gate then the IR receiver can detect the discontinuity of Line of Sight (LOS) of the IR light and the same can be used as a trigger or interrupt for the embedded system to create a condition for entry or exit of a vehicle in the parking zone. If the Entry gate IR pair will give a trigger then the number of vehicle inside the parking zone counter would be incremented by one however when the exit gate IR pair will give a trigger then the number can be decremented. This would give the real time exact number of vehicle inside each parking zone. Furthermore the IR Sensor has another application in this proposed parking system. The proposed parking system also has an automated boom barrier. When the vehicle approach the entry or exit point the IR Sensor trigger can activate the barrier system and this barrier also has a additional intelligence to allow a vehicle or not based on the real time information of occupancy status given by the ultrasonic HCSR04 sensor. This feature can be further extended for parking metering purpose the time stamp of vehicle entry and exit with the vehicle number can be stored in the cloud database and based on the time they can be charged towards parking tariff. In this work we have used two cloud related service platforms. We have used ThingSpeak for sending sensor data to cloud database using HTTP Restful API. ThingSpeak is a cloud platform by Math works with support for MATLAB. Blynk Android based application is used for data visualization for end users. Blynk is a hardware-agnostic IoT platform with customizable mobile apps. ThingSpeak and Blynk both are used as Platform-as-a-Service (PaaS) for our proposed IoT based cloud system. Figure 1 illustrates the proposed IoT based vehicle parking system. The proposed design has five major subsystems along with internet as the backbone:

i. Embedded System: Interfacing of sensors and actuators and implementation of software program and algorithms for smart parking system. Arduino UNO is used in this work for low cost prototyping.
ii. Parking Occupancy sensing subsystem: This module of the system is primarily a proximity sensor subsystem comprising of a array of HCSR04 ultra sonic sensors. Each parking slots in the parking zone are equipped with one sensor to detect whether a vehicle is occupying the slot or empty. This is done using the trigger and echo signaling techniques of the sensor to detect any obstacle which is a vehicle in this case.
iii. Entry and exit actuator subsystem: This is basically the boom barrier system control equipped with an Infrared sensor for detecting arrival of a vehicle at entry and exit point of the parking zone. The vehicle number counter can be incremented with each entry of vehicle and decremented with each vehicle exiting. This subsystem use IR Sensor input as a feedback for deciding the allocation of new parking slot of vehicle with available empty slots and giving a actuator control to operated the boom barrier stepper motor based on the decision whether to open the gate or not.
iv. Wireless Network Subsystem: This subsystem includes a NodeMCU as a IEEE 802.11 wireless network adaptor to connect to the internet backbone. The NodeMCU is having a ESP-32 wireless chip operating in 2.4 GHz ISM band for communicating with a standard WLAN Access Point (Wireless Router, In this prototype we have used a standard Linksys WRT54GL) This subsystem provides the network connectivity required as well as a TCP/IP stack implemented through ESP-32 to establish a message transaction with cloud server using HTTP RESTful API.
v. Cloud PaaS (Platform as a Service): ThingSpeak is used as a platform in the cloud model for sending the sensor data and data visualization. Further Blynk android app is used for enabling all the users to find a suitable parking slot in their android smart phones. Both of these internet based platforms are using as PaaS in the proposed system.

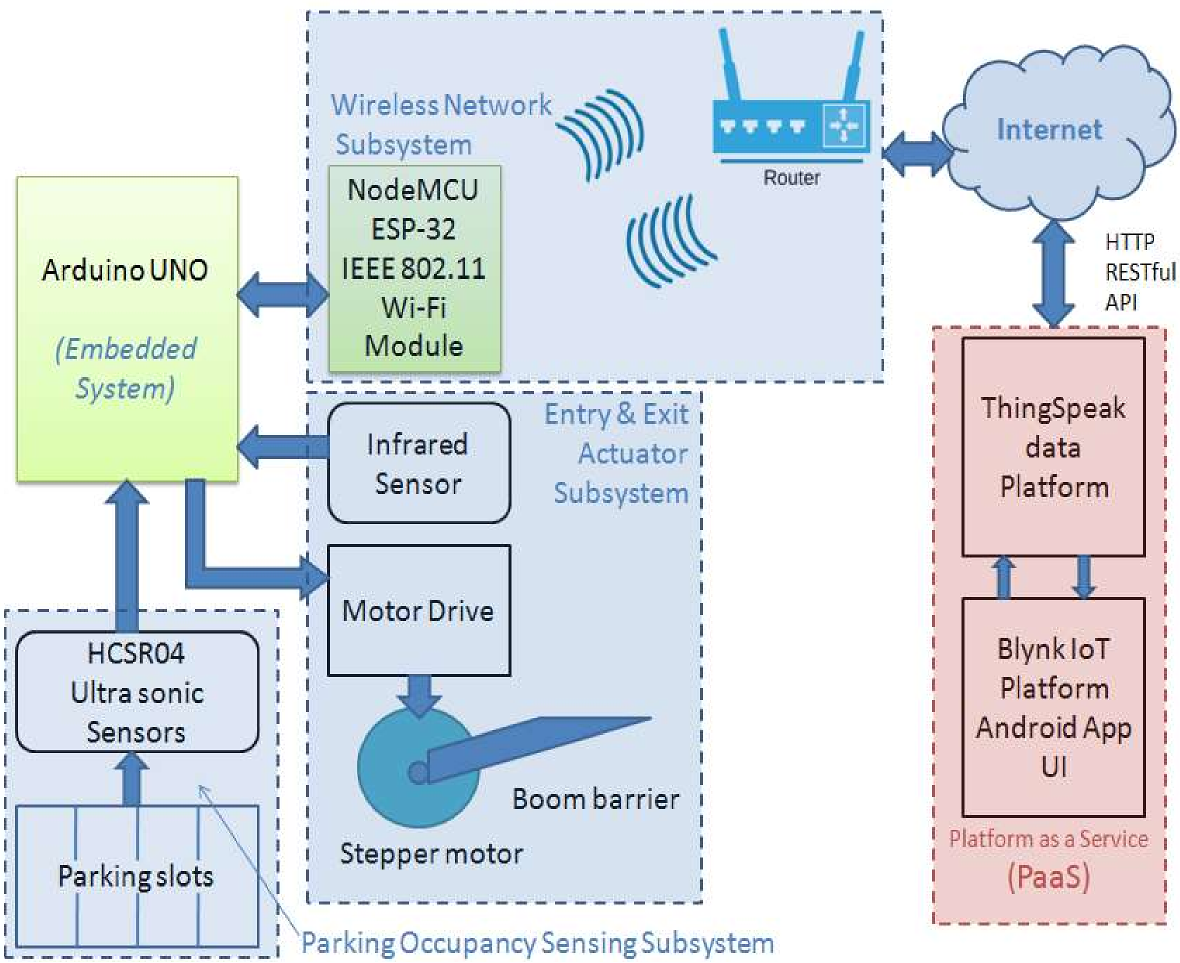

Fig. 1.*System Architecture of Low cost IoT based vehicle parking system using cloud PaaS*

Figure 2 shows the pictorial representation of a parking space having three parking slots for vehicles. Each slot is equipped with a HCSR04 ultrasonic sensor to find the occupancy of vehicle in the parking slot.

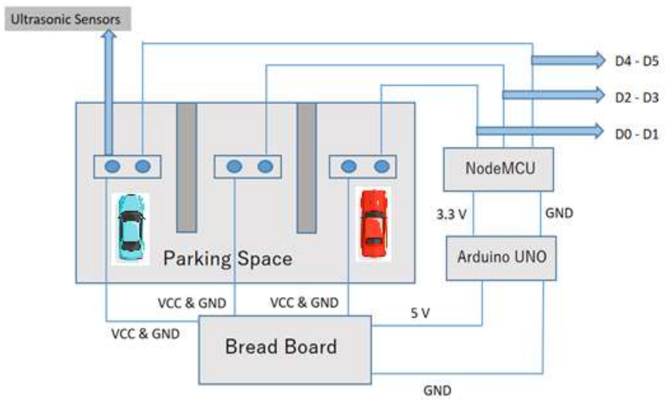

Fig. 2*.Parking Zone with three parking slots equipped with HCSR04 ultrasonic sensors to find the real-time status of occupancy of a vehicle.*

Figure 3 illustrates the components and their block level connection for designing the boom barrier system for entry and exit of vehicle. As discussed earlier there are two IR TX-RX pairs to detect the entry and exit of vehicle to and from the parking zone respectively. The boom barrier gate will be operated by a stepper motor controlled and powered by a motor driver as shown in the figure.

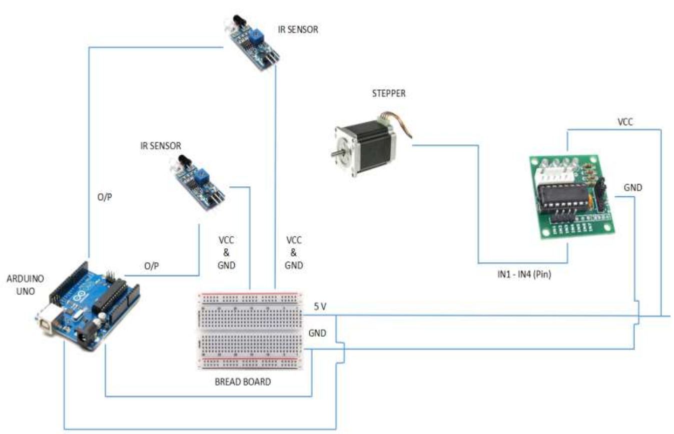

Fig. 3*. Parking Zone boom barrier system for entry and exit of vehicle*

3.2 Designing the working Prototype

The proposed system is implemented as a working prototype using the subsystems and components as discussed above. Figure 4 shows the working prototype. The Arduino UNO powered system has a NodeMCU ESP-32 for Wireless Connectivity over TCP/IP protocol stack to the ThingSpeak cloud platform as a service. The picture shows the miniaturized parking zone (as it should be in real world scenario) with HCSR04 ultrasonic sensors for real-time parking slot occupancy sensing. The picture also shows the IR Sensors deployed at the entry and exit to detect arrival or departure of vehicles. The boom barrier stepper motor control system is also part of the prototype as shown in the picture.

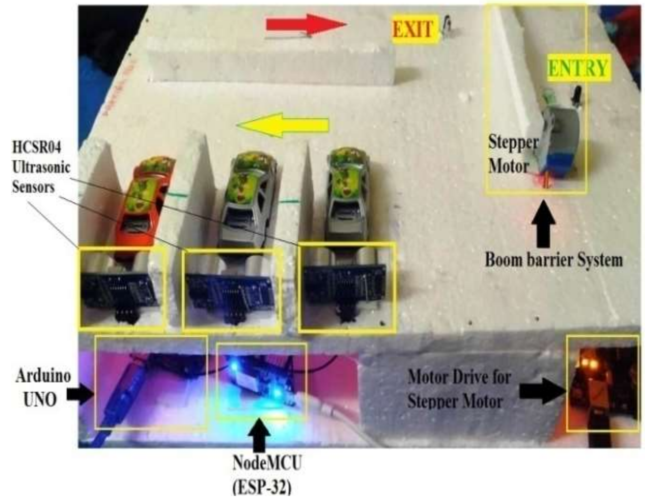

Fig. 4*.A low cost IoT based vehicle parking system prototype implementation in small scale*

Figure 5 shows the flowchart of the algorithm implemented in this proposed vehicle parking system based on IoT and cloud PaaS. The Arduino program has all the functional software subroutine as shown in the algorithm. Firstly all the hardware interfacing pins are defined and the vehicle occupancy is sensed by finding the distance between HCSR04 and vehicle using trigger and echo pins delays. After the proximity is sensed using the HCSR04 ultrasonic sensor the status of the occupancy of different parking slots are sent to the ThingSpeak cloud server using a HTTP GET message using Write API key. This is done by connecting the ESP-32 Wi-Fi module to the Linksys WRT54GL wireless router to connect to the internet. As show in the flowchart the ThingSpeak cloud database stores the data related to the parking slot occupancy in a designated parking zone and the same can be displayed on the ThingSpeak visualization GUI. A read API key is used to get the status of occupancy to the Blynk Android app. When the IR sensor detects a vehicle at the entry or exit gate it gives an event trigger to the software subroutine and increment or decrement the vehicle number counter in the parking zone for each entry or exit respectively. When a vehicle exit the parking zone as detected by the exit gate IR sensor then based on the entry and exit time stamp it will calculate the total time spent in the parking zone and calculate the tariff and forward the user to digital payment gateways for parking toll payment. When a vehicle enter the parking zone as detected by the IR sensor at the entry gate it shall first fetch the occupancy status from the database and find out the available empty parking slot. If an empty slot is found in the occupancy database then the system will allocate a slot to the user and same would be notified to the user through the Blynk android app and the boom barrier steeper motor drive shall open the gate by getting a digital output control signal from the Arduino. When the system database shows all the parking slots full or occupied then the stepper motor drive shall not get the control signal hence the boom barrier will not open and it will notify the same in Blynk app that parking is full and may reroute the vehicle to nearest parking level or zone as suitable. The parking full status will be shown in the Blynk app for all users so that a new vehicle shall not attempt to that designated parking zone to save resources like fuel as well as time to avoid inconvenience.

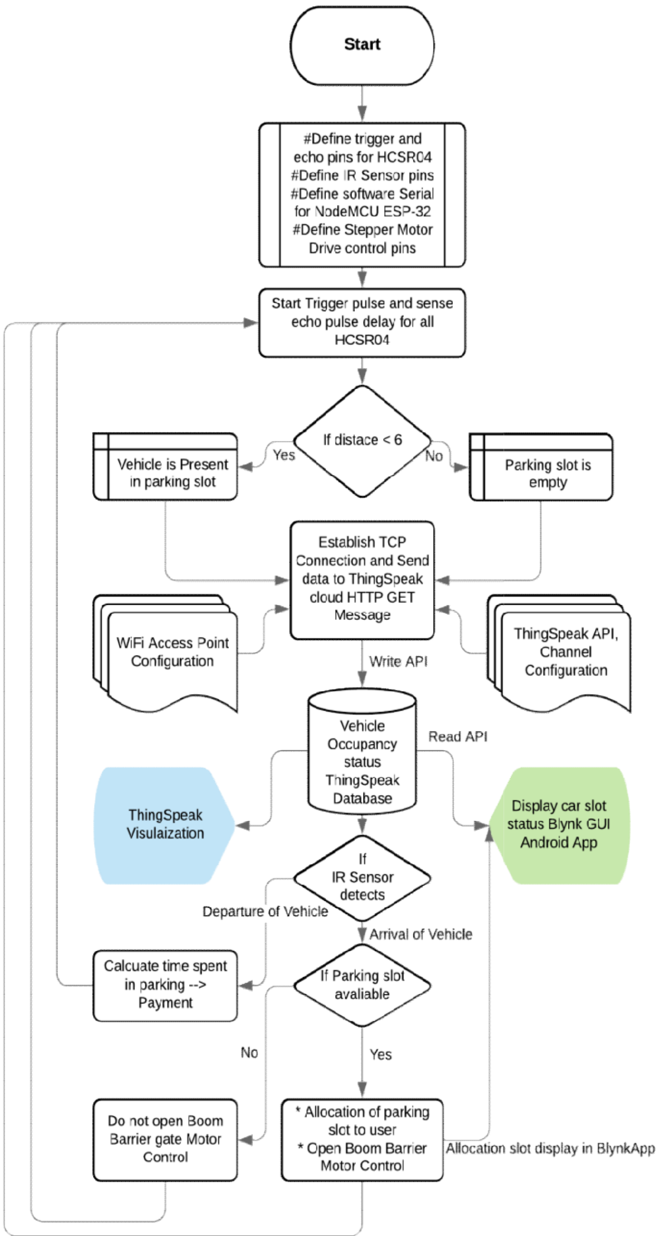

***Fig. 5**. Flowchart of Algorithm for the proposed IoT based Vehicle parking system using cloud Platform as a Service (PaaS)*

4 RESULTS

The following are some pictures of working prototypes after implementation of the system proposed and described in section 3. For proof of concept in the working prototype three parking slots are taken and to demonstrate the working three cases are considered as below. Figure 6 shows case-1, where one parking slot is occupied by a vehicle and other two are empty. The same can be visualized in Blynk app as shown. The figure of working prototype also shows the boom barrier opened because of availability of parking slot.

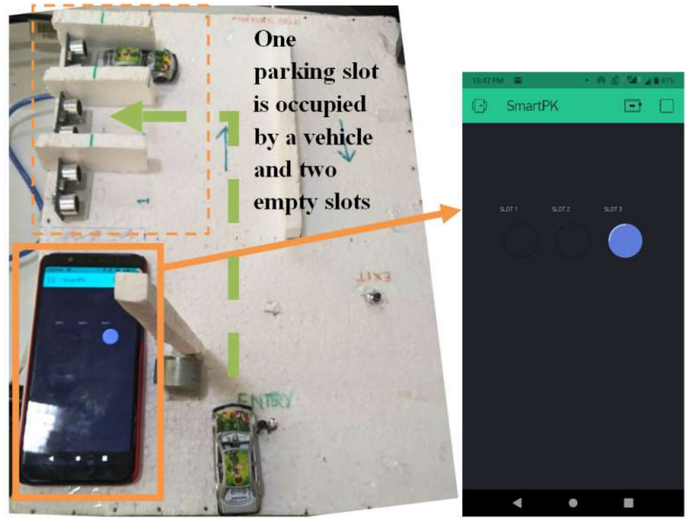

***Fig. 6**. Case-1 shows one parking slot is occupied by a vehicle and two empty slots; the same is displayed on Blynk App*

Figure 7 shows the case-2, where two parking slots are occupied by vehicles and one empty slot. The same scenario is displayed on Blynk App.

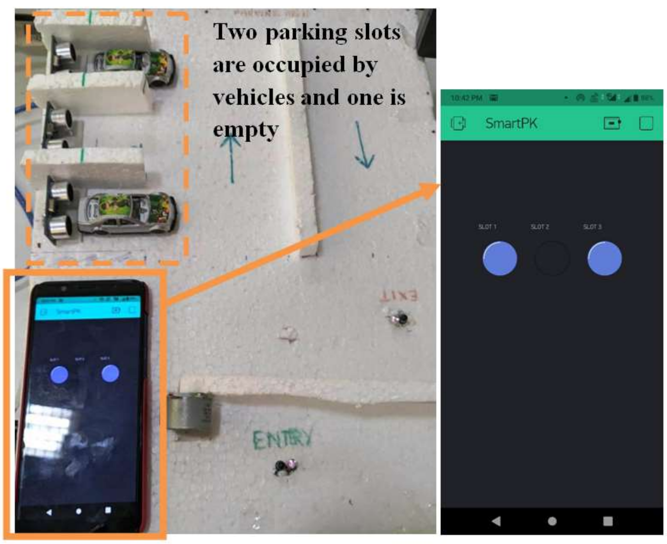

***Fig. 7**. Case-2 shows two parking slots are occupied by vehicles and one empty slot; the same is displayed on Blynk App*

Figure 8 shows the case-3, where all the tree parking slots are occupied by vehicles and the same is displayed on Blynk app. Point to be noted here in the scenario the entry boom barrier will not be opened as the parking zone is already full and the same can be known to any user logged on to the Blynk platform hence saving time and fuel and proper management of parking zone. As per the proposed system architecture and the algorithm discussed in section 3, the above three cases data is sent to the-

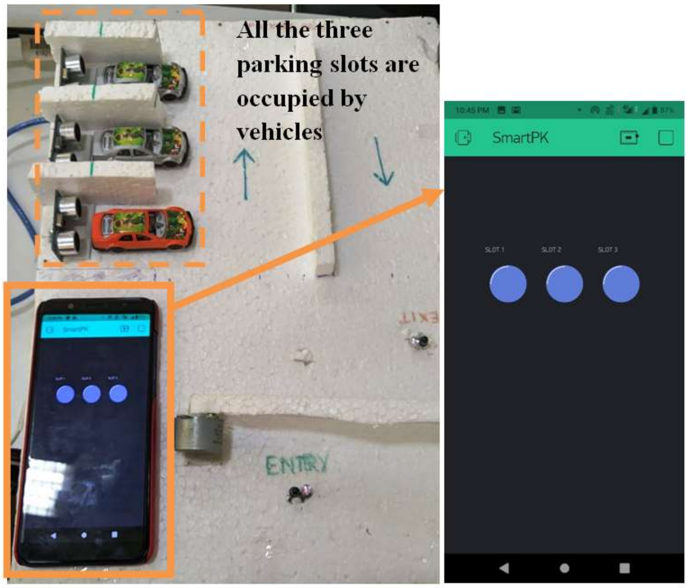

***Fig.8**.Case-3 shows all the three parking slots are occupied by vehicles and the same is displayed on Blynk App*

ThingSpeak IoT cloud prior to displaying it on Blynk platform for users. The link between ThingSpeak platform and Blynk is done using a read API function. Figure 9 shows the visualization of occupancy status of parking zone in the ThingSpeak platform. One can notice the timestamp as well as number of vehicle in parking zone from the data available in the ThingSpeak cloud.

***Fig. 9.**Time based vehicle occupancy record for a parking zone: visualization on ThingSpeak cloud platform as a service (PaaS)*

As shown in above figure 9 the ThingSpeak visualization tool is displaying the occupancy of vehicle in the designated parking zone with its relevant time stamp. Before 19:26:20 IST there was no vehicle in the parking zone as per the real time HCSR04 sensor data. Exactly at 19:26:45 IST the sensor detects a vehicle occupying slot 3 as shown in figure 6 which is case 1. At 19:27:20 IST the sensor detects two vehicles in the parking zone which is our case 2 as shown in figure 7. At 19:27:45 IST the HCSR04 sensor detects and sent the status that all the three parking slots are full which is our case-3 as shown in figure 8. This event can be seen in the Figure 9 ThingSpeak visualization as the number of vehicle as 3 in the parking zone. Figure 10 shows the test case for exit and entry of vehicle and how the occupancy record of parking zone is changing. As show in the ThingSpeak visualization till 12:59:50 IST there were 3 vehicles in the parking zone and then when sensed by HCSR04 at 13:00:00 IST the status shows one vehicle in the zone needless to mention in this duration the system detects exit of two vehicles from the parking zone. From 13:00:00 IST to 13:01:50 IST the sensors has sensed four times and updates the data to ThingSpeak cloud but the number of vehicle in the parking zone remained unchanged. At 13:02:20 IST the system shows 2 vehicles in the parking zone, this is because a vehicle has entered the parking in that duration and same reflects real time on the cloud server. In a nutshell the ThingSpeak cloud visualization shows real-time vehicle occupancy record both in exit and entry cases.

***Fig. 10**.Time based vehicle occupancy record based on exit and entry: visualization on ThingSpeak cloud platform as a service (PaaS)*

5 Result Analysis

The ThingSpeak cloud Platform as a Service (PaaS) is used to store and visualize real-time HCSR04 ultrasonic sensor data for vehicle occupancy as discussed in section III. The Blynk platform android app is also in sync with the ThingSpeak using read API and the parking slot status for various test cases is shown in result section. The results are based on real-time sensor data with a very less latency between actual events in physical space to the data available in cyber space in cloud platform. This gives a very high correlation of data-event between cyber-physical domain making it a very efficient and reliable informatics platform for data analytics. The information available to the end user through Blynk android app as shown in the results are very useful and convenient on the go and hence saving fuel & time and optimizing parking spaces. The ThingSpeak cloud analytics platform is very efficient tool for the *Parking Service provider* (PSP) to use optimization tool and data analytics models for hassle-free and efficient management of vehicle parking slots for their parking zones. In the scope of this paper a resource optimization strategy is proposed based on the data available on the cloud platform and the details are given in the next sub-section of this paper.

5.1 Resource Optimization

In Section 4 we have illustrated the working prototypes and the data available at the cloud server for parking zone with three parking slots as a proof of concept. However, in a real world implementation there would be hundreds on parking slots available in a typical smart city parking zone. To propose a resource optimization strategy we are considering a sample space of 100 parking slots in parking zone named ‘x’. It is assumed that there would be ‘k’ numbers of such parking zone in the city. To give an analytical model we would consider parking some nomenclatures as given below.

$$N_t = \sum_{minute=1}^{60} V_{occupancy} / 60 \quad (1)$$

Where,
x_1: *1st parking slot of xth parking zone in our case the 100 parking slots of parking zone 'x' would be* $x_1, x_2, x_3 \dots x_{100}$

N_t: *Average number of vehicle at tth hour of the day*

$V_{occupancy}$: *Cloud fetched real-time sensor data of total number Vehicle occupying the parking zone.*

Based on the computation from real-time HCSR04 Sensor data and equation (1) we can compute the hourly occupancy of vehicle in some 'x' parking zone. Figure 11 shows the graph of number of vehicle in the parking zone throughout different hours of the day. This would be helpful in user optimization of parking zone infrastructure and even open a potential business model of dynamic traffic planning for the parking space. For an instance let's consider, in a rush hour for a preferred parking zone the parking tariff can be more than a parking zone with less user preference. This will help in balancing the rush hour load between multiple parking zones hence optimizing the smart city resources.

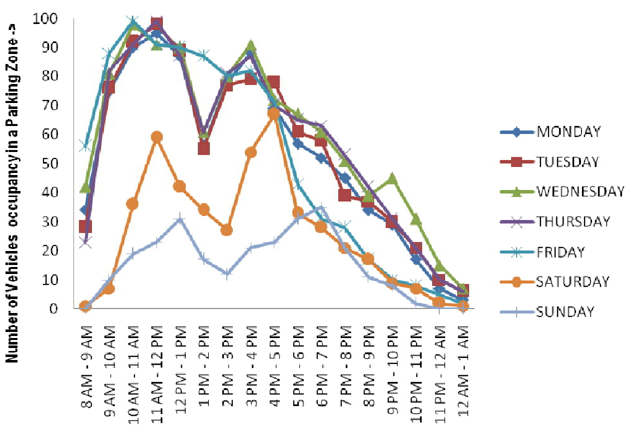

***Fig. 11**. Number of vehicle in the parking zone throughout different hours of the day (Sample data)*

5.2 Dynamic parking Tariff and Load balancing strategy as a Business Model

For the hourly occupancy of the vehicle on weekly basis a vehicle parking trend can be obtained for a particular parking zone. This can help in solving two major challenges for PSP in a smart city. *1) Dynamic Parking Tariff and 2) Load balancing between nearby parking zones.* The way we view it, they are not two separate business goals rather a conjoint strategy to achieve both the goals in single solution specific approach. Firstly, a mathematical model can be created for Dynamic Tariff (C_t) plan based on Equation (2). This dynamic tariff plan for parking would indirectly help the PSPs to encourage the user to approach a certain parking zone or discourage them to deviate to a relatively cheaper alternative. This would help the city resource planner to balance the load between two nearby parking zones in a rush hour.

$$C_t = A.h_{cost} + B.O_{cost} \quad (2)$$

$$\boldsymbol{h_{cost}} = f(Hour, Day, \boldsymbol{Trend}\ of\ occupancy) \quad (3)$$

$$\boldsymbol{O_{cost}} = f(N_c) \quad (4)$$

Where,
h_{cost}: *Hour based Cost for particular hour of the day: computed based on Equation (3).*

O_{cost}:*Occupancy based Cost based on current occupancy status from real-time sensor data: computed based on Equation (4).*

'A' and 'B' are scaling factor as decided by the city authority of PSPs: Costing and exact tariff planning is an administrative factor rather than a technical one.

N_c: *Number of vehicle in parking zone based on real-time vehicle occupancy sensor data.The trend of occupancy can be computed based on the historical data as shown in Figure 11.*

5.3 Future Scope and research direction

This work has a tremendous potential as well as future scope in data analytics based on the real time sensor data. As per this proposed IoT based vehicle parking system the cloud platform stores the real-time vehicle occupancy status in a designated parking zone. This data would be vital for resource planning and optimization for the parking zone. The historical data of time based vehicle occupancy can be very well fetched from the cloud storage and the same can be utilized to find the tread of vehicle parking in the zone. Needless to say this real time sensor data available in the cloud through IoT and sensor technologies can be used for resource optimization for the PSP. Using tools like Machine learning the PSP can predict the number of vehicle expected in any parking zone and hence would be very useful for resource planning and infrastructure optimization.

6 Conclusion

The proposed low cost IoT based Vehicle parking system using cloud PaaS can be a very efficient system for automation in vehicle parking for smart cities. This system would require a very less human intervention and hence can save fuel time and hassle free parking for users. The future scope includes a more resource optimization through data analytics as discussed in section 5. With growing population and vehicle smart city are facing immense challenge for parking and this proposed system and its results are promising for a low cost system implementation for better parking space management and hassles free parking for modern day smart cities.

Acknowledgment

The prototype of this project work has been developed and tested in Wireless Communication & Networking Lab, School of Electronics Engineering, Kalinga Institute of Industrial Technology (KIIT) Deemed to be University, Bhubaneswar, India. This work is carried out as undergraduate level Project for partial fulfillment of the degree requirements for the student authors under supervision of the faculty author.

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