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***Abstract*— In recent times the concept of smart cities have gained grate popularity. Thanks to the evolution of Internet of things the idea of smart city now seems to be achievable. Consistent efforts are being made in the field of IoT in order to maximize the productivity and reliability of urban infrastructure. Problems such as, traffic congestion, limited car parking facilities and road safety are being addressed by IoT. In this paper, we present an IoT based cloud integrated smart parking system. The proposed Smart Parking system consists of an on-site deployment of an IoT module that is used to monitor and signalize the state of availability of each single parking space. A mobile application is also provided that allows an end user to check the availability of parking space and book a parking slot accordingly. The paper also describes a high-level view of the system architecture. Towards the end, the paper discusses the working of the system in form of a use case that proves the correctness of the proposed model.**

Keywords*— *Internet of Things; Cloud Computing; Smart Parking; Smart City; Cloud of Things

I. INTRODUCTION

The concept of Internet of Things (IoT) started with things with identity communication devices. The devices could be tracked, controlled or monitored using remote computers connected through Internet. IoT extends the use of Internet providing the communication, and thus inter-network of the devices and physical objects, or 'Things'. The two prominent words in IoT are "internet" and "things". Internet means a vast global network of connected servers, computers, tablets and mobiles using the internationally used protocols and connecting systems. Internet enables sending, receiving, or communicating of information. Thing in English has number of uses and meanings. Dictionary meaning of 'Thing' is a term used to reference to a physical object, an action or idea, situation or activity, in case when we do not wish to be precise. IoT, in general consists of inter-network of the devices and physical objects, number of objects can gather the data at remote locations and communicate to units managing, acquiring, organizing and analyzing the data in the processes and services. It provides a vision where things (wearable, watch, alarm clock, home devices, surrounding objects with) become smart and behave alive through sensing, computing and communicating by embedded small devices which interact with remote objects or persons through connectivity. The scalable and robust nature of Cloud computing is allowing developers to create and host their applications on it. Cloud acts as a perfect partner for IoT as it acts as a platform where all the sensor data can be stored and accessed from remote locations[11]. These factors gave rise to the amalgamation of both technologies thus leading to the formation of a new technology called Cloud of Things(CoT). In CoT the things(nodes) could be accessed, monitored and controlled from any remote location through the cloud. Due to high scalability in cloud any number of node could be added or removed from the IoT system on a real time basis. In simple terms IoT can be explained in form of an equation stating:

Physical Object + Controller, Sensor and Actuators + Internet = Internet of Things

The ideal of creating a Smart City is now becoming possible with the emergence of the Internet of Things. One of the key issues that smart cities relate to are car parking facilities and traffic management systems[3]. In present day cities finding an available parking spot is always difficult for drivers, and it tends to become harder with ever increasing number of private car users. This situation can be seen as an opportunity for smart cities to undertake actions in order enhance the efficiency their parking resources thus leading to reduction in searching times, traffic congestion and road accidents. Problems pertaining to parking and traffic congestion can be solved if the drivers can be informed in advance about the availability of parking spaces at and around their intended destination. Recent advances in creating low-cost, low-power embedded systems are helping developers to build new applications for Internet of Things. Followed by the developments in sensor technology, many modern cities have opted for deploying various IoT based systems in and around the cities for the purpose of monitoring. A recent survey performed by the International Parking Institute [6] reflects an increase in number of innovative ideas related to parking systems. At present there are certain parking systems[8] that claim to citizens of delivering real time information about available parking spaces. Such systems require efficient sensors to be deployed in the parking areas for monitoring the occupancy as well as quick data processing units in order to gain practical insights from data collected over various sources.

The smart parking system that we propose is implemented using a mobile application that is connected to the cloud. The system helps a user know the availability of parking spaces on a real time basis. The rest of the paper is organized as follows: Section II talks about the factors responsible of Cloud-IoT

integration. Section III presents the state-of-the-art in smart parking system. Section IV describes the implementation and working of the system. Section V concludes the paper.

II. NEED FOR IOT-CLOUD INTEGRATION

Cloud computing and IoT have witnessed large evolution. Both the technologies have their advantages, however several mutual advantages can be foreseen from their integration. On one hand, IoT can address its technological constraints such as storage, processing and energy by leveraging the unlimited capabilities and resources of Cloud[4]. On the other hand, Cloud can also extend its reach to deal with real world entities in a more distributed and dynamic fashion by the use of IoT. Basically, the Cloud acts as an intermediate between things and applications, in order to hide all the complexities and functionalities necessary for running the application. Below are some of the factors that led to the amalgamation of Cloud and IoT.

- *Storage capacity*: IoT comprises of a large number of information sources (things), which produce huge amounts of non-structured or semi-structured data. As a result IoT requires collecting, accessing, processing, visualizing and sharing large amounts of data[14]. Cloud provides unlimited, low-cost, and on-demand storage capacity, thus making it the best and most cost effective solution to deal with data generated by IoT. The data stored on the Cloud can be accessed and visualized from anywhere through standard APIs.

- *Computation power*: The devices being used under IoT have limited processing capabilities. Data collected from various sensors is usually transmitted to more powerful nodes where its aggregation and processing can be done[18]. The computation needs of IoT can be addressed by the use of unlimited processing capabilities and on-demand model of Cloud. With the help of cloud computing, IoT systems could perform real-time processing of data thus facilitating highly responsive applications.

- *Communication resources*. The basic functionality of IoT is to make IP-enabled devices communicate with one another through dedicated set of hardware. Cloud computing offers cheap and effective ways of connecting, tracking, and managing devices from anywhere over the internet[16]. By the use of built-in applications IoT systems could monitor and control things on a real-time basis through remote locations.
- *Scalability*: Cloud provides a scalable approach towards IoT. It allows increase or decrease in resources in a dynamic fashion. Any number of "things" could be added or subtracted from the system when cloud integration is provided[22]. The cloud allocates resources in accordance with the requirements of things and applications.

- *Availability*: Any time any where availability of resources becomes very easy with cloud integration. Many of the cloud providers assure 5 nine availability. With cloud, the applications are always up and running and continuous services are being provided to the end users.

- *Interoperability*: IoT involves the use of devices that are heterogeneous in nature. These devices may have different hardware or software configurations as a result causing compatibility issues. It becomes very difficult in an IoT environment to ensure interoperability among these devices[19]. Cloud helps in addressing this problem as it provides a common platform where various devices can connect and interact. Devices are allowed to share and exchange data in a format that is acceptable to them.

III. SYSTEM ARCHITECTURE

This section describes the high level architecture for the smart parking system along with a mathematical model. The parking system that we propose comprises of various actors that work in sync with one another. Below is the mathematical model that defines our smart parking system.

Table 1: Nomenclature Table

SYMBOL	**MEANING**
T	Parking time
C	Driver's car number
P	Amount paid
U	User ID
S	Parking slot
M_i	Driver
O	Occupancy rate
X()	Input function
Y()	Output function
F()	Computation function
I()	Identity function

$M_i \rightarrow X(T,C,P,U,S)$ // Driver provides input to the input function

$X() \rightarrow F(S,T)$ // Input function notifies the computation function

$X() \rightarrow I(P,C,U)$ // Input function notifies the identity function

$O_i = F(S,T) \rightarrow Y()$ // Computation function notifies the output function and the resultant is stored in form of the occupancy rate.

$O_i = 0 \mid 1$ // Occupancy rate can either be 0 or 1. Where 0 specifies occupied and 1 means vacant.

The following figure gives an outlined view of the complete system.

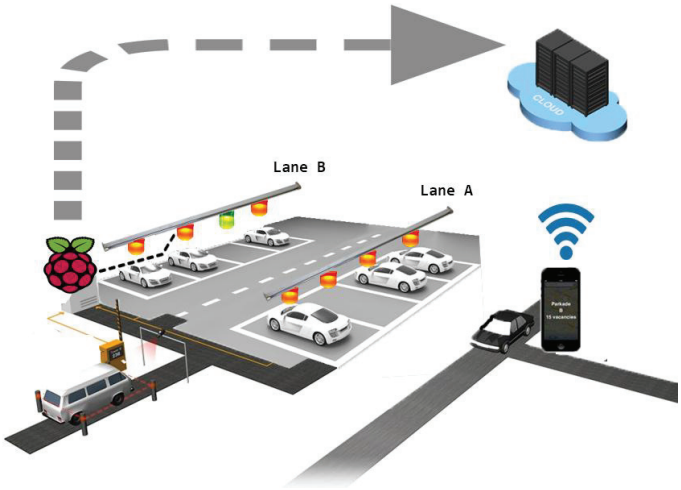

Figure 1: Smart Parking System

Talking of the above mentioned figure, it depicts a parking area where our parking system is implementation along with the way in which communication happens between various actors. The primary actors that constitute the parking system are:

- *Parking Sensors*: For our parking system we have made use of sensors like Infrared, Passive Infrared(PIR) and Ultrasonic Sensors. The work of these sensors is the same i.e. to sense the parking area and determine whether a parking slot is vacant or not. In this case we are using ultrasonic sensors to detect the presence of a car. The ultrasonic sensors are wirelessly connected to raspberry pi using the ESP8266 chip. An ESP8266 WiFi chip comprises of a self contained SOC with integrated TCP/IP protocol stack that allows any microcontroller to access a WiFi network. The sensors are connected to a 5V supply either from raspberry pi or an external source. External source being more preferable.

- *Processing Unit*: It comprises of Raspberry pi which is a processor on chip. The processing unit acts like an intermediate between the sensors and cloud. All the sensors are wirelessly connected to the processing unit. A single raspberry pi unit comprises of 26 GPIO pins i.e. 26 different sensors can be connected to it. However we can increase this number by attaching a multiplexer (MUX) to it. It is essential that the ground of raspberry pi and sensors must be connected in order to transfer data using the GPIO pins. There is a python script running on the chip that checks the status of various GPIO pins and updates this information onto the cloud. Data collected from various sensors is sent to the raspberry pi through the esp8266 chip. The raspberry pi then transmits this data to the IBM MQTT Server through MQTT protocol over a channel. MQTT[15] (Message Queue Telemetry Transport) Protocol is a publish-subscribe based "light weight" messaging protocol that is used on top of the TCP/IP protocol. It is designed to establish connections across remote locations where limited amount of data needs to be transferred or in cases of low bandwidth availability.

- *Mobile application*: The mobile application acts like an interface for the end users to interact with the system. The application is developed in Apache Cordova and Angular Js framework using Javascript as a programming language. The purpose of using Apache Cordova is to create applications that can run on both android and iOS platform with the same source code. The application is connected with the IBM MQTT server through a secure channel and a 2 factor authorization. The purpose of this mobile application is to provide information regarding availability of parking spaces and allowing the end user to book a slot accordingly. Transfer of data takes place in JSON format between IBM MQTT server and the mobile application. In order to ensure proper communication both the Raspberry pi and mobile application must be subscribed to a particular channel on IBM MQTT server.

- *The Cloud*: The IBM MQTT server is hosted on cloud. Cloud acts as a data base to store all the records related to parking areas and end users that have access to the system. It keeps a track of every user connected to the system and maintains information such as time at which the car was parked, time duration for parking a car, amount paid by the user and mode of payment. It is due to the flexible nature of cloud which permits the system to add any number of users at any time of the day. Continuous backup is made of the data stored on cloud in order to ensure easy and quick recovery of data in case of any kind of system failure.

  On closely looking at the figure one gets to see that empty parking spaces are indicated by red light in Lane A whereas green light in Lane B. This is due to the fact that in case of Lane A although there is no car currently parked but there still is a red light because the slot has already been booked by some user. On the other hand, the parking slot in Lane B shows green light because it neither has a booking nor a car parked in it.

IV. IMPLEMENTATION & WORKING

In the previous section we discussed about the architecture and technical stack related to the smart parking system. In this section we talk about the implimtation and working of the system in a real world scenario. The complete process of booking a parking slot, parking a car in that slot and leaving the parking area is explained with the help of the following flow chart.

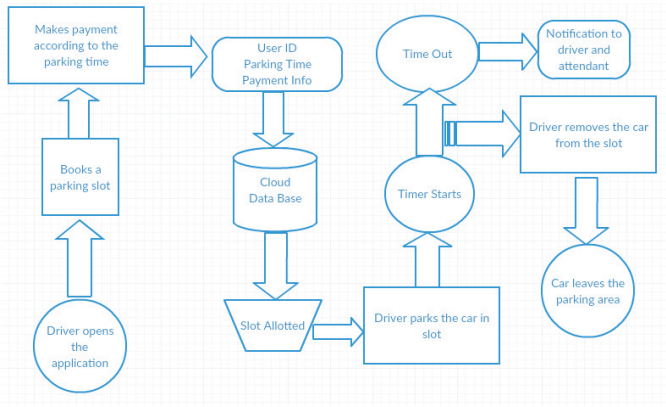

Figure 2: Flow chart of the system

We conducted an experiment in order to depict the working of our system at every stage from checking the availability of parking space to actually park a car in a vacant parking slot. This is done by implementing the smart parking system in the parking area of a shopping mall. Below are the steps that a driver needs to follow in order to park its car using our parking system.

- **Step 1**: Insall the smart parking application on your mobile device.
- **Step 2**: With the help of the mobile app search for a parking area on and around your destination.
- **Step 3**: Select a particular parking area.
- **Step 4**: Browse through the various parking slots available in that parking area.
- **Step 5**: Select a particular parking slot.
- **Step 6**: Select the amount of time (in hours) for which you would like to park your car for.
- **Step 7**: Pay the parking charges either with your e-wallet or your credit card.
- **Step 8**: Once you have successfully parked your car in the selected parking slot, confirm your occupancy using the mobile application.

The above mentioned procedure for booking a slot and parking a car in that very slot is explained with the help of the following screenshots.

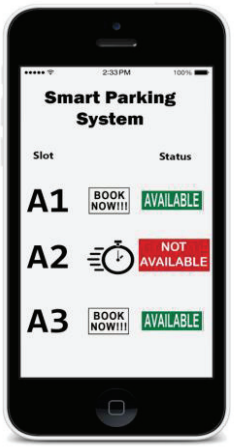

Figure 3: Booking a parking slot

The above figure depicts the presence of vacant and occupied parking slots. In this case parking slots named A1 and A3 are vacant whereas slot A2 is occupies. The driver chooses the A1 parking slot.

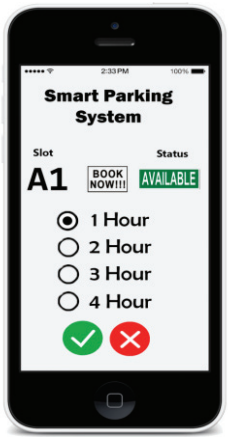

Figure 4: Selecting the amount of time

The above figure depicts the scenario when a driver needs to specify the amount of time for which it needs the selected parking slot. In this case the driver selects the 1 hour option.

Figure 5: Occupancy check

Once the driver has parked its car in the selected slot it needs to confirm its occupancy. Figure 5 depicts this very scenario in which the driver has to specify its presence. This feature is added so that only a genuine driver can park its car in a particular parking slot. If a driver fails to confirm his occupancy in the next 30 seconds of parking its car, an alarm would start ringing causing the authorities to know that a car has been parked in the wrong place. If by any chance a genuine driver fails do so he can stop the alarm any time by confirming his occupancy.

In case the driver over shoots its parking time, a notification stating this scenario would be sent to the driver as well as to the parking attendant. The driver would then have an option of extending its parking time and pay accordingly for the extra time. In case the driver fails to do so, the parking attendant would make a note of this and charge money for the extra time in form of a fine. This fine would be collected from the driver at the time when the car would be leaving from the parking area.

V. CONCLUSION

The concept of Smart Cities have always been a dream for humanity. Since the past couple of years large advancements have been made in making smart cities a reality. The growth of Internet of Things and Cloud technologies have give rise to new possibilities in terms of smart cities. Smart parking facilities and traffic management systems have always been at the core of constructing smart cities. In this paper, we address the issue of parking and present an IoT based Cloud integrated smart parking system. The system that we propose provides real time information regarding availability of parking slots in a parking area. Users from remote locations could book a parking slot for them by the use of our mobile application. The efforts made in this paper are indented to improve the parking facilities of a city and thereby aiming to enhance the quality of life of its people.

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