Proposal

WaitLess Bus Tracking Device

ECE 4007 Senior Design Project

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Submitted

February 4, 2009

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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 will consist of a solar panel and backup battery, wireless module, PSoC microprocessor, and a LED embedded map of the Georgia Tech bus transportation routes. Assembly of these components will enable the tracking device to connect to the internet to obtain GPS data of the bus locations, which it will depict by activating LEDs in the approximate geographic positions of the buses on the route map. In addition, the device will be portable and sustainable; it will not require an external power source, which will eliminate 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 three 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, 75% of the survey correspondents attributed that waiting for the bus has often caused them to be late to a destination. Furthermore, 96% affirmed that if they had an easy way to see each bus's actual location, in real-time, they could make a more accurate, informed decision of whether or not to wait.

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 can be designed and assembled for approximately $6,724.10, when accounting for labor and component costs. If, subsequently, 40 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 $933 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 will be used to poll a live XML feed from the NextBus server (via GTwireless) that contains GPS data of each bus's location. The data will then be parsed by a microprocessor and used to illuminate tri-color LEDs that will represent each bus's location. This system will assist 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 will be equipped with a LED embedded map of the Georgia Tech bus routes. This will serve as an alternative pedestrian notification system that NextBus could sell to the Georgia Tech transportation department, to be placed at each of the 40 bus stops. The bus tracking system will essentially be a "set and forget" system that requires little or no maintenance. It will be powered by a 12V battery which will be recharged by a solar panel to eliminate energy costs. The system will gather its data via the GTwireless network using a wireless internet module. A microprocessor will process the data and in turn utilize 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 decide 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, 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 will provide pedestrians with this convenience. Not only would the WaitLess system be a new product for Georgia Tech, it would also be an improvement to 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 textual time estimates 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 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 goal of the WaitLess bus tracking device is 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 display will be on a sign which can be placed at bus sites around Georgia Tech campus. This would be a product for NextBus to sell to the Georgia Tech transportation department for use by campus pedestrians.

- Product Features
    - LEDs will be placed along a map of Georgia Tech bus routes
    - LEDs will light up to indicate the location of buses on two routes
    - The whole system will be solar powered with a backup battery

- The device will be enclosed in a standalone weather-proof case with Plexiglas cover
- The system will use Wi-Fi internet to receive GPS locations

- 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 device will employ many different 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 needed to make the WaitLess system.

Table 3.1. Manufacture and Model Number of Components Needed

Component	Manufacture	Model	Quantity	Component Category
Arduino NG/ ATmega168/V	Arduino/ Atmel	NG USB/ ATmega168/V	1	Micro-processor
I^2C LED Controllers	Cat Semiconductor	CAT9552WI	8	LED operation
Red, Green, Blue LEDs	n/a	5mm RGB LEDs, Common Anode	42	LED operation
Serial to Wi-Fi Module	Roving Networks	Wi-Fly™ RN-111B	1	Wireless Internet
Solar Panel	Silicon Solar, Inc.	12V Solar Battery Maintainer 5.5W	1	Power
Battery	CSB	GP1272F2	1	Power
Solar Controller	SunGuard	SG-4	1	Power
Switching Voltage Regulator	Texas Instruments	PTN78020W	1	Power
Custom PCB	Gold Phoenix PCB	n/a	1	Sign/Mainboard
External Weather-Proof case	TBD	n/a	1	Sign

To make the WaitLess bus tracking device completely self-contained, all of its power will need to be delivered via a solar panel and battery.

- The system's solar panel will 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 must be less than 5.5W to prevent the backup battery from unnecessarily discharging.
- A switching voltage regulator from Texas Instruments will be 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)**	**Typ Current (mA)**	**Min Current (mA)**	**Typ Power (mW)**
ATmega168/V [6]	1	5	0.25	0.25	0.0001	1.25
CAT9552 LED Controllers [7]	8	5	0.55	0.25	0.0021	10
5mm RGB LEDs Non-blinking [8]	15	5	25	20		1500
Roving Networks RN-111B Wi-Fly Module [9]	1	5	120	40	0.012	200
					Total Power (mW)	1711.25

As desired, the total power drawn by the system will be less than the solar panel provides; however, power saving techniques such as putting components to sleep and flashing the LEDs will be used to further lower the power consumption. With lower power consumption, a smaller, cheaper solar panel and battery will be feasible.

The bus tracking system must be able to operate in an outdoor environment. Consequently, the system's enclosure will be waterproof and UV resistant.

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

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

- Weather resistant grommets will be used around all exterior holes to prevent water from leaking inside the case.

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.

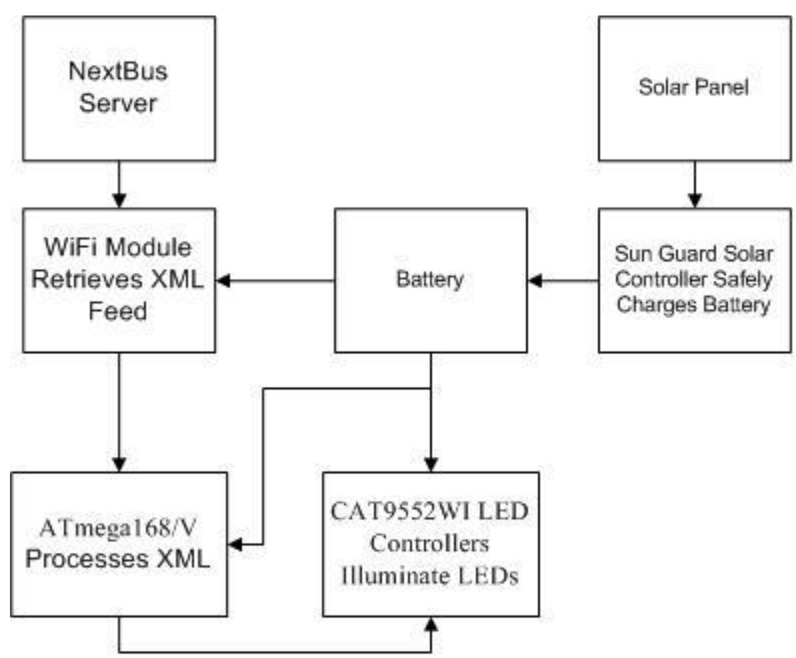

Figure 4.1. Functional block diagram of WaitLess system design.

The WaitLess bus tracking device will incorporate 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 Device 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.
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.
Solar Controller / Regulator	Coordinates the distribution of charge current from the solar panel to the tracking device or battery and also bleeds off excess current to prevent overcharging the battery.
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.
Decal Map	Map of the Stinger and Tech Trolley bus routes, behind which LEDs will be placed to indicate bus locations.

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 device 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. A solar controller will regulate the supply current from the solar panel and direct adequate power to the tracking device and battery. The solar controller will also dissipate any excess charge current to prevent the battery from overcharging, which will extend the life of the battery. The core components of the WaitLess bus tracking device require 5V of power to operate; therefore, the system design implements a switching 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 RN-111B embedded serial to Wi-Fi module will serve as the communication link between the WaitLess system and the internet. The Wi-Fi module will be 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 will receive XML data, which it will transmit to the processing platform using a UART serial link.

Processing Data

The data processing unit of the WaitLess system will tentatively consist of an Arduino board equipped with an ATmega168 microprocessor to parse the XML data and implement custom programmable logic to interpret the data. The design team will utilize the Wiring programming language, which is based on C/C++, to create the algorithms and instructions for processing the data. After data processing, the processing platform will send commands to the 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 will pull the desired LEDs cathode to ground to illuminate the LED. In order to minimize power consumption, the LED drivers will only instruct LEDs to blink; this will reduce power consumption by 50%. For display purposes, the bus routes will be illustrated on a map decal imposed on Plexiglas®. Forty-two RGB LEDs, whose locations are indicated in Figure 4.2

with black circles, will be positioned to represent bus stops and intermittent locations in-between bus stops.

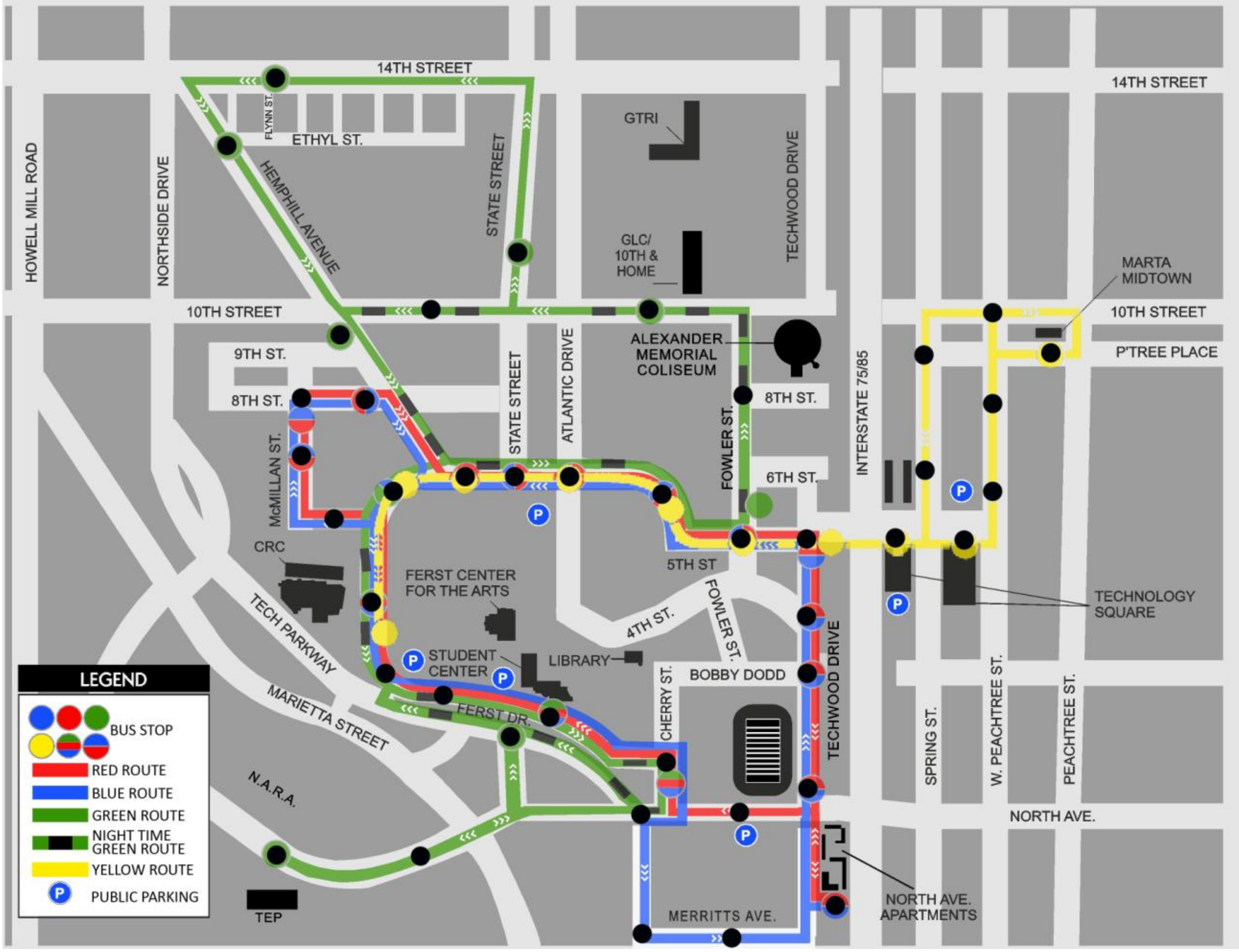

Figure 4.2. Map of Georgia Tech bus routes with indication of where LED lights will be located.

Final Product

The end product will resemble the design sketch illustrated in Figure 4.3.

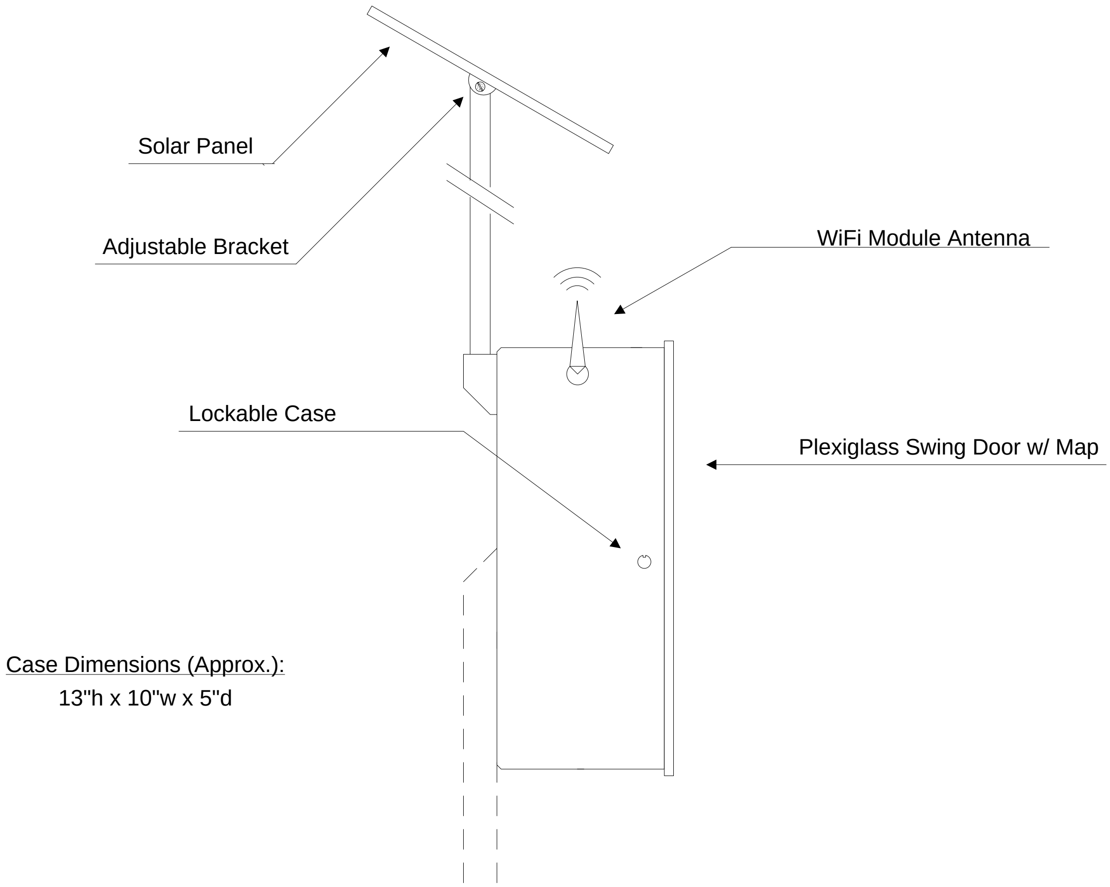

Figure 4.3. Final design sketch of WaitLess bus tracking device.

Some key features to note in Figure 4.3 are the portability of the product, a retractable pole for solar panel mounting, and a weather resistant enclosure.

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 device 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. Section 3 highlights 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 supply. 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.

Alternatives

Table 4.2 depicts an analysis of the proposed design alternatives, 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 ($20) [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	Adds to the aesthetic quality of the end product. Enables digital text and graphics.	Will add an estimated cost difference of $100-$150 versus current display design. Also requires a hardwired power supply which will generate an energy cost.
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 68 hours or approximately three days. 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, 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 concludes that implementing the single board computer or LCD display undermines the sustainable low power design goal. 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 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 that may be considered if testing proves that a single battery is insufficient.

5. SCHEDULE, TASKS, AND MILESTONE

Project success is fairly dependent on previous tasks being completed in time to begin working on subsequent tasks. This is because the data containing the GPS location information of the busses is needed before software can be written to parse it and light the correct LEDs. However, some of the hardware-oriented tasks can be completed independently from the software tasks. All tasks, if possible, will be completed on or before April 20th, 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) responsible for the task.

6. PROJECT DEMONSTRATION

To demonstrate the successful completion of this project, a live demonstration as well as a recorded video will be presented on April 30th, 2009. The working prototype, consisting of a weather-proof box with a display containing LEDs positioned behind clear Plexiglas®, will be attached to a pole with a solar panel placed atop the display. All group members will point out various features of the display, as well as a quick synopsis of how various components work.

The live demonstration will include:

- 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 at least two bus routes.
- Demonstrating that product is standalone and can run off solar power, battery, and wireless internet. There will be no wires attached to the sign during the demonstration.
- Proving that the power consumption of the system is less than the power supplied from the solar panel. Appropriate power measurements will be made beforehand and shown during the presentation.

Since a demonstration in the class room makes it impossible to see the accuracy of a real bus arriving at a bus stop, a pre-recorded video will also be shown to the audience.

The recorded video demonstration will include:

- A demonstration of the LEDs lighting up as a bus arrives at a bus stop on campus.
- This will also demonstrate the ability of the display to operate at night time off the battery.
- The video will also serve as proof of operation if NextBus's GPS signals or GT Wireless is not operating on the day of the demonstration.

If the project is unfeasible using a low-power micro-processor, because of time constraints or other unexpected difficulties, then an eBox® 2300 will be used to show a prototype proof of concept. The eBox® 2300 is more powerful, but requires a constant 2 Amps at 5 Volts [10], and consequently might have to be plugged into the wall to operate. Using the eBox® 2300 in the demonstration is the backup plan because it would not be able to operate continually off a solar panel and battery, which the design team hopes to accomplish.

7. MARKETING AND COST ANALYSIS

7.1 <u>Marketing Analysis</u>

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.

Attempts to relieve frustration about Georgia Tech bus service has been addressed but has not succeeded. Only three bus stops have been outfitted with scrolling LED signs with text-based predictions. The lack of text based accuracy and the fact that it has only been placed at 3 of the 40 bus stops on campus is why this problem is still left to be addressed. The WaitLess bus tracking device 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 device, 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 three 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 will be designed and assembled for an approximate total cost of $6,724.10. This includes equipment costs of $424.10 and labor costs of $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 NG/ ATmega168/V	150	$5,250.00	$34.95 [6]	$5284.95
I^2C LED Controllers	2	$70.00	$16.00 [7]	$86.00
Red, Green, Blue LEDs	10	$350.00	$33.99 [8]	$383.99
Serial to Wi-Fi Module	1	$35.00	$70.00 [9]	$105.00
Solar Panel	1	$35.00	$49.95 [4]	$84.95
Battery	0.5	$17.50	$18.21 [5]	$35.71
Solar Controller	0.5	$17.50	$29.00 [12]	$46.50
Switching Voltage Regulator	2	$70.00	$22.00 [13]	$92.00
Custom PCB	10	$350.00	$100.00 [14]	$450.00
External Weather-Proof case	3	$105.00	$50.00	$155.00
TOTAL LABOR	180	$6,300		
TOTAL PARTS			$424.10	
PROJECT TOTAL				**$6,724.10**

Since the WaitLess bus tracking device 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 40 units. If this many units were ordered, the price per unit in order to break even would be $622. This would cover the cost of parts, cost of development, and cost of manufacturing. The approximate manufacturing labor cost to produce 40 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 $933 each for a 33% profit over total parts, development, and manufacturing costs; this is 75% cheaper than the current scrolling LED solution offered by NextBus, while being much more effective and sustainable. Furthermore, the WaitLess tracking device will not incur any energy cost since it is solar powered.

8. SUMMARY

Currently all parts except the custom PCB and weather proof case have been ordered. Since those two parts are not needed until the end of the project, this is acceptable. Assuming funding for the prototype will be met and there are no shipping delays, all parts needed to begin programming for the project should arrive no later than mid February. The custom PCB layout is currently being designed so that it can be sent for manufacturing as soon as possible. In addition, the design team is configuring the Wi-Fi internet serial module to work with the eBox® processing platform. Once functionality is observed and characterized, the design team will begin programming the ATmega168 microprocessor found on the Arduino board.

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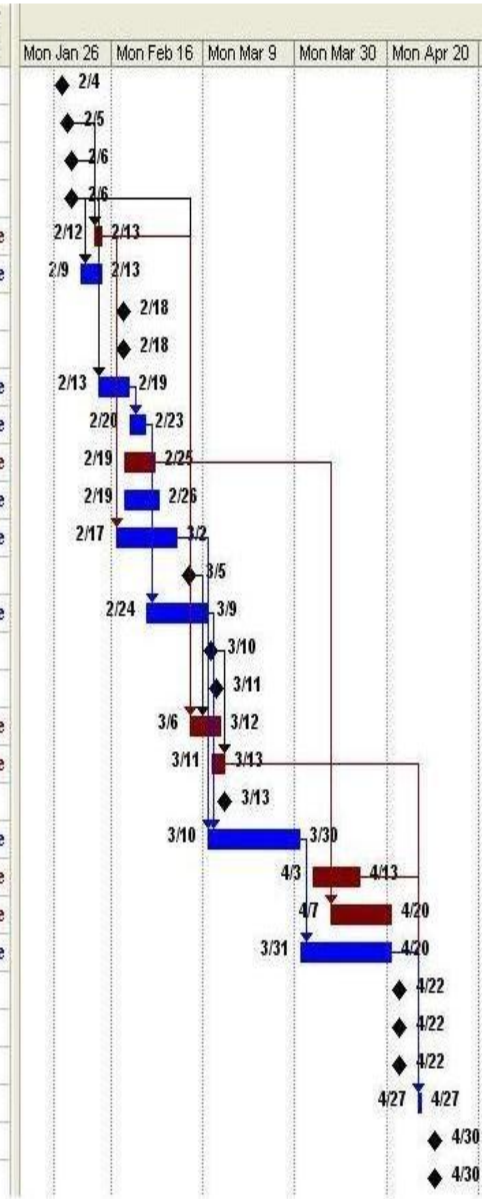
APPENDIX A – PROJECT GANTT CHART

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



APPENDIX B – WAITLESS GT TRANSPORTATION SURVEY

1. How often do you use the bus system?
    - o Every day
    - o Few times a week
    - o Few times a month
    - o 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?
    - o Yes
    - o No

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