Final Report

WaitLess Bus Tracking Device

ECE 4007 Senior Design Project

Section L04, Team WaitLess

Matthew Brooks
Chris Chidi
Josh Mauldin
Daniel Nadeau

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EXECUTIVE SUMMARY

The WaitLess bus tracking device is a standalone system designed to display the real-time location(s) of the buses on Georgia Tech's campus. The system consists of a solar panel and backup battery, wireless module, microprocessor, and a LED embedded map of the Georgia Tech bus transportation routes. Assembly of these components enables the tracking device to connect to the internet to obtain GPS data of the bus locations, which is depicted by activating LEDs in the approximate geographic positions of the buses on the route map. In addition, the device is portable and sustainable; it does not require an external power source, which eliminates long-term energy costs.

NextBus, the tracking company that Georgia Tech employs to retain the GPS location of the campus buses, currently provides a $3600 scrolling LED panel installed at several of the bus stops on campus. The display panel provides a rough text-based time estimate of the next arrival of a bus at the particular stop. In a recent survey, conducted by the design team, 96% of the survey correspondents expressed some dissatisfaction towards the current notification system.

The WaitLess bus tracking device will serve as a viable alternative notification system that will be more effective than the LED scrolling panel but for a quarter of the cost. A system prototype was designed and assembled for approximately $6,700.00, when accounting for labor and component costs. If, subsequently, 42 of these systems were produced to be installed at each of the bus stops on the Georgia Tech campus; each device could be individually sold for $784 dollars, resulting in a 33% profit margin.

1. INTRODUCTION

The WaitLess bus tracking device is a standalone system that displays the real-time location(s) of the buses on Georgia Tech's campus. This system, designed to be deployed at various bus stops around campus, is comprised of a solar power source, a battery, a microprocessor, LEDs, and a wireless internet link. The wireless internet link is used to poll a live XML feed from the NextBus server (via GTwireless) that contains GPS data of each bus's location. The data is then parsed by a microprocessor and used to illuminate tri-color LEDs representing each bus's location. This system assists pedestrians in making the decision of whether to wait for the bus or walk.

1.1 Objective

The transit company responsible for providing the GPS locations of the Georgia Tech buses is NextBus [1]. Currently, NextBus provides Georgia Tech with scrolling LED panels with text indications of estimated bus arrival times. The WaitLess bus tracking device is equipped with a LED embedded map of the Georgia Tech bus routes. This serves as an alternative pedestrian notification system that could be sold to the Georgia Tech transportation department, to be placed at any bus stop(s). The WaitLess bus tracking system is essentially a "set and forget" system that requires little or no maintenance. It is powered by a 12V battery which is recharged by a solar panel to eliminate energy costs. The system gathers its data via the GTwireless network using a wireless internet module. A microprocessor processes the data and in turn utilizes I^2C protocol to illuminate LEDs based on the GPS coordinates of buses.

1.2 Motivation

A student at the Georgia Institute of Technology often faces the decision of whether it would be quicker to wait for the next bus or to walk to his/her destination. Many students are often late to class because they decided to wait for the bus instead of just simply walking. The design team surveyed 30 Georgia Tech students about their opinions on the current bus transportation service notification system, and the following conclusions were extrapolated from the results:

- 75% of the population asserted that they had been late to their destination because they decided to wait for a bus instead of walking.
- 96% of the population affirmed that knowing the position of the buses on campus would be beneficial in deciding whether to walk or wait for the bus.
- 96% of the population also affirmed that knowing the location of the buses is more indicative of wait time than an approximate arrival time.
- The overall approval rate of the current transportation notification service was 38%.

If students had an easy way to see each bus's location, in real-time, they could make a more accurate, informed decision of whether or not to wait at a stop. The WaitLess system provides pedestrians with this convenience. Not only is the WaitLess system a new product for Georgia Tech, it improves the transportation service already provided, addressing the dissatisfaction with current wait times of the buses.

1.3 Background

Most real time arrival systems, currently in use, are either completely web based applications or only display estimated arrival times. For example, NextBus provides Georgia Tech with a LED scrolling panel that displays time estimates in minutes projecting the next bus arrival at a particular stop. These displays are often misleading since there is no clear indication of where the bus is actually located and whether there are potential delays. Moreover, the technologies used to digitally display arrival times are not standalone and typically require a local 120V AC source, which adds an extra expense due to energy costs.

GPS

The Global Positioning System (GPS), which NextBus utilizes to track the Georgia Tech buses, is a satellite-based navigation system made up of a network of 30 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use [2]. Companies like SageQuest offer fleet tracking services for other companies that rely on a fleet of vehicles. The location of the vehicles being tracked is acquired using GPS and the GPS data is relayed to SageQuest through cell phone networks. SageQuest can alert clients of fleet vehicles that are speeding, sitting idle, leaving a set boundary, or many other events [3].

2. PROJECT DESCRIPTION AND GOALS

The goals of the WaitLess bus tracking device were to provide a product that pedestrians on the Georgia Tech campus can use to help them decide whether to wait for the bus or walk. The sign, holding the solar panel and display, can be placed at bus sites around Georgia Tech campus. This is a product to sell to the Georgia Tech transportation department for use by campus pedestrians.

- Product Features
    - LEDs are placed along a map of Georgia Tech bus routes
    - LEDs light up certain colors to indicate the location of buses on all routes
    - The whole system is battery powered with a solar panel battery maintainer
    - The device is enclosed in a weather-proof case with a transparent plastic cover
    - The system uses a Wi-Fi module to connect to the internet and receive GPS data
- Goals

- Completely self-contained with easy installation, no external wires required
- Low power, less than 500 mA current draw
- Target cost of prototype parts, less than $424
- Target labor cost to produce prototype, $6300

3. TECHNICAL SPECIFICATIONS

The WaitLess bus tracking system employs various components, all working together to attain GPS information, process the data, and display the location via tri-colored LEDs. Table 3.1 outlines the components used to make the WaitLess system.

Table 3.1. Manufacturer and Model Number of Components Needed

Component	Manufacturer	Model	Quantity	Component Category
Arduino Duelmilanove/ ATmega328/V	Arduino/ Atmel	Duelmilanove USB/ ATmega328/V	1	Micro-processor
I^2C LED Controllers	Cat Semiconductor	CAT9552WI	7	LED operation
Red, Green, Blue LEDs	n/a	5mm RGB LEDs, Common Anode	42	LED operation
Serial to Wi-Fi Module	ConnectOne	Secure Socket iWiFi	1	Wireless Internet
Solar Panel	Silicon Solar, Inc.	12V Solar Battery Maintainer 5.5W	1	Power
Battery	CSB	GP1272F2	1	Power
Switching Voltage Regulator	Texas Instruments	PTN78020W	1	Power
Custom PCB	Gold Phoenix PCB	n/a	1	Sign/Mainboard
External Weather-Proof case	FiBox USA	n/a	1	Sign
Logic Level Shifter	Gravitech.us	Mr-Mini-Level-Shifter	1	Mainboard

To make the WaitLess bus tracking device completely self-contained, all of its power is delivered from a solar panel and battery.

- The system's solar panel can supply a maximum of 458mA at 12V [4].
- The backup battery will be able to supply 1A at 12V for 7.2 hours [5].
- Total power drawn from the system is on average .85 Watt, this helps to prevent the backup battery from unnecessarily discharging.
- A switching voltage regulator from Texas Instruments is used due to its high efficiency of approximately 96% [13].

Table 3.2 shows the power drawn from each component and the total expected power use.

Table 3.2. Typical Component Power Draw

Component	Quantity	Operating Voltage	Max Current (mA)	Typical Current (mA)	Min Current (mA)	Total Typical Power (mW)
ATmega328/V [6]	1	5	40	33	30	165
CAT9552 LED Controllers [7]	7	5	0.55	0.25	0.0021	8.75
5mm RGB LEDs Non-blinking [8]	15	5	25	2	2	150
ConnectOne Secure Socket iWiFi Module [9]	1	3.3	190	100	0.012	330
					Total Power (mW)	653.75

As desired, the total power drawn by the system is less than the solar panel provides; this is achieved largely by simply flashing the LEDs to save power consumption. With the lower power consumption, the smaller, relatively cheap solar panel and battery can be used. On average the total current draw of the system is about 170mA. This is far less than the 450mA the solar panel can provide.

In order to be capable of operating in an outdoor environment, the system's enclosure is waterproof and UV resistant.

- The system is able to operate in temperatures ranging from 10-100 ºF.

- A polycarbonate based enclosure is used to ensure that the enclosure is waterproof, UV resistant, and strong enough to maintain the weight of the solar panel and display.

- The exterior vinyl sticker will be placed inside the enclosure in further iterations of the product; currently it sticks on the outside, which is susceptible to the weather.

4. DESIGN APPROACH AND DETAILS

4.1 Design Approach

Design Overview

The functional block diagram depicted in Figure 4.1 illustrates the holistic assembly, highlighting how each component interacts with other parts and executes its functional role. Refer to Appendix C for the detailed system schematic, which shows exactly what connections are needed between all devices and modules.

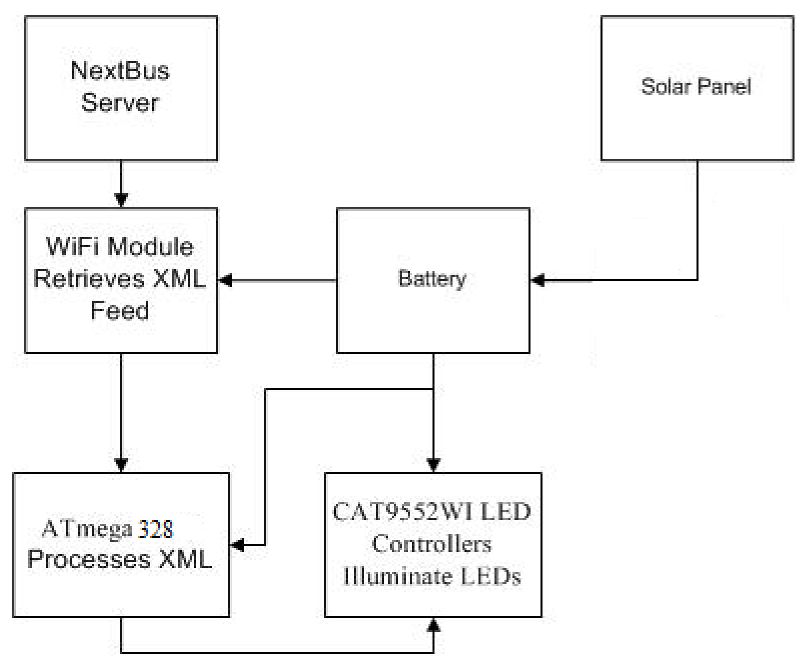

Figure 4.1. Functional block diagram of WaitLess system design.

The WaitLess bus tracking system incorporates the following components listed in Table 4.1 to achieve the stated features and goals of the project design.

Table 4.1. Components of the WaitLess Bus Tracking System and Associated Functions

Component	Function / Feature
Solar Panel	Converts light into electricity to simultaneously charge the battery supply and supply power to the tracking device. Contains a built in regulator to prevent excess charging of battery and maintain battery life.
Battery	Will serve as a backup power source for the tracking device when lighting is limited such as during nighttime.
Switching Regulator	Implements pulse width modulation to step down the voltage supplied to all load components from 12V to 5V.
Embedded Serial to Wi-Fi Module	Connects to the GT LAWN network and polls the NextBus.com server for XML feed of the GPS locations of the buses.
Processing Platform	Receive serial data from Wi-Fi module and implement programmable logic to activate LED drivers and lights.
RGB LEDs	5mm RBG LEDs will be used as the indicators on the map; these will have the capability of lighting any color to represent each bus route color.
LED Drivers	Receive commands from processing platform by means of I^2C and activate desired LEDs.
Logic Level Shifter	Provides the logic level translation from 3.3V to 5V logic levels so the ATmega328 processor can communicate via serial with the Wi-Fi module.
Decal Map	Map of the Stinger and Tech Trolley bus routes, behind which LEDs will be placed to indicate bus locations.
Case	To house all of the above equipment and show the bus route map with PCB mounted beneath it.

Each component listed in Table 4.1 can be categorized into the following functional roles: power supply, receiving data, processing data, and outputting or displaying data.

Power Supply

The power supply for the WaitLess bus tracking system is designed to be completely sustainable. The solar panel is capable of supplying enough current to power the device load while simultaneously charging the battery. Moreover, the solar panel possesses a blocking diode which prevents the panel from overcharging the battery, consequently maintaining the life of the battery. All components of the WaitLess bus tracking device require 5V of power to operate; therefore, the system design implements a switching voltage regulator to step down the supply voltage from 12V to the desired 5V.

Receiving Data

The initial phase of the tracking process involves requesting and receiving the GPS data from the NextBus server. The ConnectOne embedded serial to Wi-Fi module serves as the communication link between the WaitLess system and the internet. The Wi-Fi module is configured to execute a sequence of commands to login to GT LAWN and periodically poll the NextBus server for the GPS data. Consequently, the module receives XML data, which it transmits to the processor via a UART serial link. The TX serial line from the Arduino Processor is attached to a voltage divider, to bring down the voltage from 5V logic levels to 3.3V logic levels. The TX of the Wi-Fi module is connected to the logic level shifter, which translates the logic levels from 3.3V back up to 5V. This logic level conversion is needed since the processor is powered from 5V and the Wi-Fi module is powered from 3.3V. Refer to Appendix C for the system schematic that shows these connections in more detail.

Processing Data

The data processing unit of the WaitLess system consists of an Arduino development board equipped with an ATmega328 microprocessor to parse the XML data and implement custom programmable logic to interpret the data. The design team utilized the Wiring programming language, which is based on C/C++, to create the algorithms and instructions for processing the data. After data processing, the processor sends commands to the CAT9552 LED drivers by means of I^2C protocol.

Output and Display

Upon receiving an activation command from the processing platform, seven 16-channel LED drivers pull the desired LED's cathode to ground to illuminate the LED. In order to minimize power consumption, the LED drivers instruct LEDs to blink as fast as possible; reducing power consumption by 90%. For display purposes, the bus routes are illustrated on a map decal imposed on a transparent polycarbonate cover. Forty-two RGB LEDs, whose locations are indicated in Figure 4.2 with black circles, are positioned to represent bus stops and intermittent locations in-between bus stops.

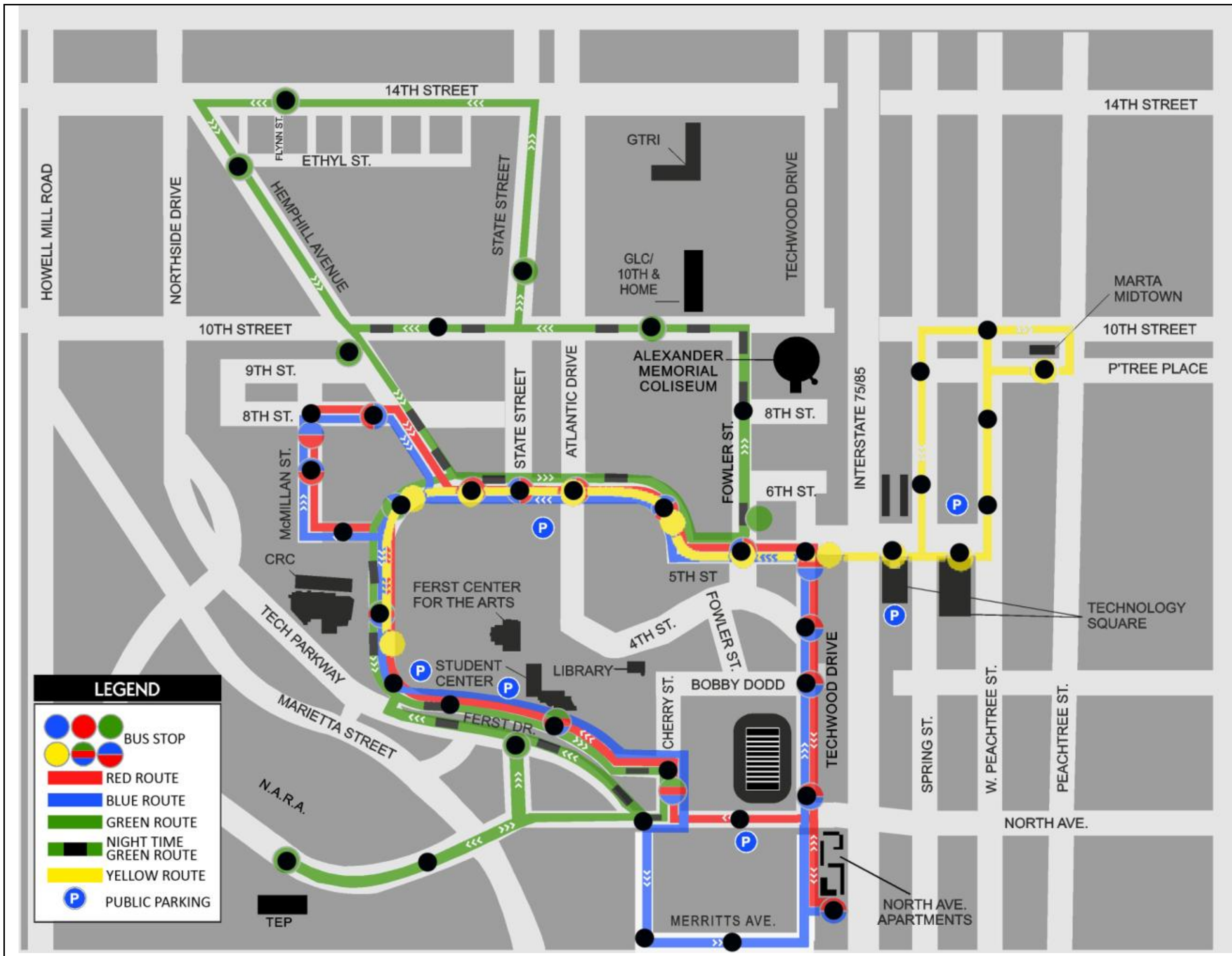

Figure 4.2. Map of Georgia Tech bus routes with indication of where LED lights will be located.

Final Product

The end product resembles the proposed design sketch illustrated in Figure 4.3.

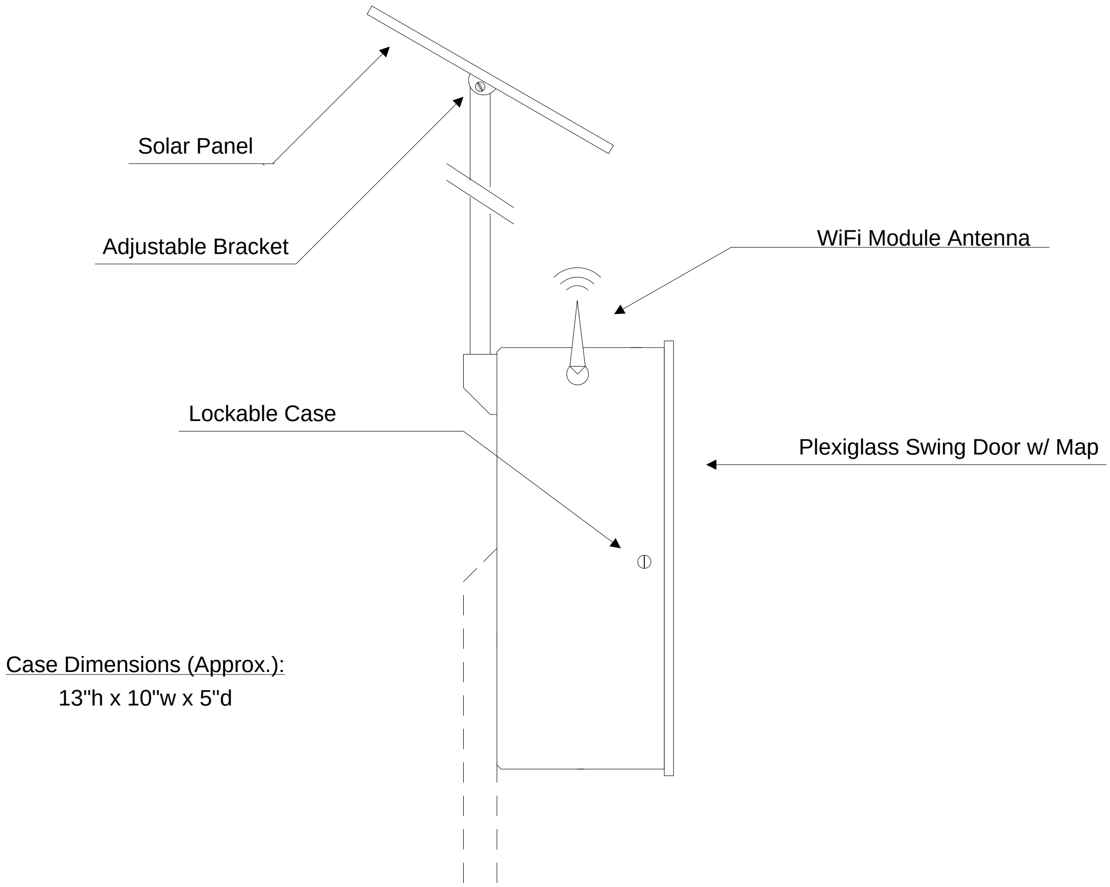

Figure 4.3. Final design sketch of WaitLess bus tracking system.

Some key features to note in Figure 4.3 are the portability of the product, a pole for solar panel mounting, and a weather resistant enclosure. The project website [15] contains numerous photographs of the finished prototype. The prototype closely follows the specifications from the proposed design sketch with the exception that the swing door is locked with screws located on the face of the cover.

4.2 Codes and Standards

There are several codes and standards that apply to the project design; however, these regulations and standards only serve as a reference to understanding how individual components of the design operate.

- IEEE 802.11b: Embedded Serial to Wi-Fi module
- XML: GPS data feed from NextBus
- UART Serial Protocol: Serial transfer between Wi-Fi module and microprocessor
- I^2C Protocol: Communication between microprocessor and LED controllers

4.3 Constraints, Alternatives, and Tradeoffs

Constraints

A significant aspect of the WaitLess bus tracking system is its sustainability. The device is designed to have a self-sufficient energy supply. For this design goal to be feasible, the device must follow the constraint of consuming less power than the solar panel provides. Table 3.2 highlighted the power supply and consumption rates of the WaitLess system; however, it is also essential to take into account external factors that may hinder the energy supplied. Prolonged periods of cloudy or rainy days, for instance, will reduce the amount of power produced by the solar panel, which will increase the burden on the battery. There is the potential that the solar panel will not produce enough current to simultaneously power the WaitLess system and charge the battery, which will cause the battery to eventually discharge completely. This can also be a problem if the bus stop is completely surrounded by trees or other large obstructions. Possible ways to address this issue are found in Table 4.2 below.

Alternatives

Table 4.2 depicts an analysis of the proposed design alternatives considered in the beginning, indicating the positives and negatives associated with each alternative.

Table 4.2. Pros and Cons of Design Alternatives

Alternative	Positives	Negatives
Dual battery supply	Extends the battery life of device.	Will add a cost for the second battery ($18) [5], and will also add weight to the overall design.
Single board computer (eBox®)	Increases processing ability of the device: simplifying XML parsing and allowing LCD output.	Will add an estimated cost difference of $200 versus the Arduino microprocessor [10]. Also requires more energy than the solar panel can provide, resulting in a need for hardwiring a power supply. This will also increase product installation costs and will generate a cost associated with energy consumption.
LCD Display	Would add to the aesthetic quality of the end product. Enables digital text and graphics.	Will add an estimated cost of $150-$200 versus current display design. Also requires a hardwired power supply which will generate an energy cost. Also, would have a higher risk of being stolen.
Remote solar panel mounting	Allows optimal solar power generation when trees and other obstructions are present.	Requires increased labor effort and cost for installation. Wire and cable must be drawn and secured.

The design alternative, which would address the aforementioned power failure issue, would be to install a second battery in parallel to the original. Two batteries would theoretically enable the WaitLess system to run solely on battery power for an estimated 100 hours or approximately six days of daylight operation. This extended battery life should be sufficient to allow the WaitLess bus tracking device to maintain functionality through sustained periods of inclement weather.

The design team considered using a single board computer as the processing platform for the project design. The proposed single board computer, known as an eBox®, runs the Windows CE operating system, requiring the design team to use C++/C# for programming the device. The eBox® has more features and capabilities than the Arduino microprocessor, and may simplify the wireless communication and XML parsing aspects of the project.

Another alternative to the project design would be to implement a LCD display instead of the map and LED combination. Employing an LCD display would enable text output and enhanced digital graphics, which would add aesthetic quality to the design. However, utilizing a LCD display would require a more robust processing platform and a high voltage power source.

To address the issue of having sunlight obstructions such as trees around a bus stop, a longer wire could be used to attach the solar panel high above the obstruction. This could be at the top of a tree, covered shelter, or on the side of a nearby structure such as the side of a building. This will allow the solar panel to attain sunlight while the unit itself is located at the bus stop below.

Tradeoffs

Despite the potential of enhancing the capabilities of the WaitLess bus tracking device by incorporating some of the proposed alternatives, there are significant tradeoffs encountered with these implementations which ultimately lead to an increase in cost. From Table 4.2, the design team concluded that implementing the single board computer or LCD display undermines the sustainable low power design goal. The eBox® computer has a current draw of about 2 Amps versus the .17 Amps the current implementation draws. There is a significant cost benefit of having sustainable power which adds to the marketability of the end product. Moreover, these components would require hardwiring to a 120V AC source because the solar panel is unable to provide enough power to support these devices. Furthermore, the need for hardwiring would negate the design's portability and increase installation costs since it would be necessary to draw cable to the desired mounting location. Conversely, the dual battery supply is a practical alternative; however, testing has proved that a second battery is not necessary as the system could operate from a single battery with moderate sunlight for ~50 hours continuously and still be able to charge up again.

5. SCHEDULE, TASKS, AND MILESTONE

Project success was fairly dependent on anteceding tasks being completed in time to begin working on subsequent tasks. This is because the data containing the GPS location information of the buses was needed before software could be written to parse it and light the correct LEDs. However, since we had so many problems with finding a Wi-Fi module that worked, we had to change the order in which we completed all our tasks. We used temporary test data structures to represent received XML feeds. This way we could complete all the logic and algorithms for the project while also trying to find a Wi-Fi module that worked reliably and was capable of connecting to GTwireless. Also, since some of the hardware-oriented tasks, such as building the pole/case, were able to be completed independently from the software tasks, overall project delay due to issues with the Wi-Fi module were minimal. The project required 14 weeks to finish; all tasks were completed on April 23rd, 2009. The Gantt chart in Appendix A outlines the planned start and finish dates, whether the task is software or hardware intensive, the estimated degree of difficulty, and the team member(s) which were responsible for the task.

6. PROJECT DEMONSTRATION

To demonstrate the successful completion of this project, a live demonstration as well as a recorded video was presented on April 24th, 2009. The working prototype consists of a weather-proof box with a display containing LEDs behind a transparent map of the bus routes; it is attached to a pole with a solar panel placed atop the pole. All group members highlighted various features of the display, as well as a quick synopsis of how various components work.

The live demonstration included:

- Showing the sign with the weather-proof box attached that houses the display and map, and showing the LEDs lighting up for the location of buses on all four bus routes.
- Demonstrating that the product is standalone and can run off solar power, battery, and wireless internet. There were no wires attached to the sign during the demonstration.
- Proved that the power consumption of the system is less than the power supplied from the solar panel. Power measurements made before the presentation showed the current draw of the WaitLess system to be ~170 -160 mA, which is well below the specification required for sustainability.

As a supplement for the live project demonstration, a pre-recorded video demonstration of the WaitLess prototype was shown, highlighting the following features and attributes:

- LEDs lighting up as a bus arrives at a bus stop on campus
- Ability of the display to operate at night time off of battery power
- Capability to operate in inclement weather conditions i.e. rain

7. MARKETING AND COST ANALYSIS

7.1 Marketing Analysis

As public mass transit becomes more of a necessity, so does the need of accurately informing passengers of arrival times and bus locations. Displaying only arrival times (as most current technologies do) can often be misleading since delays are not usually taken into consideration. However, showing exactly where each bus is in real-time will lead to a more accurate estimate of wait time and an informed decision can be made.

Attempts to relieve frustration about Georgia Tech bus service has been addressed but has not succeeded. Only a few bus stops on campus have been outfitted with scrolling LED signs with text-based predictions. The lack of time-based predictions accuracy and the fact that it has only been placed at a few of the many bus stops on campus is why this problem is still left to be addressed. The WaitLess bus tracking system will be most appealing to small campus sized bus systems where vandalism is low, wireless internet is available, and where pedestrians have the option to walk in addition to waiting for the bus. However, the WaitLess system, with some significant changes to the communication capabilities of the system, could also address needs in larger, city-wide transportation services.

7.2 Cost Analysis

The technology currently employed by NextBus, which includes scrolling LED signs, costs $3,600, according to a NextBus sales representative. Currently, these signs are only available at a small number of the bus stops on campus; most likely because of the high cost and the requirement that electricity be available at the bus stop. Moreover, this sign only shows text based predictions; it only lists the predicted arrival times in minutes. These predictions are inaccurate and only lead to more frustration. As shown in Table 7.1, the WaitLess bus tracking device prototype was designed and assembled for an approximate total cost of $6,700 when factoring labor, engineering, and parts cost for one prototype to be built. The equipment costs accumulated to $400.00 and labor costs were estimated to be $6,300.00 at $35/hour engineering time [11].

Table 7.1. Summary of Predicted Labor and Parts Cost to Produce Prototype

Component	**Labor Hours**	**Labor Cost**	**Equip Cost**	**Total Cost**
Arduino Duelmilanove/ ATmega328/V [6]	150	$5,250.00	$34.95	$5284.95
I^2C LED Controllers [7]	2	$70.00	$16.00	$86.00
Red, Green, Blue LEDs [8]	10	$350.00	$33.99	$383.99
Serial to Wi-Fi Module [9]	1	$35.00	$62.90	$97.90
Solar Panel [4]	1	$35.00	$49.95	$84.95
Battery [5]	1	$35	$18.21	$53.21
Switching Voltage Regulator [13]	2	$70.00	$22.00	$92.00
Custom PCB [14]	10	$350.00	$100.00	$450.00
Weather-Proof case [16]	3	$105.00	$50.00	$155.00
Logic Level Shifter [12]	1	$0	$12.00	$12.00
TOTAL LABOR	180	$6,300		
TOTAL PARTS			$400.00	
PROJECT TOTAL				**$6,700.00**

Since the WaitLess bus tracking system is designed to be easily deployed at almost all bus stops on campus, the maximum number of units the Georgia Tech campus would need is 42 units. If this many units were ordered, the price per unit in order to break even would be $588. This would cover the cost of parts, cost of development, and cost of manufacturing 42 units. The approximate manufacturing labor cost to produce 42 units is $1600 based on $10/hour unskilled assembly labor at 4 hours per unit [11]. Taking into account all these costs, each WaitLess device could be sold for $784 each for a 33% profit over total parts, engineering development, and manufacturing costs; this is 78% cheaper than the current scrolling LED solution offered by NextBus, while being much more effective and sustainable. Furthermore, the WaitLess bus tracking system will not incur any energy cost since it is solar powered.

8. SUMMARY AND CONCLUSIONS

Currently, the project prototype has been completed, tested, and verified. The system is fully operational with the capability of tracking all buses on the four bus routes of the Georgia Tech campus. The whole system operates at around 170 mA of current draw which is well below the charge current of approximately 450 mA provided by the solar panel. Therefore, the system should be able to operate continuously through the life of the battery. Moreover, the system was able to operate in outdoor conditions including heavy rain and at night.

However, several modifications could be made to enhance the functionality of the product. The project design team has contemplated the following enhancements and modifications to implement in future design alterations:

- Reduce the depth and increase the durability of the display case by using a metal case
  - Implement a smaller, more efficient battery
  - Solder all electronic components to one PCB design
  - Investigate and potentially implement discrete surface mount LEDs
- Place the vinyl decal map inside of the transparent casing to preserve it from outside elements
- Implement WPA wireless internet security for easier module connectivity
- Mount 4 individual surface mount LEDs near each bus stop hole. Each LED would only light up one color for each route, so the user can tell when multiple buses are at the same stop
- Add an LED array panel below the map display to output text-based arrival time estimations for each stop
- Utilize RGB LEDs that properly output yellow light to increase the visibility of the Tech Trolley indication on the WaitLess display. Currently, green and red both light up to attempt making a yellow color. However, the green LED overpowers the red LED and the combined color ends up looking only green.

- Reduce the resistor value across the green lead for the LED light to reduce the brightness of the green light in order to mix properly with the red to make yellow

In summation, the completed prototype meets all the design goals and specifications established during the design phase of the project. During the project demonstration, the design team proved the functionality of the product as well as its sustainability and wireless connectivity. Nevertheless, the enhancements aforementioned above will be considered and implemented before the product is ready for trials and/or production.

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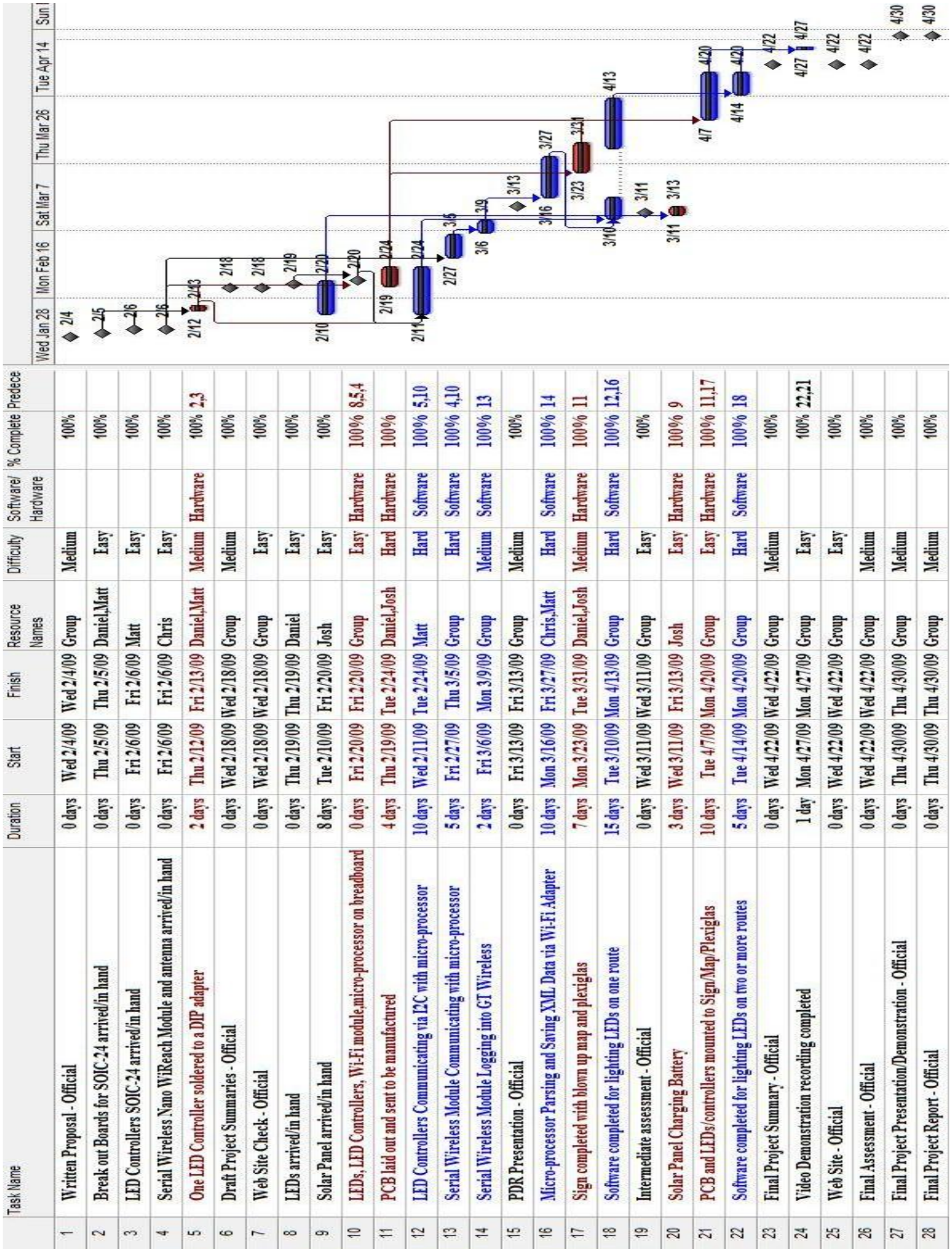
APPENDIX A – PROJECT GANTT CHART



	Task Name	Duration	Start	Finish	Resource Names	Difficulty	Software/ Hardware	% Complete	Predece
1	Written Proposal - Official	0 days	Wed 2/4/09	Wed 2/4/09	Group	Medium		100%	
2	Break out Boards for SOIC-24 arrived/in hand	0 days	Thu 2/5/09	Thu 2/5/09	Daniel,Matt	Easy		100%	
3	LED Controllers SOIC-24 arrived/in hand	0 days	Fri 2/6/09	Fri 2/6/09	Matt	Easy		100%	
4	Serial Wireless Nano WiReach Module and antenna arrived/in hand	0 days	Fri 2/6/09	Fri 2/6/09	Chris	Easy		100%	
5	One LED Controller soldered to a DIP adapter	2 days	Thu 2/12/09	Fri 2/13/09	Daniel,Matt	Medium	Hardware	100%	2,3
6	Draft Project Summaries - Official	0 days	Wed 2/18/09	Wed 2/18/09	Group	Medium		100%	
7	Web Site Check - Official	0 days	Wed 2/18/09	Wed 2/18/09	Group	Easy		100%	
8	LEDs arrived/in hand	0 days	Thu 2/19/09	Thu 2/19/09	Daniel	Easy		100%	
9	Solar Panel arrived/in hand	8 days	Tue 2/10/09	Fri 2/20/09	Josh	Easy		100%	
10	LEDs, LED Controllers, Wi-Fi module,micro-processor on breadboard	0 days	Fri 2/20/09	Fri 2/20/09	Group	Easy	Hardware	100%	8,5,4
11	PCB laid out and sent to be manufactured	4 days	Thu 2/19/09	Tue 2/24/09	Daniel,Josh	Hard	Hardware	100%	
12	LED Controllers Communicating via I2C with micro-processor	10 days	Wed 2/11/09	Tue 2/24/09	Matt	Hard	Software	100%	5,10
13	Serial Wireless Module Communicating with micro-processor	5 days	Fri 2/27/09	Thu 3/5/09	Group	Hard	Software	100%	4,10
14	Serial Wireless Module Logging into GT Wireless	2 days	Fri 3/6/09	Mon 3/9/09	Group	Medium	Software	100%	13
15	PDR Presentation - Official	0 days	Fri 3/13/09	Fri 3/13/09	Group	Medium		100%	
16	Micro-processor Parsing and Saving XML Data via Wi-Fi Adapter	10 days	Mon 3/16/09	Fri 3/27/09	Chris,Matt	Hard	Software	100%	14
17	Sign completed with blown up map and plexiglas	7 days	Mon 3/23/09	Tue 3/31/09	Daniel,Josh	Medium	Hardware	100%	11
18	Software completed for lighting LEDs on one route	15 days	Tue 3/10/09	Mon 4/13/09	Group	Hard	Software	100%	12,16
19	Intermediate assessment - Official	0 days	Wed 3/11/09	Wed 3/11/09	Group	Easy		100%	
20	Solar Panel Charging Battery	3 days	Wed 3/11/09	Fri 3/13/09	Josh	Easy	Hardware	100%	9
21	PCB and LEDs/controllers mounted to Sign/Map/Plexiglas	10 days	Tue 4/7/09	Mon 4/20/09	Group	Easy	Hardware	100%	11,17
22	Software completed for lighting LEDs on two or more routes	5 days	Tue 4/14/09	Mon 4/20/09	Group	Hard	Software	100%	18
23	Final Project Summary - Official	0 days	Wed 4/22/09	Wed 4/22/09	Group	Medium		100%	
24	Video Demonstration recording completed	1 day	Mon 4/27/09	Mon 4/27/09	Group	Easy		100%	22,21
25	Web Site - Official	0 days	Wed 4/22/09	Wed 4/22/09	Group	Easy		100%	
26	Final Assessment - Official	0 days	Wed 4/22/09	Wed 4/22/09	Group	Medium		100%	
27	Final Project Presentation/Demonstration - Official	0 days	Thu 4/30/09	Thu 4/30/09	Group	Medium		100%	
28	Final Project Report - Official	0 days	Thu 4/30/09	Thu 4/30/09	Group	Medium		100%	

APPENDIX B – WAITLESS GT TRANSPORTATION SURVEY

1. How often do you use the bus system?
   - Every day
   - Few times a week
   - Few times a month
   - Never

2. What is your average wait time? _______________

3. How pleased are you with the consistency of arrival times?

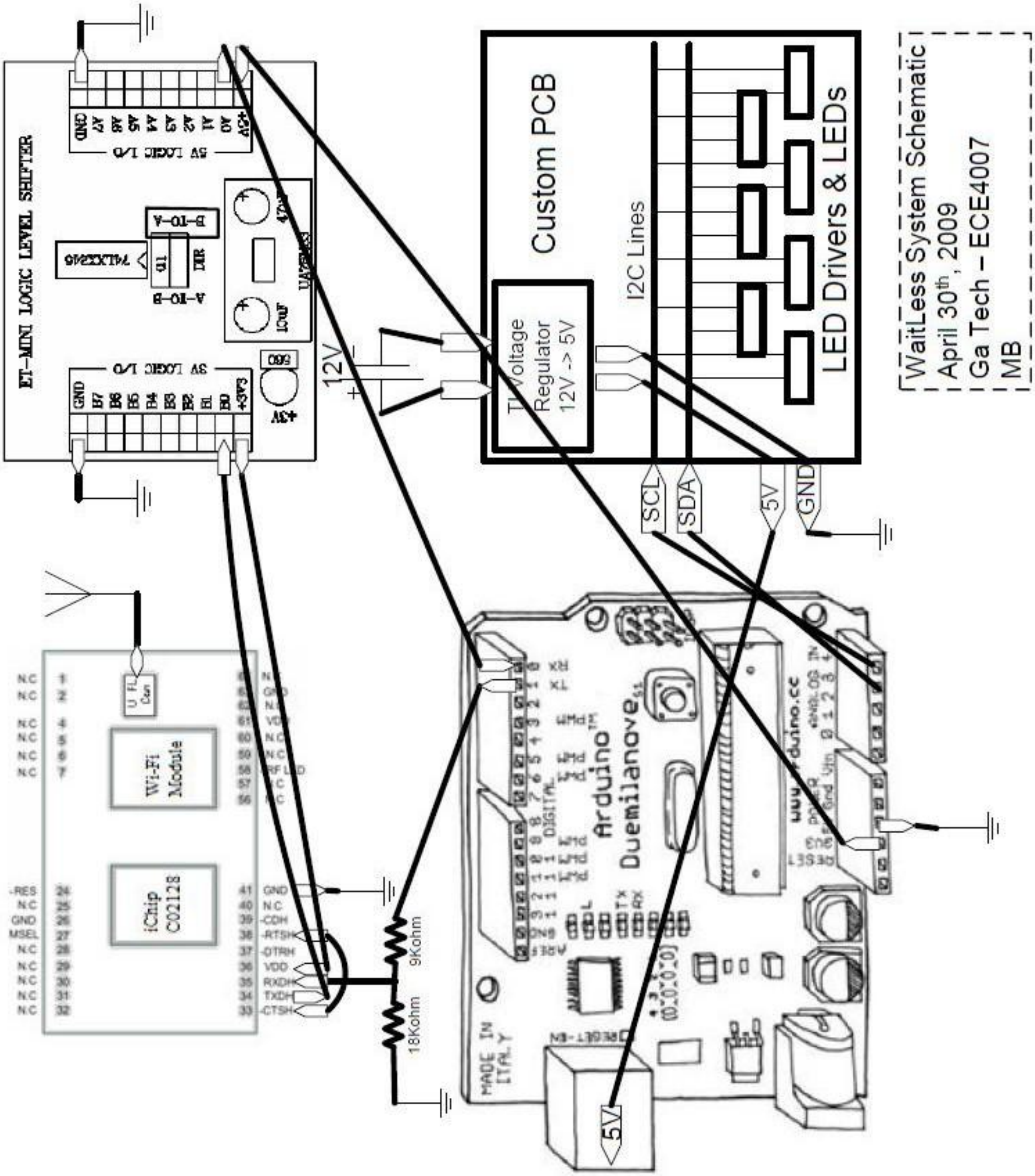
   Not Pleased __ __ __ __ __ __ __ __ Very Pleased

4. Have you ever been late to your destination because you waited for a bus instead of walking?
   - Yes
   - No

5. Would knowing the position of buses on campus be beneficial in deciding whether to walk or wait for the bus?
   - Yes
   - No

6. Would knowing the position of buses on campus be more beneficial in deciding whether to walk or wait for the bus than knowing just the predicted arrival time?
   - Yes
   - No

APPENDIX C – WAITLESS SYSTEM LEVEL SCHEMATIC



APPENDIX D – WAITLESS PCB SCHEMATIC