BusPlan

ECE 445 Project Proposal – Fall 2018

TA: Evan Widloski

Scott Liu — sliu125@illinois.edu

Connor Lake — crlake2@illinois.edu

Aashish Kapur — askapur2@illinois.edu

I. Introduction

i. Objective

Buses are a form of standard mass transit service and are usually dispatched at fixed frequencies [9]. For example, MTD deploys their buses roughly once every 10 minutes during school hours and once every 30 minutes otherwise [6]. However, during rush hours we have observed buses to be completely packed; while on other occasions we have also found buses to carry only very few passengers. This poor load-balancing results in inefficiencies at multiple stages: losing existing customers due to overwhelmingly full buses, deterring potential customers due to crowded first impressions, operating at extremely light loads, etc.

Herbert argued in his article within the context of urban bus transportation: "Fewer riders lead to less frequent service leads to fewer riders" [13]. Guihaire and Hao also speculate the car drivers might consider switching to public transport if we have a less crowded system [9]. It is therefore imperative that we develop a solution to address this commonplace issue.

Our team proposes the *BusPlan* project: a network of smart detectors that actively survey the amount of people waiting for a bus, gather information, and send this information to a central unit that performs aggregation and analysis. Ultimately, our BusPlan service would be able to find patterns, predict trends, and provide relevant visualizations back to the bus company, who will use this to make strategic business decisions.

ii. Background

Four stages of public transport operations have been identified by Ceder in his book *Public Transport Timetabling and Vehicle Scheduling* [3]:

1. Network route design
2. Setting timetables
3. Scheduling vehicles to trips
4. Assignment of bus crew

These steps together form a well established mode of public transport operation planning, and has already been adopted successfully worldwide. However, our team believes that the heart of the aforementioned problem lies within steps 2 and 3. The innovative network of devices that we propose would disrupt the traditional workflow, and greatly enhance the system's productivity and efficiency. By automatically detecting the amount of passengers waiting at a bug stop frequently and accurately, we would be able to obtain a sequence of numbers taken at successive equally spaced points in time. Furthermore, by analyzing and manipulating this time series data using modern tools, we would be able to achieve powerful forecasts that would replace timetables and scheduling completely. We believe that this would provide significant value to the bus company.

Many theories have already been proposed by experts to find an optimal way to form timetables or schedules [1] [10] [4] [8]. Some propose laying out optimal networks [5] while others focus on forming timetables after the fact [11] with real world case studies. They all offer incredible insight into formulating ideas to tackle this formidable challenge. However, most of them fall short when considering a truly dynamic environment that is subject to frequent change. Even theories that incorporate computer programs [16] [12] have been developed without this particular consideration. This is purely because they can only ever study past, outdated information as opposed to a stream of present, ever-changing information.

The buses that MTD use to provide service are already digitally augmented with STOPwatch technology [15]. It would be completely reasonable to add additional features to further enhance its efficiency. We also recognize the importance of a minimum bus service frequency [2] and will cater to delivering a model which takes this factor into account.

iii. High-Level Requirements

- Develop a module that displays the current number of people nearby on a seven-segment display
- Successfully collect an accurate measurement of number of people at bus stops
- Relay this data to a centralized server and use it to determine optimized bus dispatch schedules
- Use data to provide useful visualizations for bus companies

II. Design

Each detector has three main parts: a power supply, a control unit, and a WiFi module. The power supply ensures that the system is powered continuously. The WiFi module listens for probe beacons from nearby wifi stations (phones, laptops, etc). The radio chip connects and relays data from one node to surrounding nodes. The controller unit reads the data from the wifi chip and intelligently caches and sends it using the radio chip.

Figure 1 illustrates the high level design overview.

Figure 2 illustrates a more detailed, node-specific hardware architecture.

i. Power Supply

i.1 Solar Panel

Each detector will be powered using a solar panel, which will charge the battery and power the device. Bus service runs 7am to 2am the following day, however the load at the edge hours will be much less, so we may have the scanning frequency lower than normal, saving power. Worst case, the solar panel must provide enough power for 19 hours of use.

i.2 Li-Ion Charger

The charger takes power from the solar panel and converts it to the correct voltage/amperage for the battery. It makes sure to use constant current or constant voltages stages to charge the battery without charging it too fast.

i.3 Li-Ion Battery

The lithium-ion battery will act as a buffer to aid in power delivery from the solar panel. We do not expect to collect and store enough power to last the device through the night. Instead we will optimize the power usage and size of the battery through empirical power draw testing.

i.4 Voltage Regulator

This integrated circuit supplies the required 3.3V to the node system. This chip must be able to handle the peak input from the battery (4.2V) at the peak current draw (~300mA).

We define two strict requirements that must be met:

1. The voltage regulator must provide 3.3V $\pm$ 5% from a 3.7V to 4.2V source.

2. Must maintain thermal stability below 125° C at a peak current draw of 250mA.

ii. Control Unit

We would like to use esp8266 wifi chip to power the logic of the device as well. However since none of us have experience using this chip, we

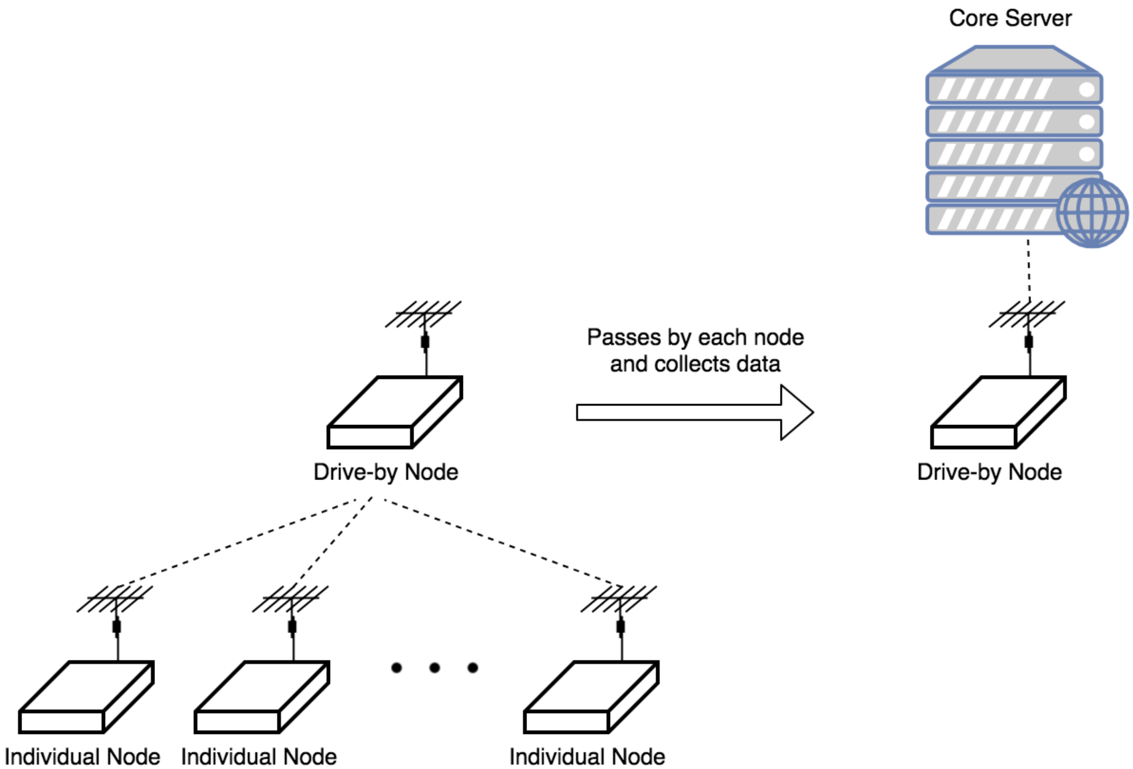

Figure 1: *High Level Overview*

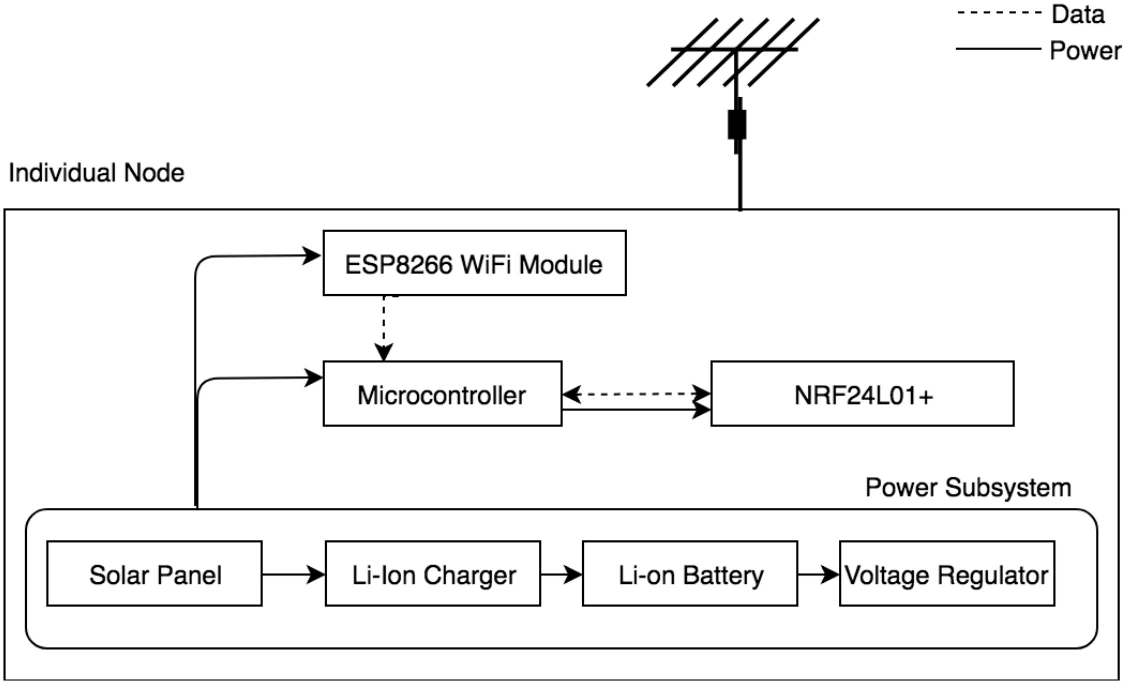

Figure 2: *Node Level Overview*

may have trouble connecting to and programming it to successfully perform our desired functionality. We may especially have trouble getting it to talk successfully with the NRF24L01. If this is the case we plan on using a much more familiar chip to us, the ATMega microcontroller as the core controller of our device. This is because it is generic enough to talk to both the esp8266 and the NRF14L01 in real time to manage and control the data.

iii. Visual Feedback

Our device would have several status LEDs to indicate the overall status of the device (e.g. if it has successfully been powered on). It would also have two 7 segment displays that shows the current number of nearby wifi devices.

iv. Data Storage

Our device needs to store temporary data before it is transmitted to our central server. The esp8266 has built in flash memory that we will use to store the detected MAC addresses and their timestamps before the NRF24L01 can connect to a nearby device and pass the data on.

v. Wifi Module

We plan on using the esp8266 chip. We picked it because it's low cost, robust, and a library already exists to sniff wifi probe requests which is exactly what we plan on doing.

vi. External Server

We will also be building an api to be hosted on a central server which will be in charge of getting the gathered and transmitted data from all the devices, performing the bus frequency optimization, and giving data visualizations.

vii. Data Analysis

Once we have all the data in JSON format it will be stored in a MongoDB or MySQL database. Using the database we will create an algorithm to find the most congested bus stops at different times of the day. We will also build graphs and visualizations, including tracking anonymous general customer behavior.

III. Safety and Ethics

i. Potential Hazards

The fact that our device will be sitting outside and be powered using batteries, there is a potential hazard of the battery shorting from rain and catching fire. Additionally if the build quality is not high enough and the charging circuit doesn't work right, it could overcharge the battery, also leading to fire. We must take both these scenarios into account making sure to waterproof our components and take care and precaution in the design and build of our battery circuitry.

ii. Data Privacy

Because we are collecting data from phones and associating it with unique identifiers, this gives us the ability to track the movement of these devices, and therefore most likely the owner of the device as well. This information can be used for inappropriate uses if it does not remain anonymous. Matching of someone's identity with their device would me we could track any given user as they use the bus system. We are therefore obligated to make sure no additional PII (personally identifiable information) is collected on these devices so as to ensure each unique identified remains detached from any person.

iii. Digital Security

Security is a big concern with the data we are collecting. We plan to use asynchronous cryptography to have a public key that will encrypt all data that is sent from each individual device. Theoretically anybody could pull the data, but it would be encrypted with a public key. The private key would be stored only on the central master server that will take the collected data, decrypt it, and store it.

In addition to the above, our team pledges to follow the IEEE Ethics guidelines [14] as well as the ACM Ethics guidelines [7] as closely as possible.

iv. Current Competition

https://www.accuware.com/products/locate-wifi-devices/

References

[1] Simon J. Berrebi, Kari E. Watkins, and Jorge A. Laval. A real-time bus dispatching policy to minimize passenger wait on a high frequency route. *Transportation Research Part B: Methodological*, 81:377 – 389, 2015. Optimization of Urban Transportation Service Networks.

[2] Larry A. Bowman and Mark A. Turnquist. Service frequency, schedule reliability and passenger wait times at transit stops. *Transportation Research Part A: General*, 15(6):465 – 471, 1981.

[3] Avishai Cede. *Public Transport Timetabling and Vehicle Scheduling*, chapter Chapter 2, pages 30–57.

[4] Avishai Ceder. Bus frequency determination using passenger count data. *Transportation Research Part A: General*, 18(5):439 – 453, 1984.

[5] Avishai Ceder and Nigel H.M. Wilson. Bus network design. *Transportation Research Part B: Methodological*, 1986.

[6] Champaign Urbana Mass Transit District. 1 yellow: Weekday - day. `https://mtd.org/maps-and-schedules/routes/1-yellow-weekday-day/`. Accessed: 2018-09-13.

[7] Association for Computing Machinery. Acm code of ethics and professional conduct. `https://www.acm.org/code-of-ethics`. Accessed: 2018-09-14.

[8] B. Gavish, P. Schweitzer, and E. Shlifer. Assigning buses to schedules in a metropolitan area. *Computers & Operations Research*, 5(2):129 – 138, 1978.

[9] Valerie Guihaire and Jin-Kao Hao. Transit network design and scheduling: A global review. *Transportation Research Part A: Policy and Practice*, 42(10):1251 – 1273, 2008.

[10] Jan Owen Jansson. A simple bus line model for optimisation of service frequency and bus size. *Journal of Transport Economics and Policy*, 14(1):53–80, 1980.

[11] W. Lampkin and P. D. Saalmans. The design of routes, service frequencies, and schedules for a municipal bus undertaking: A case study. *Journal of the Operational Research Society*, 18(4):375–397, 1967.

[12] Joao Mendes-Moreira, Luis Moreira-Matias, Joao Gama, and Jorge Freire de Sousa. Validating the coverage of bus schedules: A machine learning approach. *Information Sciences*, 2015.

[13] Herbert Mohring. Optimization and scale economies in urban bus transportation. *The American Economic Review*, 62(4):591–604, 1972.

[14] Institute of Electrical and Electronics Engineers. Ieee code of ethics. `https://www.ieee.org/about/corporate/governance/p7-8.html`. Accessed: 2018-09-14.

[15] University of Illinois Faculty and Services. University of illinois faculty and services: Transit. `http://www.fs.illinois.edu/services/more-services/tdm/transit`. Accessed: 2018-09-09.

[16] N. Seshagiri, R. Narasimhan, S. L. Mehndiratta, and B. K. Chanda. Computer generated time-tables and bus schedules for a large bus transport network. *Transportation Science*, 3(1):69–85, 1969.