A Novel Wireless Solution for Acquiring and Representing Data on Current and Past Parking Trends.

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Abstract

Parking spaces can be hard to find in large lots. Large amounts of time can be spent trying to find an available space, and when one is found there is a risk of losing the space to another person. We propose a possible solution to finding available spaces: an embedded circuit which uses IR sensors to determine if a spot is taken or available. This information would then be transmitted to a web server which would then provide a user interface showing available spots. We believe that this system will mitigate the time wasted in finding a suitable parking space.

I. Introduction and Motivation

A. Introduction

As the progression of time marches forward, the population of our world continues to increase. As such, there is a consistent increase in the number of drivers on the road every year. From 2008 to 2013, the total number of licensed drivers in the state of Utah increased from 1.75M to 1.9M [1] [2]. The increase in drivers using public roadways has put additional stress to an already stressed parking framework in place in our state. This stress has been notably perceived by anyone who commutes to the University of Utah (The U), as there has been an increase in the number of student and faculty commuters who use private transportation as their main means of travel to and from said institution. In the same time frame stated above, the number of students registered at The U increased from 28,211 in 2008 to 31,515 in 2014, an increase of 11% [3] [4]. Of these 31,515 students, 23,907 were undergraduate, and 87% of undergraduate students identified as commuters, i.e., not living on school-owned facilities [5].

The staggering number of individuals commuting to the The U means that finding a suitable parking location can be a major inconvenience. There is a considerable amount of time that must be spent in search of a parking space for anyone not arriving at The U before sunrise. This time wasted can lead to missed examinations and being late to potentially important meetings. The problem is such that some commuters have conceded defeat and either begin their travel to The U hours before they need to do so, or have opted to take advantage of public transportation. However, use of these alternatives has not mitigated the parking problem faced by those who elect to drive to The U. Furthermore, there are circumstances in which these alternatives are not an option, such as last-minute meetings or, more realistically, being late.

In response to this issue, our group aims to mitigate the headaches that are associated with parking at The U, primarily with respect to finding a suitable parking location. We aim to engineer a parking space monitoring system that tracks whether a parking space is occupied or vacant. The system will be comprised of sensory nodes that will communicate with one-another, as well as with a master node. This master node will transmit all the data for an entire parking lot to an off-site server, where it will be processed and the status of each parking space will be displayed graphically via a user-web interface. Users of the system will be able to access the web service before they depart on their commute and formulate a parking strategy, thereby mitigating the time lost in search of an empty parking space.

While there are other parking solutions implemented today, none have the resolution that we are aiming for. Many of these systems that are in use today are essentially counters that keep a running count of the total number of cars that pass through an entry point. While these systems seem adequate, they are missing several key pieces of data:

1) Where are the taken spaces concentrated?
2) What is the total number of parking spaces?
3) Cars that have vacated spaces, but not yet exited the lot/structure.
4) Historical analysis of data for a specific time frame.

For these reasons, we believe that our system is an improvement upon existing systems that implement similar functionality.

The system will be demonstrated in real-time during the Senior Demo Day in December. We will have the fully-functional web service displaying data from the server, which will be acquiring data from a live unit monitoring 4 spaces. The unit will be located in the parking lot of the Merrill Engineering Building (MEB). If for some reason we are unable to place the system in the parking lot, we will instead place the system in the demo room, or at a hallway intersection to simulate objects being detected by the system.

B. Motivation

The motivation behind this project comes from frustration, specifically the frustration that is associated with finding a parking space in the middle of the day. Each member of the group has had to, at one point or another, arrive at The U in the later hours of the morning or midday. During these times, it is near impossible to find a decent parking spot with a quick scan of the desired lot. The result is that we, among others looking for parking, must drive up and down the rows of cars in hopes of finding a spot that has been recently vacated or has been overlooked. The act of crawling through the lot not only wastes time, it also contributes to the release of excess pollutants into the atmosphere. We hope that this system will mitigate some of these effects by informing individuals of open spaces, thereby reducing the searching, which will reduce the production of exhaust gases that are a result of crawling around the parking lot.

Additionally, we believe that this idea has the potential to be marketable. Our primary target market would be institutions of higher learning with a high percentage of commuting students. Our secondary target market would be amusement park operators. Both of these entities have tremendous problems with parking, specifically with the difficulties associated with finding a suitable location.

II. Background

Parking monitor systems have been around for a while. The systems come in a variety of technologies that are designed to monitor parking lots. Most of the systems use image processing to identify available spots. Other systems count the number of cars that have entered the lot and keep a running total of free spaces. The parking lot monitoring system that this paper describes is derived from a combination of these already existing systems.

A. Spot Identification

Patent US7893847 claims that with image processing and a parking availability determiner, their system can identify open spots [6]. The system uses image processing to identify parking spaces with the use of symbols and relays the information over a network to a central system. Other systems use image processing to estimate the total number of open spots available.

Another type of system monitors the flow of traffic entering and leaving the parking structure and keeps a count of spot availability. This type of system can be seen at the City Creek Shopping Center in Salt Lake City, Utah. The system keeps a running total of open spots per level of the parking structure and displays the numbers on monitors. This type of system is popular for larger parking structures.

B. Spot Reservation

Patent US20140249742 A1 describes a way in which a driver gets matched to an available parking spot. The software is designed to estimate the time of arrival of the driver and reserves the space [7]. Other types of spot reservation is available through web browser assistance. The system offered by www.theparkingspot.com allows for users to reserve a parking spot at select airports.

III. Proposed Work

A. Baseline Deliverables

The system will be comprised of two custom printed circuit boards. One board design will be designated as a master node, and the other will be designated as a slave node. The slave node will be responsible for the acquisition of data for 4 parking spaces in total. The monitoring of these spaces will be done with the use of infrared (IR) sensors connected to the PCB. The slave boards are limited to monitoring 4 spaces per slave because of the fact that parking spaces are easily represented in quadrants, and because of hardware constraints to be discussed later in this proposal. The slave nodes will communicate with the master node by use of the IEEE 802.15.4 communications protocol, known as ZigBee and discussed later in this section.

The master nodes will be responsible for accumulating the data from the slave nodes and transmitting the data to the database. The transmission of the collected data will happen over Wi-fi, thereby affording us the use of a widely used communications protocol. The master node will be able to track at most 32 individual units, each of which will be end-point slave devices.

The master and slave PCBs will each have headers so that an XBee−PRO® 900HP radio can be connected directly. The radios will be used to implement a master−slave communications network via the Zigbee protocol. This communications protocol was selected due to its low power consumption and mesh network capabilities. A rechargeable battery will be used to supply power for both master and slave devices. The master node will have the CC3200 component provided by Texas Instruments to communicate via Wi-Fi. Fig. 1 shows a high-level diagram of the communication between slave and master nodes, and the master node to the server. Additionally, fabrication of a plexiglass case is being considered to ensure the hardware is protected from environmental exposure.

At the present time, a server has been setup to host the data being transmitted by the master nodes. The data will be processed and stored in a database to await usage. The data will be used by the end user via a web interface. Currently,

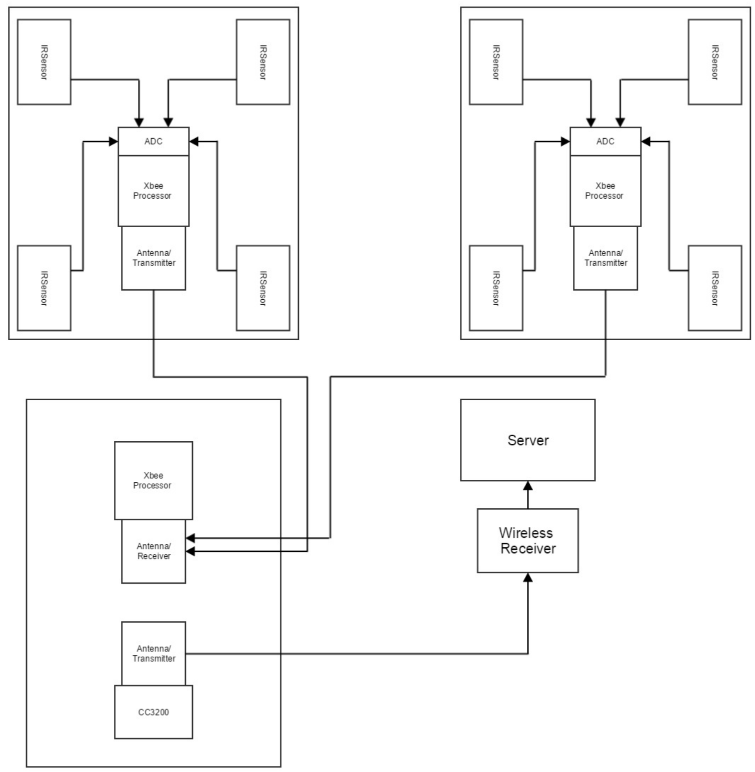

Fig. 1: High-level block diagram of baseline deliverables.

the website is being constructed to display the state of the parking spaces on a graphical representation of the parking lot. Additionally, the website will guide the user from the entrance of a given parking lot to the closest available spot.

For the demonstration of the system, we will have a single master node monitoring two slave nodes, for a total of eight parking spaces monitored. The reason for the limited scale of the project is purely monetary. The system should be able to scale up to an almost arbitrary number of slave and master nodes, and the ZigBee protocol has been proven to scale up to 400 nodes [8].

B. Stretch Goals

It is a goal of ours to develop this project in a way that the end product is marketable. However, the primary goal is to showcase our engineering ability in designing a system that has the potential to become a marketable product. If time permits, the following optimizations to the system will be implemented, thereby requiring more engineering, as well as potentially increasing the systems marketability.

The first goal is to create a self-sustaining product by powering the entire solution with energy harvested from solar panels. These panels would also be used to charge the battery packs, and the battery would be converted to a backup power supply. This enhancement would potentially require a rework of the currently planned power system. Additionally, we desire to develop a user-friendly mobile application for the Android operating system. This application would be a companion to the web interface, and each will display the same data. Finally, we want to provide extra features to our end application. One extra feature has been discussed is the ability to reserve parking spaces ahead of time for a nominal fee. This feature would provide useful for commuters that live far from their destination and would generate extra revenue for the owner of the parking lot.

IV. Schedule and Work assignments

A. Schedule

A rough schedule follows:

1) By the end of May, we intend to complete the PCB design and schematic, the design will be sent for fabrication, and parts will be ordered.
2) By the end of June, receive first iteration of PCB and assemble it.
3) By the end of July, the transmitting station, and server/receiver will be assembled. We will also be testing and verifying our board.

4) By the end of August, the web application will be started with continued testing on the boards and receiver as needed.
5) In September, we will continue testing.
6) In October, we will start the formal report, and continue testing as needed.
7) By November, testing is expected to be done with a finished product. The remaining time will be spent on finishing the formal report.

B. Work Assignments

To better facilitate the development of the project, the project has been divided into three major components; embedded software development, PCB design and power system design, and the server back−end and web interface. Each member of the team has been assigned to one of these specific tasks to act as a product owner and project lead in their corresponding assignment. The assignment decisions were based on taking into consideration the talents and engineering strengths of each individual, as well as personal interest.

Product ownership of the embedded software development is assigned to Victor Avila and Austin Hinton. These two individuals have expressed an interest in embedded system design, as well as wireless communications. Specifically, Austin will be primarily responsible for any and all ZigBee protocol related software, and Victor will be responsible for the Wi-Fi aspects of the project. Jason Parkin expressed an interest in analog digital circuit design, and is therefore designated as the primary point of contact for the power system portion of the project. Derek Moore expressed interest with PCB design, and has proven to be proficient with the Altium Designer tool, therefore he will be designated as the point of contact for the PCB design and the schematic design for the slave and master nodes PCBs. Finally, due to his workplace experience, and expressed interest, Ian Noy will be responsible for the server back−end and the web interface.

Despite the fact that individuals have been assigned specific tasks on which they should focus their attention, this does not mean that they are only to work on said tasks. All team members are encouraged and expected to assist other members if their assistance or expertise is needed.

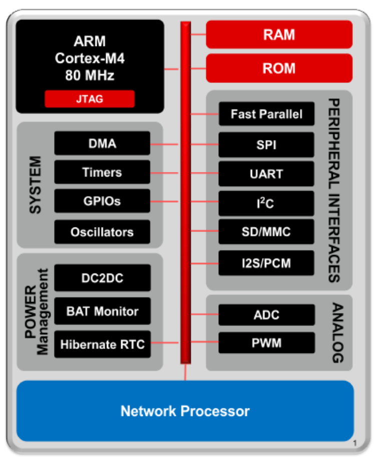

Fig. 2: CC3200 microcontroller hardware overview. [9]

V. Required Resources

A. TI SimpleLink^{TM}CC3200 Module

The main node of the system will be built around the TI SimpleLink^{TM}CC3200 Single-Chip Wireless Microcontroller Unit (MCU). This MCU is designed with an ARM ® Cortex ® M4 processor running at 80 MHz, 128 KB of embedded RAM, and peripheral drivers stored in embedded ROM [9]. Additionally, this MCU includes a 4-channel, 12-bit analog to digital converted (ADC), which will be used to convert the signals generated by the sensors into useful information. The processor also contains a variety of peripheral interfaces such as SPI, I2C, UART, SD/MMC, and 4 general purpose timers with pulse width modulation capability. Fig. 2 shows the hardware overview of the MCU.

Additionally, the MCU contains a complete Wi-Fi network controller subsystem. The subsystem is capable of communicating under the 802.11 b/g/n protocols. The subsystem is implemented with a dedicated ARM MCU, an integrated TCP/IP stack capable of up to 8 simultaneous socket connections, 802.11 wireless radio and Baseband, and Medium Access Controller.

B. *XBee-PRO® 900HP*

The XBee-PRO® 900HP is a 900 MHz RF Module that communicates using the 802.15.4 ZigBee protocol. This module is incredibly robust, and a complete list of features can be found in the datasheet [10]. The following is a brief list of features that made the module an attractive choice.

- The module contains an embedded ARM Cortex-M3 EFM32G230 processor.
- The frequency range of the module is 902-928 MHz.
- The data rate is 10 Kbps or 200 Kbps (depending on the distance). The data rate of 200 Kbps is achievable up to an outdoor line-of-sight range of 6.5 km. The outdoor line-of-sight range is 14 km for a data rate of 10 Kbps.
- The operation voltage is $2.1-3.6$ VDC.
- The current for the transmit, receive, and sleep modes are 215 mA, 29 mA, and 2.5 μA, respectively.
- The supported data interfaces are UART and SPI.
- The module has 4 10-bit ADC inputs, perfect for handling the inputs from the IR sensors on the slave boards.
- The networking topologies include DigiMesh, Repeater, Point−to−Point, Point−to−Multipoint, and Peer−to−Peer.

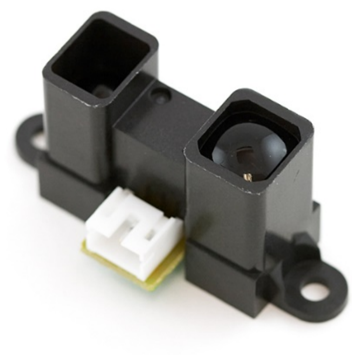

Fig. 3: IR Proximity Sensor [11].

C. *Infrared Sensor*

An infrared sensor (IR) will be used for detecting objects within a 5 foot distance of each slave node. The exact sensor that will be used is shown in figure 3. The IR sensor sends out a light signal within the infrared frequency range. When an object is within 5 feet or less the light will be reflected back to the device where it will be converted to a voltage signal. An analog output of 2.8 V to 0.4 V is generated with relation to the distance of the object; 0.4 V for objects at a distance of around 5 feet, and 2.8 V for objects within close proximity. This voltage signal will then be converted to a digital signal through an analog to digital converter on the slave device. This digital signal will be used to determine whether or not a particular parking space is vacant or occupied.

D. *Information Delivery*

Once availability has been identified it is important to display the information to a user. As described above, some systems use monitors to display numbers. Other techniques include webpage browsing, email, and text messaging. In Catherine Wah's paper, drivers are notified by SMS and VoiceXML [12]. VoiceXML is an Interactive Voice Response system that connects a caller to a database that delivers information to the driver through a series of voice prompts.

E. *Server*

The server that will be acting as our web host, file sharing, and data processing will be running Ubuntu 12.04 Server Edition. The server will have an Apache Server backend, MySql as the database implementation, and PHP for basic web hosting capabilities. As of right now, we do not have a domain name assigned to the server, so instead a public IP with port 80 open acts as the internet address. The software that will receive the packets transmitted by the parking modules will most likely be written in C++ and accept the packets on a specific port. Other packages that are installed on the server include: git, openssh, perl, python, samba, and webmin.

VI. Testing and Risk Assessment

A. Testing

As is true for all engineering, testing is an integral element of the process. As such we plan to test consistently as the project is being developed. For the embedded software elements of the project, testing will be facilitated through extensive use of the TI CC3200 Launchpad development board. This system will also be where all of the development of the software will take place. Additionally, it will be used for early-stage system deployment and proof-of-concept. For the PCB, and specifically the power systems, testing will be done with the use of schematic simulation tools such as PSpice. Doing so will help us to quickly determine aspects of the project that may not work, as well as help with the overall development of the project. The web interface will be tested early via a database of test data and a walking skeleton of a front-end web client. Additionally, the server itself will be stress tested to determine what type of traffic load the server can take before reliability of the data becomes an issue.

B. Risk Assessment and Mitigation

Due to the fact that this project is based on a system that will be implemented in an outdoor setting, there are several distinct risks that are involved. Primarily amongst those the potential for exposure to the elements. In order to mitigate the environmental effects that the project may experience, the system will be placed in a plexiglass enclosure. This enclosure will be designed such that it is completely waterproof. Plexiglass was chosen for the construction of the enclosure due to the fact that it will not prohibit the signals from propagating from the XBee radios or the Wi-Fi module.

Another potential risk that must be addressed is the possibility of the PCBs not functioning as we expect them to. This scenario is of particular importance due to the fact that the PCBs are the cornerstones of the project. Although every member of the team has had some experience in PCB design, the collective total is minimal. As such, if conditions are such that the PCBs are not functioning correctly and there is not enough time to resolve the issue, the TI CC3200 Launchpad will be used for the demonstration of the system. However, PCB issues, if any, should arise fairly quickly and early in the development of the project, and should be found and resolved with adequate testing.

VII. Summary

Finding an available parking space can be difficult in large lots. The difficulty scales up when there are numerous individuals vying for the same space, and when time constrictions are in place. Through the use of IR sensors, ZigBee, and Wi-Fi communication, our solution will detect open spots, communicate this information to a server, and the data will be processed and displayed in a user-friendly manner. This system will mitigate the annoyance and hassle associated with finding a suitable parking space.

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