Smart Parking for Disabled Parking Improvement Using RFID and Database Authentication

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***Abstract*— In many populous cities across the world, parking tends to be at the forefront of traffic concerns. Many cities have seen rises in urban population as people move to the cities for job opportunities. The increase in population also means more cars in the city making parking spaces valuable commodities. In many of these cities, parking spaces near venues and other services are reserved for disabled parking. In the United States, federal law sets the requirements for the number of spaces that must be made available along with the size of each area. Requirements for authorization to park in these spaces are also set by federal offices and the authorized person is given a placard designating their legal right to park in these designated parking spaces for the disabled. Our proposed method, which adds RFID and database authentication to the use of ultrasonic sensors, LED, and cloud technology methods, will assist with ensuring that the limited disabled-parking spaces are used by those authorized to do so, and will alert the parking authority when a space is occupied by an unauthenticated person. Our goal is to explain how some of the currently researched smart parking methods can be used for disabled parking management and improved with the addition of authenticating disabled parking authorization.**

Keywords— Internet of Things, IoT, Smart Parking, parking, disabled parking, RFID,

I. INTRODUCTION

In the last decade, technology has made many advances. Memory storage devices have grown in capacity and shrunk in physical size. Communication devices have achieved extended ranges while improving energy efficiency and extending battery life. Alternate forms of energy have received more attention and funding and are seeing more widespread use. All these advances have been building up toward a future Smart City application of the Internet of Things (IoT). The advancement of sensor and mobile technologies has made it available for research and implementation of various smart parking systems [1].

Many studies have been done and continue to be done on the various methods to achieve a smart city and the challenges that need to be addressed to bring it to fruition. Suryotrisongko et al. [2] present a very strong design idea for smart cities, incorporating what they call a Four-Hospitality standard, focusing on persons with disabilities. Though their focus is on the design of the city for disabled persons, it does not address smart disabled parking directly. Within the various smart city studies, one of the recurring study topics revolves around smart parking. As city and company resources grow in complexity, the management of these resources becomes a daunting task. There is a need to find smart ways to manage these various resources. The use of IoT technology can aid in the development of smart systems to manage these resources, and one such system is a smart parking system [3]. The creation of intelligent transportation systems that could improve the lifestyles of city inhabitants requires the development of smart systems, chief among them is a smart parking system using IoT technology [4]. Yang et al. [5] provide a detailed example of how an IPIS (Intelligent Parking Information System) has benefited both drivers and non-drivers in their Hong Kong based study.

As more people move into cities for work and other opportunities, more vehicles appear on city streets, congesting traffic, adding to the air pollution, and occupying more parking spaces. In some cities across the world, there are more registered vehicles than available parking spaces. Finding solutions to improve the parking situation will provide ripple effects such as easing traffic congestion and cutting down on illegal parking.

Though many studies have been done on various methods of employing smart parking solutions using IoT, not much research has been explicitly focused on handicap accessible parking spaces. In many cities, like Bridgeport, Connecticut, USA, public disabled parking spaces can be found in prime parking locations near many businesses and venues. By law, disabled parking spaces must be provided within specific distances to these venues and parking is only allowed in these spaces by persons authorized by the state. These authorized persons possess a state-endorsed disabled parking placard issued by the state Department of Motor Vehicles. The placard may be permanent or temporary based on the person's disability.

Other studies have developed apps and used other IoT methods for monitoring and reserving parking spaces. While

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they vary in IoT application, ultrasonic sensors, pressure sensors, cameras, wireless sensors, and gateways have been employed.

For this work, we look to build on some of the previous research but focus on a method to authenticate that the driver parking in a disabled parking space is authorized to do so. In this context, we look to use a combination of an ultrasonic sensor, RFID reader, multicolor LED, and database to determine if the disabled parking space is occupied, take a picture of the license plate, and authenticate the placard with the RFID reader against the data in the database. The proposed system would be able to determine if the disabled parking space is occupied via the ultrasonic sensor, and if it is, it triggers the RFID reader which attempts to read the RFID tag on the disabled placard, sending the data back to the server for cross-referencing against the database. While the verification is taking place the LED blinks red, if authenticated, the LED stays solid green, if not authenticated, the LED stays solid red and an alert is sent to the local parking authority.

The rest of this paper is laid out as follows; section 2 covers the related work done on the smart parking application of IoT, section 3 discusses the key technologies of our proposal, and section 4 explains our system architecture. While section 5 discusses the hypothetical implementation results, in section 6 we bring up possible future work that can be done to further the system, and finally, in section 7 we draw our conclusions. All references can be found in section 8.

II. Related Work

As we went through previous work that researched IoT based smart parking systems, we found different papers proposed different system structures and many sensing and data collection technologies. In this work, we introduced our own structure in a way that involves disabled parking authentication, and we made use of the different technologies proposed in other works, compare them together based on system structure, efficiency, accuracy and authentication capability, to come up with our idea.

Baroffio et al. [6] proposed a solution for smart parking based on computer vision to detect the available parking spaces, and ad-hoc network for data collecting and transmission, the technology used here is to move part of the data analysis to the sensing devices and convey the output which resulted in less energy consumption and less bandwidth for data transmission. The system consists of a network of wireless camera nodes; the images that are acquired by those nodes will be processed in the sensors and further in the central processing unit. In conclusion, this paradigm ends up with a more efficient performance as compared to the traditional one regarding the consumed energy, bandwidth and accuracy. However, this work did not mention anything about parking authentication problems nor how users can know about the available parking slots.

Lee et al. [7] proposed a smart parking system based on ultrasonic and magnetic sensors; this system can work on both indoor and outdoor parking spaces. The authors made a comparison with RFID based parking systems and found that they are not convenient since each car should have an RFID tag. According to this drawback, they proposed a new system based on wireless sensor networks, smartphone Bluetooth and USIM for location detection; they also used ultrasonic sensors for indoor spaces and magnetic sensors for outdoor spaces. This system is more convenient and less costly than RFID based ones. Vehicle location is specified by sending signals to the wireless sensor network over a user's smartphone Bluetooth, and that is why this system provides high accuracy. Though it is an impressive smart parking application, it does not address the authentication of specialized disabled parking spaces.

Lambrinos et al [8] use an app and SMS based approach for the reservation and confirmation of the use of disabled parking spaces. Their system, however, does not authenticate the placard itself, only that the account holder in their system has reserved and occupied the requested space. Their system does provide a method of tracking unauthorized or illegal parkers.

A vision-based and machine learning approach was taken by Ling et al [9] where they used machine learning algorithms to "learn" the parking spaces. They used positive and negative images to teach the system how to identify empty and occupied spaces. This approach visually identifies parking spaces but does not address disabled parking.

Sadhukhan [1] suggests an interesting approach to smart parking incorporating the use of an ultrasonic sensor, LED, alarm, and camera. To detect available and occupied spaces, but does not use the imaging to identify disabled symbols on license plates.

Krishnamurthy et al. [10] present an effective study on the results of a smart parking management implementation in San Fransisco and its positive effects on both transit and traffic. Their study focused on the overall parking situations in pilot blocks and the positive outcomes, however, though the study was successful, no focus was provided on disabled parking.

Our proposal incorporates an ultrasonic sensor, for occupancy detection, an RFID reader for tag authentication, and an RGB LED light for status notification. Data will be uploaded to an online database where authentication will be checked. The difference with our proposal is the use of an online database for cross-referencing parking authentication with data obtained from local parking authorities. We believe our proposal has the potential to improve the efficiency of disabled parking space usage while assisting the local parking authority in their endeavor to enforce legal parking restrictions to those disabled parking spaces.

III. Key Technologies for Our Proposed Model

Different technologies have been combined to work together to implement our proposed model, and those technologies are described in this section.

A. Sensing Technology

It is essential for any IoT system to have a sensing system to collect data from the outside world and then convey it to a central processing unit and make decisions based on it. In our model, we used an Ultrasonic sensor for each parking slot, to keep track of the oncoming cars that need to park in that slot. The principle idea behind the ultrasonic sensor is that it has a transducer to send and receive ultrasonic pulses consequentially, and by measuring the transmission time, the distance is calculated using the speed formula. This sensor gives accurate readings, and it is cost-efficient as compared to other sensing technologies like cameras for example.

B. *Radio Frequency Identification Technology (RFID)*

RFID has proven to be rather versatile which is advantageous in that it is recognizable by both the transportation industry and the transport sectors and has seen wide use in intelligent transportation systems (ITS) as a safety enhancement for drivers [11]. It is a wireless technology used for automatic identification, tracking, and authentication purposes by reading identification information from specific tags called RFID tags which are attached to physical objects that are required to be tracked. Essentially this technology transfers data from those RFID tags to what is known as the RFID readers using the radio wave. Additionally, a middleware should be involved to manage the tracking process. This technology has been regarded as the core and the next revolution of the Internet of things [12]. We chose this technology for authentication purposes in our model for the following reasons. First, RFID tags have a low cost. Secondly, it is easy to deploy it with preexisting systems and objects.

C. *Processing Technology*

The processing unit is an essential part of the IoT system to work, this unit is where the collected data is analyzed, and decisions are made. For our model, we used raspberry pi3 B+ as the brain of the IoT system. It is the perfect fit for our project due to it is low cost and small size. Additionally, it is easy to configure since it runs open-source software.

IV. SYSTEM ARCHITECTURE

A. *Hardware System Architecture*

our model consists of a Raspberry Pi3 B+ with an ultrasonic sensor, RGB LED module, RFID reader, solar panel, and rechargeable battery, as shown in figure 1. The unit is battery powered, using the solar panel to recharge the battery, and it is attached to the pole holding the disabled parking sign.

B. *Software System Architecture*

The software system consists of two parts; the first part is the database where the authorized users' information is stored, and the second part is the data analysis. The system works as follows. When space is occupied, determined by consecutive readings from the ultrasonic sensor, this triggers the LED to blink red while it is processing and triggers the RFID reader to attempt to read the RFID tag on the disabled placard in the vehicle. The RFID reader will read the tag and send the data to the Pi3 where the database is hosted. Then the system will compare the data received to the data in the database for authentication. If there is no match or no readable tag, the system will turn the LED to a solid red and send an alert to the security office that there is an unauthenticated/ unauthorized parking situation. If there is a match to the database, the LED will be set to blue. If there is a constant reading of no objects within 50 cm, the system sets the LED to green, showing that the parking space is available. The flowcharts in Figures 6 and 7 show the software architecture flow of the system for cars entering the parking space and exiting the parking space, respectively.

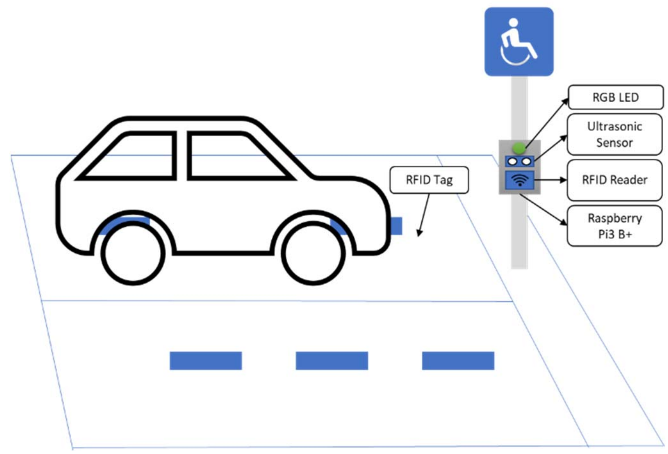

Figure 1 Hardware Architecture

V. IMPLEMENTATION RESULTS

We built a prototype module using a Pi3 B+ and connected to it an ultrasonic distance sensor, RGB LED, RFID reader, and used a locally hosted SQLite database. The ultrasonic distance sensor determines if there is a car parked in the space; if it senses an object within 50 cm for multiple readings, it triggers the next actions. The LED blinks red while the data is being gathered and processed. Then the RFID reader begins attempting to read the RFID tag on the disabled placard. The system compares the RFID tag ID to the data in the database, if it finds a match, the LED is set to blue if no match is found the LED is set to red and a message is sent to security informing them of an unauthorized parking situation. While the ultrasonic distance sensor does not detect anything within 50 cm, the LED is green indicating that the parking space is available.

We incorporated ThingSpeak, a cloud-based analysis, and app tool, to perform the analysis and create a visual dashboard that represents the various parking statuses.

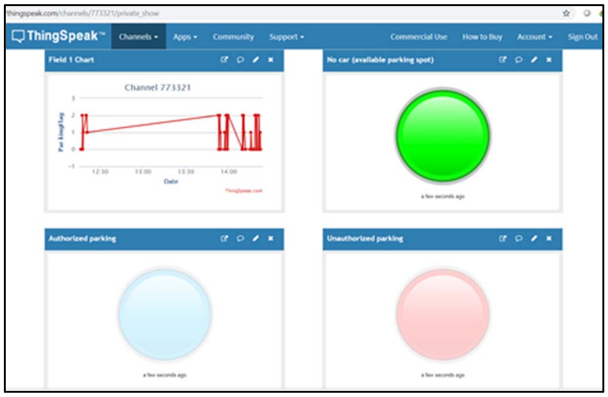

Figure 2 ThingSpeak Dashboard showing available parking

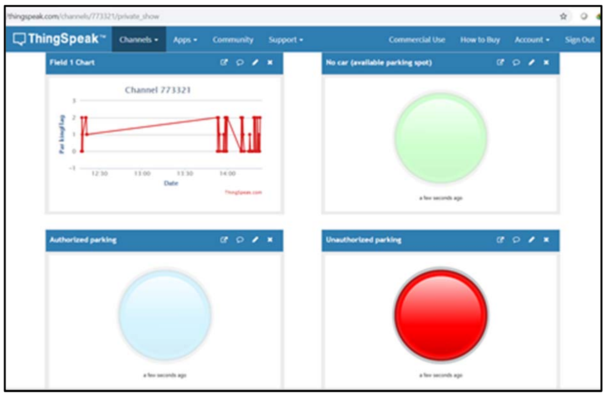

Figure 3 ThingSpeak Dashboard showing unauthorized parking

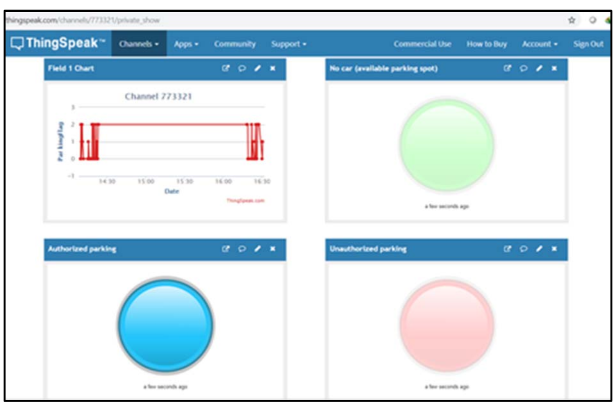

Figure 4 ThingSpeak Dashboard showing authorized parking

This dashboard is accessible via a web interface and an app to allow security to monitor the status of various parking spaces in real-time, through an easy to understand dashboard. The dashboard also shows a chart of the recent sensor readings used by the system to determine the parking status.

An integration with Webhooks services via IFTTT cloud services, allowed us to create and send alert messages. When an unauthorized parking situation occurs, and email is sent to security containing the type of event, date, time, and coordinates in latitude and longitude. The coordinates can be plugged into any map, like Google Maps, for a visual of the location.

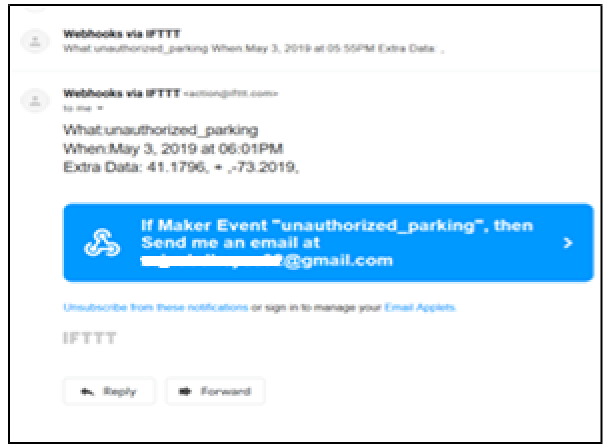

Figure 5 Email alert sent from unauthorized parking event

VI. Future Work

Smart parking is an essential feature of a successful smart city implementation. In order to have a meaningful smart parking application, disable parking must be taken into account. Though it is a small part of the population, it is an important and legally protected population. To address this application, we have presented this prototype. It is only possible when we have our devices, equipment, and applications connected to the internet. Additionally, establishing a relationship with local motor vehicle departments and parking enforcement will be necessary to provide accurate and up to date information for the database.

We have used Raspberry Pi3 B+ to implement this model, which makes it cost-effective. The additional components for building the prototype and expanding the model are fairly priced since there are many Raspberry Pi compatible options. Future implementations can incorporate cameras, to capture images of the hanging placard and license plate, coupled with OCR software to identify the universal disabled symbol that appears on all the placards and on the license plates issued in some U.S. states. The purpose of incorporating the imaging and OCR would be to account for those authorized drivers, hailing from a different state, whose data would not appear in the database of the state where the solution is implemented. This would also mean updating the logic of the system to look at the OCR identification results, for an image match, when the RFID information does not match the database.

VII. Conclusion

After reviewing the multiple implementations of various smart parking systems and finding them lacking indirectly addressing the needs for disabled parking, we proposed our prototype, building off various successful implementations of similar smart parking systems, but adding RFID and database authentication, specifically for determining that the occupant is authorized to park in the designated disabled parking space. Our prototype proved to be cost-effective while increasing the accuracy and efficiency of monitoring, tracking, and authorizing disabled parking.

Our implementation proved to be successful in identifying an empty disabled parking space. Determining when it is occupied and authenticating the RFID tag to identify an authorized and unauthorized parking situation.

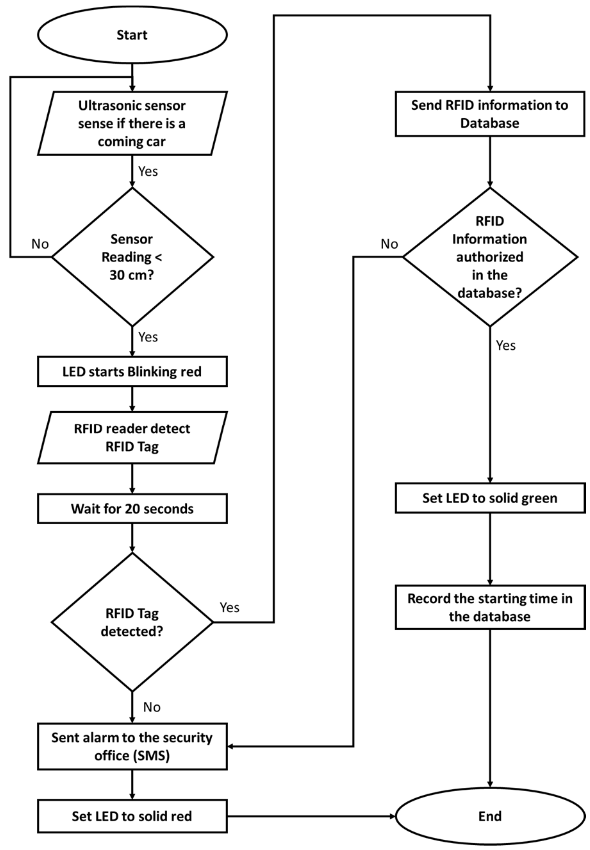

Figure 6 software system architecture flowchart for car entrance

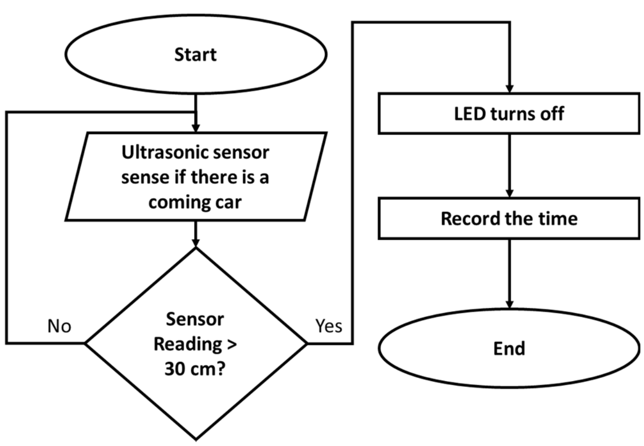

Figure 7 software architecture flowchart for a car leaving

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