Parking Lot Availability and Traffic Prediction System

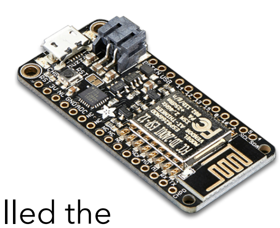
An end-to-end solution for monitoring parking lot availability and traffic situations using embedded IoT devices, a machine learning algorithm, and a backend service.

Introduction

As The College of New Jersey increases its student and faculty size, there is an ever increasing need to provide additional occupancy and coordination to accommodate its growth. One area where coordination can be improved is related to campus parking. Parking on campus is limited to eighteen locations throughout TCNJ and can be filled, and on occasion overflow to the lawns, rather quickly by students, faculty and visitors. On a typical day, many drivers attempt to find a parking space by driving around to different parking lots and guessing where parking spaces are available. This guesswork is inefficient for drivers who must drive around campus in search of space to park.

The Parking Lot Availability and Traffic Predication System is designed to provide drivers with information about the availability of parking lot spaces throughout campus, which will not only alleviate traffic congestion but also increase coordination for all drivers that come on campus. This system is made up of three modules: the nodes for detecting traffic conditions, a network and service to aggregate traffic data, and a front-end user interface for drivers and officials to see parking and traffic data at a glance.

Node Detection Hardware



Each parking lot on campus will require one or two traffic nodes in order to detect the traffic conditions. Each node will be comprised of hardware designed by Adafruit Industries and TCNJ's School of Engineering.

Each node will feature an embedded microcontroller from Adafruit Industries called the Adafruit Feather. The key features of the Adafruit Feather are that it is low-power, it includes wireless connectivity and it is highly customizable via with the Arduino Development environment. The Feather's small-footprint is also optimal for building slim and compact cases that will be designed by students from TCNJ's School of Engineering and School of Science.

Each node will be paired with a Sharp Corporation LIDAR-Distance module that will be used when detecting traffic characteristics for a given parking lot. This module uses infrared lasers to provide the microcontroller with data to properly detect incoming and outgoing cars for a given parking lot. The LIDAR-Distance module, and the node itself, does not capture or send video, audio, or images of its surroundings during its operation. Once the node detects that there is activity in a given lot, the information is sent over a custom wireless network to an aggregator which will present that information to an end-user.

Node Detection Software

The Adafruit Feather hardware are Arduino compatible and will be programmed with the Arduino and RadioHead libraries. The algorithm used for detection and transmission will be written in Arduino C/C++ and then flashed to the microcontroller for use in its operation.

Each node will be in one of three different states during its operation: idle state, detection state and transmission state. The idle state is a custom hardware profile that will conserve the most power when waiting for a car to enter or exit a parking lot. When the node detects an incoming or outgoing car, the node will use its algorithm to properly detect that the object was actually a car. If the device detects that there was a change in a parking lot's occupancy, then the information is sent over a custom wireless network to an aggregator that will then serve the information about the state of a given parking lot to the end-user.

Detection Heuristics

The LIDAR-Distance sensor provides a way to detect incoming and outgoing traffic in a given parking lot. The sensor outputs analog values that correspond to the voltage yielded by the sensor when it is powered. The onboard microcontroller takes the analog input and converts it to a digital value via it's Analog to Digital converter. The detection algorithm monitors the digital values to detect a passing car. When nothing is in front of the sensor the voltage remains steady within a small range. A change in voltage outside of this range indicates an object in front of the sensor. When the microcontroller is first started, an average of the first few voltages provided by the sensor is determined to be the voltage outputted by the sensor when no object is in front of it. All subsequent values are compared to this to detect a spike in voltage large enough to indicate an object. In this way, calibration to the variations between individual sensors is done automatically so that differences between them have no effect on the detection of a car. The algorithm differentiates between a car and another object such as a person, by the amount of time the object is in front of the sensor. If a spike lasts long enough to for a car to drive past the sensor then the detection algorithm recognizes that a car has passed.

Front-End User Interface

TCNJ students, professors and staff will be able to view the availability of the different parking lots easily on their phones. A node.js server will receive from the aggregator messages sent by individual nodes whenever a car enters or exists a parking lot. Each node has a unique id to identify which parking lot the message originates from. A Postgres database will update in response to each message to keep track of the number of available spaces in each parking lot.

Parking lots will be displayed in order of most to least empty spots to allow people to quickly decide what parking lot to park in. After data has been collected about what parking lots have available spaces when, a machine learning module to predict where the user should plan to park later in the day can be created. This would allow people to check for parking availability before driving to the college so they are not checking their phones after arriving.

LoRa Network

The LoRa network for this project is designed to be a low-power and long range solution between the nodes and the aggregator. It is configured to support symmetrical upload and download speeds between the aggregator and the nodes at 1kbps. The speed of the network is intentionally slow to maximize the range of the network and to prevent network abuse through the TCNJ internet. The tested range of the network is approximately 500 meters (or a third of a mile) with nodes successfully sending and receiving signals from either end of campus. The network can support up to 1000 nodes and can be configured to be a mesh network or an infrastructural network.

LoRa Network Hub Hardware

On every single microcontroller there is wireless chip that will be used to communicate parking lot information back to an aggregator. The wireless chip is a Semtech SX1272 wireless transceiver that is configured to run on the open license free ISM 915 MHz spectrum space. This wireless chip uses a wireless standard called LoRa® which is a new long range wireless IoT standard made by Semtech. The wireless chip on each node will connect to a central aggregator which will take the payloads from each node and provide an interface to the developer.

The aggregator is made up of two pieces of hardware: a Raspberry Pi and a dedicated LoRa receiver microcontroller. The Raspberry Pi is model B+ v1.2 which includes: Broadcom BCM2835 CPU, 512 MB of RAM and 40 GPIO pins. The dedicated LoRa receiver is an Adafruit Feather microcontroller that is flashed to receive and send LoRa packets to and from the nodes.

LoRa Network Hub Software

Each node runs an infinite loop through the three different states stated in the **IoT Software Overview** section in the paper. In the transmission state, the microcontroller uses the RadioHead library to interface with the Semtech LoRa wireless chip through the microcontroller's SPI interface.

For the aggregator, the Raspberry Pi runs on the Raspbian OS Jessie Lite with nodeJS to act as the control program to route information between the nodes and the rest of the LoRa infrastructure. The aggregator's wireless chip is tuned for range and outputs at the maximum FCC allowed power for maximum network coverage.

Conclusion

This system's architecture relies on a number of low-power nodes connecting to a custom wireless network to aggregate and display the state of each parking lot for the end-user. Each module in this project is optimized for The College of New Jersey's parking infrastructure.

This project's aim is to provide students, faculty and staff with the ability to plan ahead and find available parking lot spaces on campus. With the amount of cars on campus on a given day, the architects and developers of this project strive to make TCNJ a better and more coordinated campus.