Design a Smart Bus System

ELEC 399 Final Project Report

Project Website: http://www.ece.uvic.ca/~bhung/399/index.html

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Group No. **6**

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Glossary

APC	Automatic Passenger Counting
API	Application programming interface
GPRS	General Packet Radio Service
GPS	Global Positioning System
GTFS	General Transit Feed Specification
LCD	Liquid crystal display
LED	Light-emitting diode
RF	Radio frequency
SBS	Smart Bus System
VGA	Video Graphics Array
VRTS	Victoria Regional Transit System

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Chapter 1. Goal

The project goal is to explore ideas of integrating the Victoria Regional Transit System with appropriate communication technologies and to develop a corresponding Smartphone app. In a SBS, users can access real-time passenger information such as schedules, trip planners, bus capacity estimates, bike rack availability and bus stop locations, via Smartphone, on computers and at bus stops. This system would be inclusive to all users including people with special needs.

The project objectives include

a. To explore wireless technologies to connect buses, bus stops and users;

b. To propose buses and bus stop infrastructure to support the desired functionalities;

c. To develop user-friendly interfaces for accessing real-time transit data;

d. To assist people with special needs in travelling independently by public transit systems.

Chapter 2. Project Overview

The "Connec4" - Smart Bus System project is initiated by four undergraduates from the Department of Electrical and Computer Engineering at the University of Victoria (UVic) in May 2012, in response to course ELEC 399 Design Project I at UVic.

Victoria Regional Transit System coordinates the delivery of public transportation throughout Victoria. The current transit system in Victoria has not kept pace with more modernized systems where real-time transit scheduling and traffic data are accessible to the general public. It is not rare to encounter frustrations when buses are not arriving on pre-made schedules due to real-time uncertainties. On the other hand, emerging personal communication and computing technologies, such as Smartphone, are fast growing popularity worldwide with hundreds of millions users. To resolve the imbalance between the current system and the ever-evolving technology, it is innovative to enable effective communication among the transit control center, buses, bus stops, and passengers.

The Smart Bus System (SBS) is a system which applies available communication technologies (e.g. GPS,) to connect transit authority and passengers. It provides the public with an easy and comfortable way of travelling. Especially in Victoria, a city that hosts a large non-local student population who highly rely on the public transit, the availability of real-time transit data would be largely beneficial. For example, an accurate real-time scheduling would reduce students' tardiness, allow better time management, and offer easy navigation around the city.

Besides students, Victoria has an aging population. In the years to come, Victoria will experience an influx in transitions from cars to public transit. Due to the uncertainty and unreliability of the static schedules and the lack of information on bus routes, people tend to feel intimidated to the bus alternative and more likely prolong car use which gives more freedom. By making real-time transit data available and maintaining a high level of accuracy, the discouragement could be removed. People should feel the bus system is catered to their personal schedules despite being held to the bus schedules.

Besides students and senior citizens, an inclusive transit system would provide accessible and comfortable rider experience to people with special needs. For example, a Smartphone app with vibrating functions could be developed to alert people with visual impairment. Also, the availability of wheel-chair space could be accessed on computer, at bus stop, or via phone. Advancements like these and others will make it easier to use public transit and provide individual freedom.

Therefore, using our motivations, the project goal and objectives were developed. Their details became the basis for the project proposal. The proposal introduces a preliminary design of a Smart Bus System featuring desired functionalities, supporting technologies and infrastructures. A successful implementation of the system will provide the public with an easy and reliable way of travelling and greatly encourage the use of public transit.

Chapter 3. Detailed Project Description

3.1 Project Description

The Smart Bus System (SBS) project is initiated in response to course ELEC 399 Design Project I at the University of Victoria (UVic) in May 2012. The project is supervised by three faculty members at UVic's Engineering Department - Dr. Fayez Gebali, Dr. Kin Li and Dr. Michael McGuire. A presentation was delivered on July 31, 2012, and this project report featuring a product definition and a detailed system design is delivered to the department.

Team *Connec4* is a group of four undergraduate students from the University of Victoria's Department of Electrical and Computer Engineering who are enthusiastic in applying communication technology to improve public transit user experience.

3.2 Project Milestones

A detailed project plan with dates is summarized in Table 1 and Figure 1.

Table 1: Project milestones

Task	Planned Completion Date	Actual Completion Date
Complete background and market research	12-06-15	12-06-12
Define product definition	12-06-19	12-06-13
Set list of alternatives	12-06-23	12-06-23
Review alternative options	12-06-24	12-06-23
Select alternative	12-06-24	12-06-23
Contact potential associates	12-07-06	12-07-05
Compose preliminary components list including company, delivery times, price, possible design	12-07-06	12-07-19
Analysis 1 – Costs/Implementation	12-07-13	12-07-19
Analysis 2 – Benefits/Comparisons	12-07-13	12-07-19
Revise components list	12-07-15	12-07-20
Final design process – step by step plan, prototype design	12-07-22	12-07-26
Finish implementation scope	12-07-29	12-07-30
Group presentation	12-07-31	12-07-31
Final report	12-08-03	12-08-02

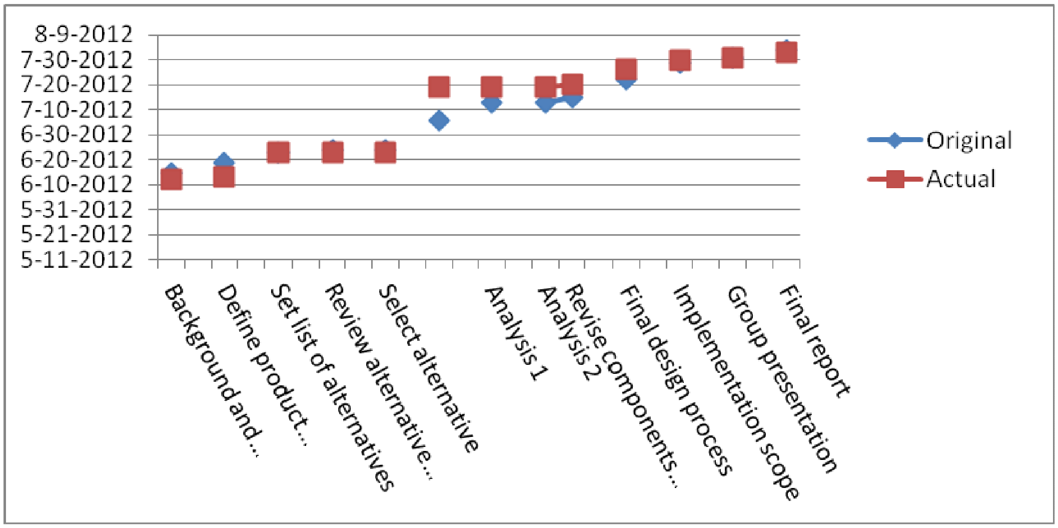

Figure 1: Project milestones

3.3 Project Deliverables

For the project, a list of deliverables to be produced by August 2012 was created as shown in Table 2.

Table 2: Deliverables

Deliverables	Status
Background/Market research – specs.	Done
Project proposal	Done
Product definition	Done
Alternative analysis	Done
Prototype design	Done
List of HW/SW components	Done
Cost/Implementation analysis	Done
Benefits/Comparisons analysis	Done

Report	Done
Presentation	Done
Website	Launched

3.4 Biography

3.4.1 Team Members

Team *Connec4* is a group of four undergraduate students from the University of Victoria's Department of Electrical and Computer Engineering who are enthusiastic in applying communication technology to improve public transit user experience.

Xiaoya Guo (Jessie)

Jessie is a 4th year Electrical Engineering student interested in power system and sustainable energy solutions. She is sure that the idea of a smart transit system in Victoria will encourage more people to use the public transit and lead to a greener future. Her past Co-op work experiences include digital medical image processing at the BC Cancer Agency, technical support at AbeBooks.com, transmission system modeling management at Alberta Electrical System Operator, and electrical substation design at BC Hydro. In her spare time, she enjoys working out and outdoor activities.

Emily (Chu Feng) Huang

Emily is a third year Electrical Engineering student interested in digital signal processing. She believes that the design of smart bus stop could help out passengers with disabilities and give the public ample guidance when travelling. She had experienced different transit systems while she resided in Singapore and Taipei; therefore she could use her personal experiences as research reference. She also has fundamental knowledge of programming languages such as C and JAVA so she could help implementing the communication system of smart bus stop. With the previous experience working in EcoCAR team, she has basic knowledge of car structures. In her spare time, she enjoys participating in charity organizations' fund raising events and doing community service. Therefore, she could constantly speak to people with disabilities to understand their needs.

Ping-Hsiang Hung (Benson)

Benson is a 3rd year Computer Engineering student interested in embedded system and network security. He worked with computer vision development in AUVic, submarine hazard research at the Geological Survey of Canada, forest fire analysis and management at the Canadian Forest Service, and university website maintenance support at the University of Victoria Communication Services. Currently he acts as the project coordinator for the AUVic team and manages team outreach, website, recruitment, as well as computer system development for the autonomous underwater vehicle. He enjoys foil fencing and sabre fencing during his spare time and attend fencing tournaments sometimes. He has experienced the semi-smart transit system before; therefore he understands that the smart transit system project will give the public more conveniences by improving the current transit operation and providing timely bussing information.

Lara Juras

Lara is a 4th year electrical engineering student specializing in electromagnetics and interested in optimizations in technology that can improve everyday practices and allow her to be creative. This project captured her interest since it is innovative and involves design freedom. She also is excited about the communications aspect and applying course work. Lara brings her previous work experience to the group from assisting project managers at ASYS GmbH with a solar panel machine line project, acting as a project coordinator with the hardware development project managers at Research in Motion and working with databases in the electrical team at Lafarge Canada Inc. Not to mention, her travel experience across the world (e.g. Germany, Spain) provides invaluable insight to current technologies in public transportation systems. This also means she understands the insecurities people may feel in an unfamiliar area and recognizes the need for a "Smart Bus System." In her free time, she enjoys practicing yoga and pilates, viewing films and traveling to new countries to experience the culture.

3.4.2 Supervisors

Dr. Fayez Gebali

Dr. Gebali received his B.Sc. in Electrical Engineering (first class honors) from Cairo University, his B.Sc. in Mathematics (first class honors) from Ain Shams university, and his Ph.D. degree in Electrical Engineering from the University of British Columbia where he was a holder of an NSERC postgraduate scholarship. Dr. Gebali is a Professor and Chair of the Department of Electrical and Computer Engineering at the University of Victoria. His research interests include parallel algorithms, networks-on-chip, three-dimensional integrated circuits, digital communications, and computer arithmetic.

Dr. Kin Fun Li

Professor Kin Fun Li has earned bachelor and doctoral degrees in computer engineering and master's in business administration. He is the Director of Computer Engineering Program at the University of Victoria, Canada, where he teaches both hardware and software courses in computer-related areas. His dedication to teaching brought him numerous student-initiated awards. Li's research interests include computer architecture, web searching and mining, and application specific hardware. He is actively involved in the organization of many international conferences in these research areas. Besides teaching and researching, Li, a senior member of IEEE, initiates, supports and participates in numerous international activities to promote the engineering profession and education.

Dr. Michael McGuire

Dr. Michael McGuire received his B.Eng. in Computer Engineering from the University of Victoria in 1995. He remained at that university until 1997 to complete a Master's degree in Electrical Engineering, developing Fuzzy Logic based algorithms for hand-off control in wireless cellular networks. After his Masters, he spent two years at Lucent Technologies at Holmdel, NJ. His projects included testing the first generation of multi-protocol cellular telephones and developing fault detection and management software for high capacity optical transmission systems. From 1999 until 2003, Michael enrolled at the University of Toronto to complete his PhD with the Digital Signal Processing group. After the completion of his doctorate, he then joined the faculty of the Department of Electrical and Computer Engineering at the University of Victoria. His research interests are signal processing for communications, model-based filtering, and non-parametric estimation. He currently holds grants from the National Science and Engineering Research Council of Canada as well as research contracts for industrial partners. Dr. McGuire is a member of the IEEE Communications, Computer, and Signal Processing Societies.

Chapter 4. Workload Distribution and Achievements

Benson Hung

My contributions to the project consisted of smart bus stop system research, website design/development, microcontroller research, cost analysis, smart bus system's scenario cases development, and project presentation. I also wrote the seminar reviews for the progress report.

Emily Huang

My main contributions to the project consisted of smart bus system research in Singapore, long range communication methods research and revision, preliminary logo design, user scenario cases to request a 'pick-up', attending project presentation, and writing progress and final reports.

Lara Juras

Some of my contributions for the project included researching the Winnipeg transit system technologies, writing weekly supervisor meeting agendas, researching the LED display technologies, writing sections for the various reports, designing the animation for the presentation and reading/writing the last two textbook sections for the reports.

Xiaoya(Jessie) Guo

My main contributions to the project consisted of arranging group meetings, taking minutes, researching on Victoria Regional Transit and various intelligent transportation technologies, drawing preliminary design diagrams, establishing the architecture and protocol for the transit web service API, participating in writing reports, and attending the final presentation.

Chapter 5. Project Discussion

5.1 Background Research

5.1.1 Intelligent Transit System in Other Cities

5.1.1.1 Taipei Smart Bus System

The Taipei Smart Bus System has been implemented for over 8 years. The starting project was focused on the on-board technology and then gradually expanded to the bus stops.

a. On-Board Technology

The Taipei Smart Bus System is hosted by a number of private companies associate with the government. Majority of the buses have the following features:

- Smart card machine.
- GPS devices.
- On-board announcing system.
- On-board LED display.
- Speed limit devices.
- The Transit Control Centre can monitor statuses for all buses in the fleet.
- All of the new buses have on-board TV that provides news, weather reports, government advertisements and commercial advertisements.

b. Bus Stop Technology

Some major stops in Taipei have upgraded to smart bus stops which include some or all of the following features:

- LED signs displaying bus numbers and real-time “next buses” arrival times.
- Trip planner on the touch screen panel.
- Tourists’ attractions list on the touch screen panel.
- Nearby restaurants map on the touch screen panel.
- Daily news on the touch screen panel.
- Photo post card creator.

c. Real-time Information

The real time schedule is handled by the transit control centre. If a bus arrival event is deviant from the assigned schedule, the transit centre will send the new schedule to be displayed at bus stops and on the website.

5.1.1.2 Singapore Bus Service Transit (SBS Transit)

a. On-Board Technology

- Unlike BC Transit, bus fare in Singapore is calculated according to distance traveled by passengers using GPS technologies. Therefore, passengers have to scan bus passes when boarding and getting of the bus.
- Some buses have LED display with stops names.
- All buses have on board TV showing news and weather broadcast.
- There are wheelchair accessible buses for people with special needs. Wheelchair accessible bus availability could be checked by visiting SBS Transit website or through Smartphone app.

- Bikes are allowed on buses during Mon - Fri: 9.30am - 4.00pm, 8.00pm as well as weekends and holidays. .

b. Bus Stop Technology

- LED display with real-time information at interchanges and bus terminal.
- Bus numbers and paper bus route maps (with all bus stop names displayed on map) are showing at all bus stops.

c. Real-time Information

The real time schedule is handled by SBS Transit has ***iris*** NextBus (Intelligent Route Information System) service for tracking real-time bus schedule using GPS technologies. Passengers can access real-time schedule using WiFi-enabled devices and by downloading iris NextBus related apps. For GPRS enabled devices, users can text "74744+space+bus stop number+bus number" to transit authorities to obtain real-time information at $0.05 SGD per text.

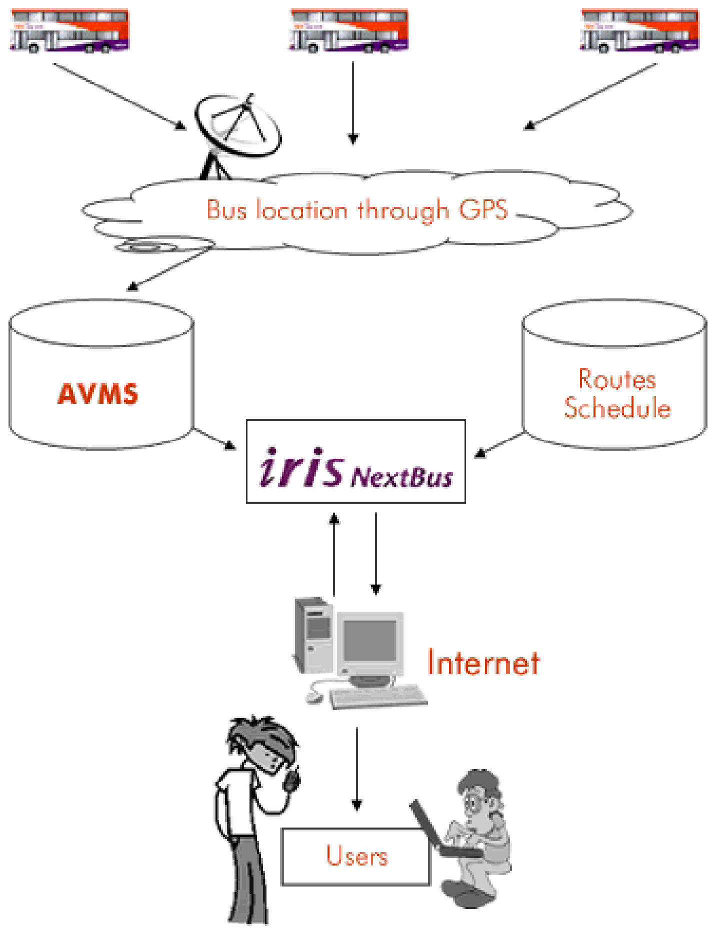

Figure 2: iris NextBus flowchart

5.1.1.3 Winnipeg Transit System

a. On-Board Technology

1. On-board Computer:

In 2009 Winnipeg Transit completed the installation of GPS antenna on top of all transit buses. Each bus in the fleet is equipped with an on-board computer that stores the service schedule information and links to the GPS system on the bus. With this on-board technology developed by Infodev Electronic Designers, buses can compare the real-time GPS location to the assigned schedule and report the deviations to the Transit Control Center.

2. Automatic Passenger Counting (APC) System:

Each bus in the fleet has installed passenger counting system to count the number of persons boarding and exiting the bus at each bus stop. The basic system installation and data collection method are illustrated in Figure 3 and Figure 4.

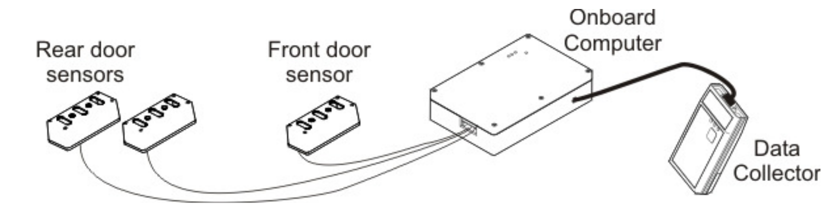

Figure 3: APC Basic System Installation

Figure 4: Basic Data Collection Method

b. Bus Stop Technology

Major bus stops in Winnipeg have installed bright and simple to read LED signs that displays real-time arrival times for all buses servicing the stop. These LED signs are programmed to adjust display brightness based on time of day and sun location. Each LED sign is equipped with a computer that has transit data programmed into. Signs update schedules around once a minute by requesting updated bus arrival times from the Transit schedule server over a wireless communication network. This system ensures that “real time” information is accessible to passengers waiting at a bus stop.

Figure 5: LED Sign

c. Real-time Information

Bus riders in Winnipeg can access real-time bus schedule on the Winnipeg Transit website, on their Smartphones, and via SMS text messages. Winnipeg Transit's Open Data Web Service provides a way for developers to retrieve live information about Winnipeg Transit's services. This encourages development of various 3^{rd} party Smartphone apps to enhance the public transportation user experience.

5.1.2 Communication Technologies

Both long-range and short-range communication protocols were investigated to connect buses, bus stops, the transit center, and Smartphones.

a. Long-range wireless communication

In this section, four long-range wireless communication protocols – WiFi, GPRS, GPS, and 3G - are compared.

Table 3: Data sheet – WiFi / GPRS/ GPS

	WiFi	**GPRS**	**GPS**	**3G**
Range	32 m (120 ft) indoors and 95 m (300 ft) outdoors	Everywhere	Everywhere	Everywhere
Frequency	2.4-2.5MHz	1.9 MHz in US and Canada	Two frequencies: L1: 1575.42 MHz L2: 1227.60 MHz	850-1900 MHz Nationwide
Rate	Standard type 802.11g 54Mbps	56–114 KB/second	4,800 KB/s	Latest UMTS System: 28 Mbit/s in existing services and 22 Mbit/s in the uplink
Usage	Exchange data over wireless network. Applicable devices: computer, cell phone, etc.	Mainly used for mobile communication	Mainly used for tracking position	Mainly used for mobile communication

Since GPS is mainly used for tracking position, the option of using GPS technology to build up communication between users and the transit centre is eliminated. Therefore, the possible options left are WiFi, GPRS, and 3G. The following table shows the comparison between the two options.

Table 4: WiFi vs. GPRS vs. 3G

Technology	Pros	Cons
WiFi	Can be used on many devices such as a personal computer, Smartphone, tablet, or digital audio player	Limited range of WiFi signals if obstructions are present
	Easy to build WiFi hotspot	Not an "always on" network
	Can be accessed worldwide	Speed decreases if there are more than two or three WiFi users at one location
	Secure Wi-Fi Protected Access encryption (WPA2)	
	Have negligible harmful effects to human. There is no risk from low level, long-term exposure to wi-fi networks (According to "WHO")	
GPRS	Can work in large distance or remote area	High monthly contract cost
	Quick and easy implementation	Variable network frequencies between providers and countries
	On all cell phones	Network not always stable compared to WiFi
	SMS messaging and broadcasting	Speed dependency on distance: the closer to the signal tower, the faster the speed
		Other network related functions cannot be used when GPRS is in

		use
3G	A more advanced technology than 2G GPRS	The monthly contract cost is high
	All Smartphones have 3G technologies	
	Portable High Speed Internet Access	
	Internet connectivity is always available	
	Greater Bandwidth	Its network frequencies varies between providers and countries, but available in most parts of the world
	Secure and Reliable	
	3G users have the facility of enjoying video conferencing sessions with other 3G customers	

Compared to 3G technologies, WiFi highly relies on hotspot locations for setting up communication between users and transit centre. The possible solution is to establish WiFi hotspot locations at every bus stop for users to communicate with the transit centre. However, this solution would be costly and time consuming. Therefore, the team decided to use 3G as the main channel of communication.

Today, 4G communication technology has becoming more popular which may take over 3G Network in the future. The team has also listed down the pros and cons showing in Table 5.

Table 5: 4G pros vs cons

Pros	Cons
Higher speed in transferring data	not available in many locations of world
More stable network	it is still in the formative stages and could result in bugs or glitches
	You will have to purchase a wireless modem or take it on rent
Good security and privacy protection	The monthly contract cost is high
	Not every Smartphone has 4G

Despite 4G is a more advanced technology than 3G, 3G is still a relatively mature and popular technology among users. 3G technology is available on every Smartphone and also worldwide whereas 4G is not. For ELEC499 project implementation, the team will focus on 3G technology but will also give space for expanding the communication channel to 4G because the team believes that 4G is expected to catch on and become the premier connectivity provider in the coming future.

b. Short-range wireless communication

In this section, three short-range wireless communication protocols – NFC, RF (QR code) and Bluetooth - are compared in Table 6 and Table 7.

Table 6: NFC vs. Bluetooth

Technology	Pros	Cons
NFC	No pairing; automatic connection; easier and faster on user side	Slower data rate
	Faster set-up	Vulnerable to eavesdrop by special antenna and to data damage by an RFID jammer
	Shorter range reduces unwanted interception, suitable for crowded areas	Only a limited number of Smartphones supported
	Lower power consumption	
	Compatible with existing passive RFID systems	
Bluetooth	Faster data rate	Requires pairing by manual configuration
	More improved security	Slower set-up
	All cell phones have Bluetooth.	Higher likelihood of unwanted interception
		Higher power consumption
		Bluetooth can only connect up to 7 devices at the same time

Table 7: QR vs. NFC

Technology	Pros	Cons
QR Codes	Inexpensive	Can be difficult or time consuming to scan

	Print/display anywhere	Not always weatherproof
	All phones can download QR reader	
NFC	Quick and easy to scan	More costly hardware
	Weatherproof	Limited phones supported
	Two way communication possible	

In conclusion, none of the three protocols would meet the objective of effectively informing blind people when and which bus is arriving while they are waiting at the bus stop: scanning QR code is physically challenging for people with special needs, especially for people with visual impairment; NFC communication requires the user to hold the phone within a maximum distance of 20 cm to transfer and receive data, and therefore is difficult to implement when the bus stop is crowded or when the bus arrives in a long time; Bluetooth requires pairing by manual configuration which could be challenging and time-consuming, and it can only connect to 7 devices at one time. Given these limitations, short-range communication protocol is not applicable for communication between buses, bus stops, and users.

5.2 Preliminary Design

To achieve the goal and objectives, a preliminary design of the Smart Bus System was proposed featuring functions of three categories:

a. On-board
b. Bus stop
c. User interface.

5.2.1 Communication Backbone

One of the objectives of the project is to provide an inclusive bus system that helps people with special needs to board bus easily. CanAssist has developed a Smartphone app to help a blind person getting to the bus stop, but at the bus stop it is very challenging for the person to know when and which bus is arriving. To resolve this issue, the first solution is to enable communication between a bus and a user's Smartphone so that the user can request the bus driver for pick-up at a certain bus stop. However, this option is abandoned because BC Transit does not allow direct communication between a user and a bus for security reasons. This leads to the second alternative - to use the bus stop to connect a bus and a user via class 3 Bluetooth that can discover devices within 5 meters. This will require all buses and bus stops to have Bluetooth beacon installed. The Bluetooth at the bus stop will be able to detect the Bluetooth on buses that are approaching, and then inform the user's Bluetooth-enabled cellphone of which buses are arriving. However, the downside is that when multiple buses arrive at the same bus stop around the same time, not all buses will stop at the bus stop. Without bus driver knowing that a person wishes to board, the person will have to figure out where the bus is at. This is difficult for people who have visual impairment. This leads to the third solution. In this case, a transit web service is established as a hub to connect buses, bus stops, and smartphones. Buses sends GPS coordinates to the web service in real-time to update bus schedules, and the web service makes this information available at bus stops and Smartphones via 3G networks. To request a “pick-up”, a user standing at a bus stop sends a request to the web service, web service configures which bus to forward the request to using the real-time transit database, forwards the request to this bus, and finally, bus responds to user via the web service. When the bus arrives, the driver will stop the bus at the bus stop, and announce the bus number using a microphone or some other voice system so that the blind person know if it is the right bus to board.

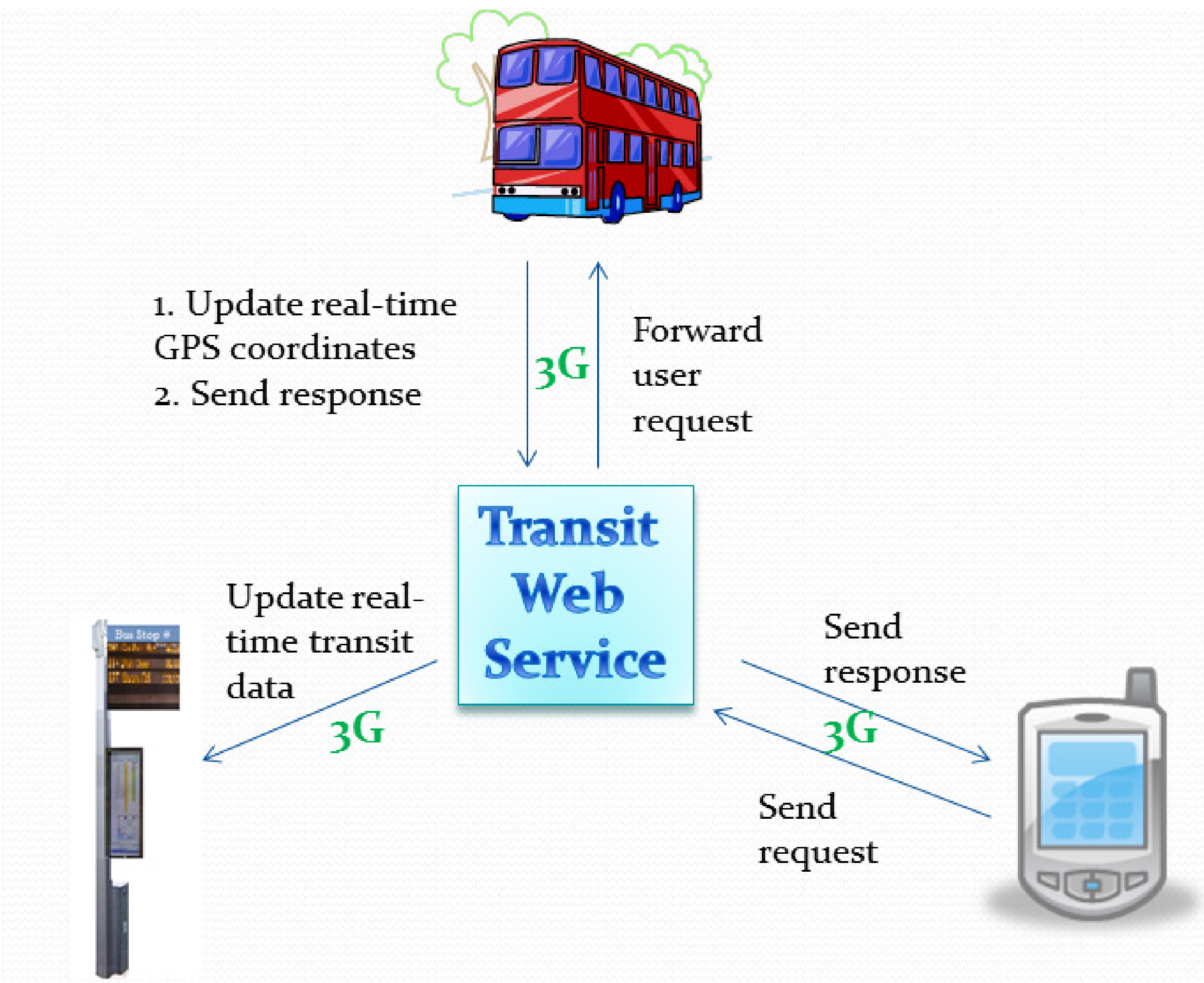

Figure 6: SBS communication backbone

5.2.2 On-board Infrastructure

To support the communication backbone, existing buses and bus stops need to integrate with new communication technology. Currently BC Transit fleet have GPS antenna to track bus locations and Automatic Passenger Counters (APC) to estimate bus capacity at different times of a day. However, this information is not available in real time but only for post-processing in the garage due to the lack of a communication protocol between buses and the transit center. In the proposed Smart Bus System, each bus will install an on-board computer that is interfaced with GPS enabled microcontroller and 3G router to enable real-time processing and transferring GPS coordinates and passenger information to the transit center via 3G. Bike rack limit switches will estimate the number of available bike racks and report to the transit center via 3G in real-time. A single-line LED sign and speakers will announce “next stops” triggered by real-time GPS coordinates relative to a bus stop.

Figure 7 illustrates how a smart bus with on-board advancements would enhance rider experience. Firstly, with the “Next-stop” display and voice announcing system, passengers will know where they are and when to get off the bus. People unfamiliar with the route or area will be more likely to take buses as the announcing system provides a navigation guide. Secondly, the passenger data collected from the Automatic Passenger Counter (APC) will be translated into statuses for people to know the seat availability on a bus. The transit dispatch center can use this information to determine the need to dispatch extra buses during peak-passenger hours. Thirdly, limit switches on bike racks will report the number of bike racks available. Cyclers will be more willing to take buses by knowing beforehand if bike racks are full. A set of desired functionalities and proposed infrastructures are summarized in Table 8.

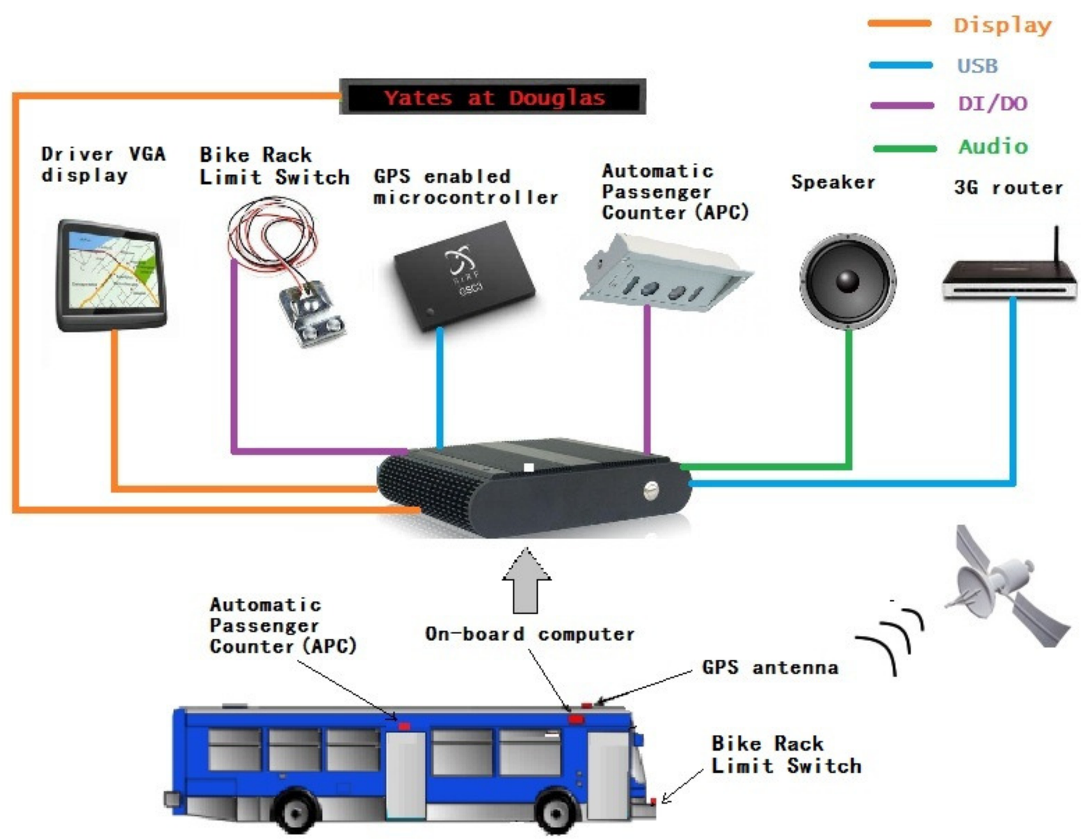

Figure 7: Smart bus

Table 8: On-board technology

Desired Functionality	Proposed Infrastructure and Technology
Communicating with transit control center	3G router
"Next Stop" announcement	LED display, speaker
Real-time position tracking	GPS antenna, GPS microcontroller chips
GPS navigation for bus drivers	On-board computer with VGA display
Estimate bus capacity and availability	Automatic Passenger Counter (APC)
Report bike rack availability	Limit switches on bike racks

5.2.3 Bus Stop

Figure 8 illustrates a preliminary design of a smart bus stop. In the proposed Smart Bus System, each bus stop will install LED signs that displays real-time arrival times, bus capacity and bike rack availability for all buses servicing the stop, a microcontroller with 3G router that requests updated bus arrival times from the Transit schedule server over 3G networks. To increase safety, remote bus stops will have LED lights installed. As well, paper schedule will remain as a backup in case of electronics failure. Bus route maps, assistance phone numbers and cab numbers will also be available on the paper schedule. A set of desired functionalities and proposed infrastructures are summarized in Table 5.

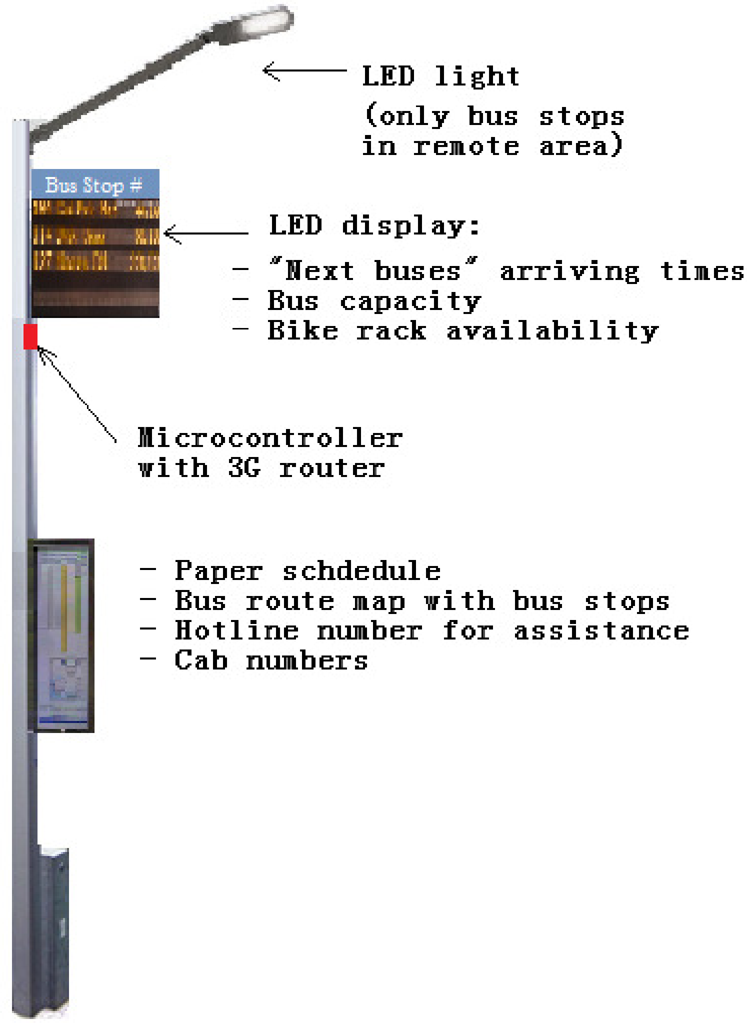

Figure 8: Smart bus stop

Table 9: Bus stop technology

Desired Functionality	Proposed Infrastructure and Technology
Receive real-time transit data from the transit center	3G router, microcontroller
Display transit data of next buses	LED display
Lighting in remote area	LED light
Provide static transit information as a backup	Paper schedule Bus route map locating all bus stops Transit assistance hotline Cab hotline

5.2.4 User Interface

Figure 9 illustrates three ways a user can access transit data: a. Website, b. Phone, and c. Smartphone. Transit data gathered by the transit center will be made available on the internet and to the phone service provider. Users can check schedules and other information via the transit website, hotline / text messages, and Smartphone apps. Finally, all the real-time information will be available via website and a Smartphone app. In more details, the app will feature real-time schedule, trip planner, bus stop locator and bus arriving alarm. A set of desired functionalities and proposed infrastructures are summarized in Table 10.

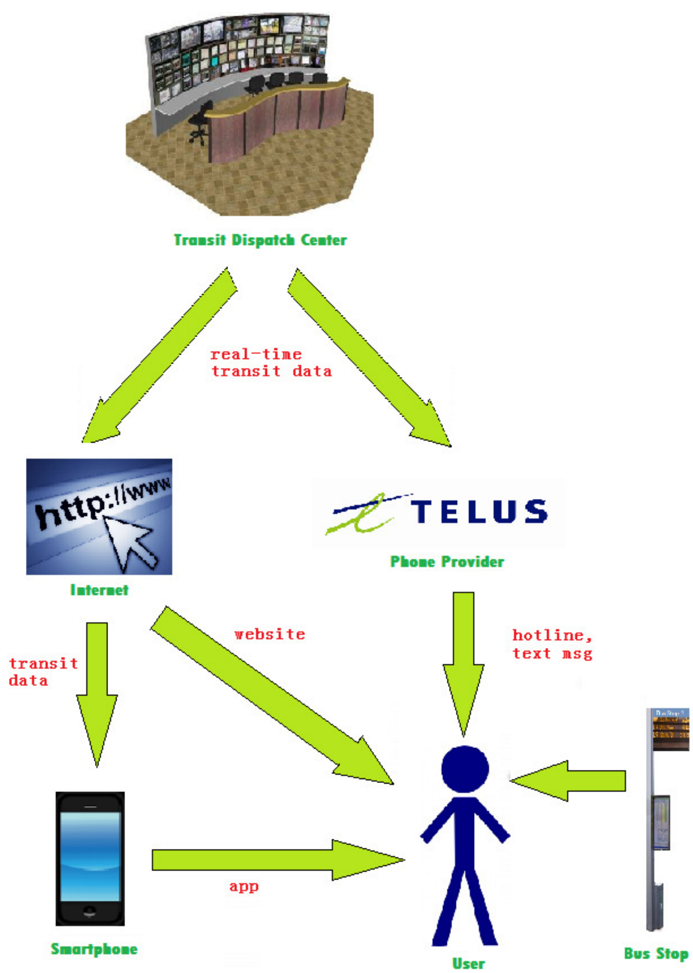

Figure 9: User interface

Table 10: Portable user interface

Desired Functionality	Proposed Platform
Real-time passenger information	Smartphone Website Phone service provider
Real-time map with bus flow and bus stops	Smartphone Website
Real-time trip planner	Google trip planner
Bus arriving alarm	Smartphone
Multilanguage support	Smartphone

5.2.5 User Cases

The team brainstormed a total of 8 scenario cases for people who have special needs. The following diagrams illustrate how a person requests a 'pick-up' under different situations.

Premises

1. *Communication method between the 3 entities: 3G*
2. *Assume real-time schedule*
3. *Transit Centre holds uses' requests in their queue(for storing users' requests) and delivers it to bus when bus is approaching*

Normal Case

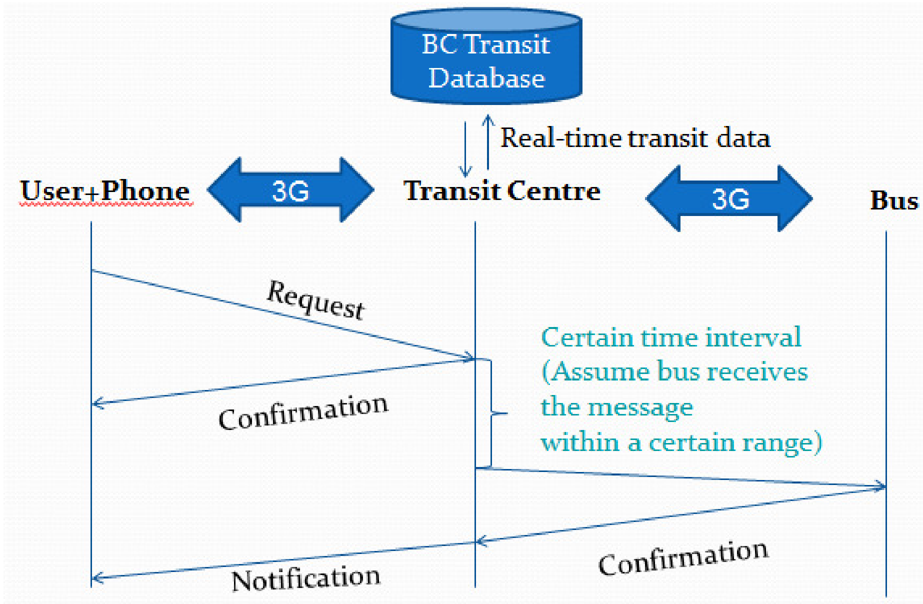

Figure 10: User Normal Case

Description: User looks up bus schedule for stop they are at or want to go to. They proceed to send a request for the bus they want to the transit authorities via a 3G network. Transit centre receives their request and forwards the bus stop information to the bus on route. Bus on route delivers message back via 3G alerting them they are near the bus stop. Transit centre relays message to bus user.

Person cancels the request

Case 1: Person cancels the request before the bus receives it (eg. The bus is still far from bus stop)

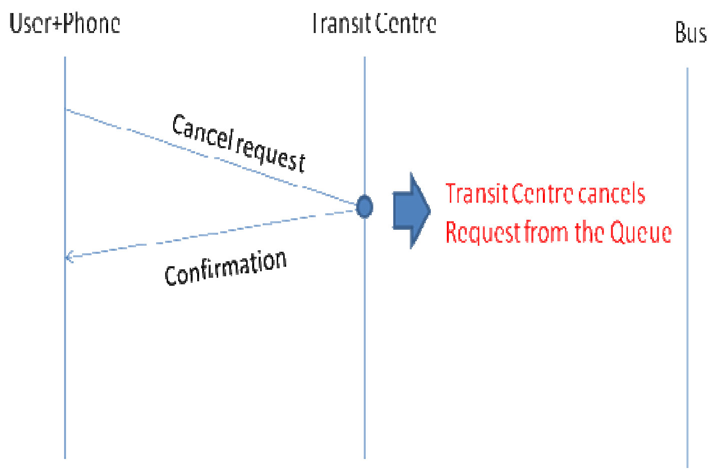

Figure 11: Person Cancels Request Scenario Case 1

Description: User sends a cancel request to the transit centre. Transit centre cancels the stored data in their queue and sends a confirmation message to the user.

Case 2: Person cancels the request after bus receiving it (eg. bus is approaching bus stop)

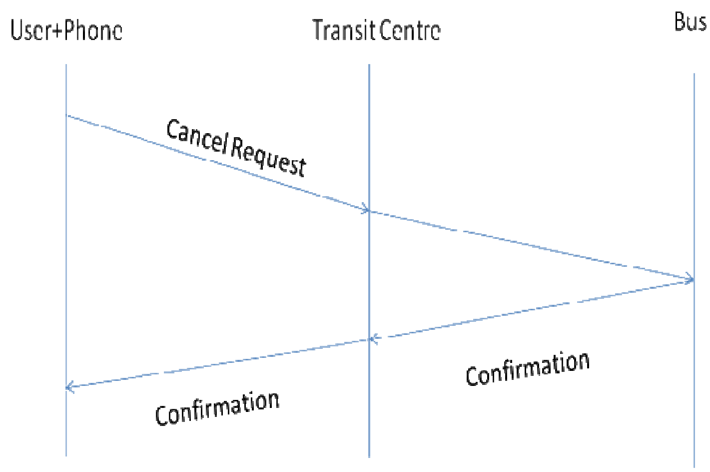

Figure 12: Person Cancels Request Scenario Case 2

Description: User sends a cancel request to the transit centre. Transit Centre then forward the request to bus. Bus automatically cancels the 'pick-up' request and delivers a confirmation message to transit centre. Finally, transit centre relays the message to the user.

Bus Delay

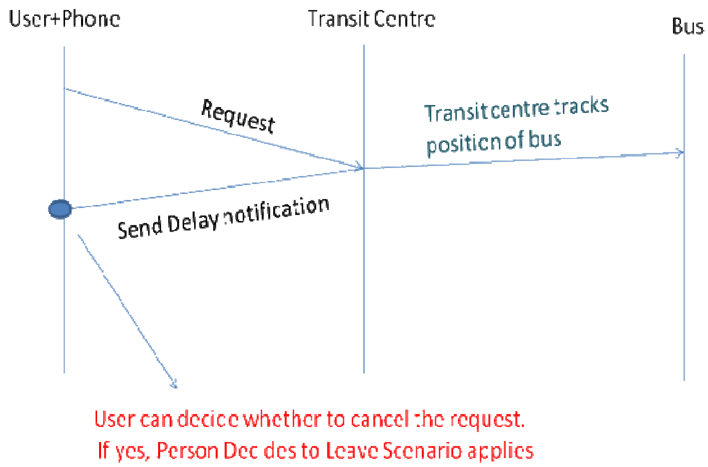

Figure 13: Bus Delay Scenario

Description: User sends a 'pick-up' request to the transit centre. Transit centre has all the information of bus on route in real-time so transit centre will know if bus delays. Transit centre sends a message back to notify the bus is delayed and gives to options to the user:

1. Cancels the request (Person Decides to Leave Scenario applies)
2. Keep Waiting (Bus Delay Scenario)

Incorrect Data Sent

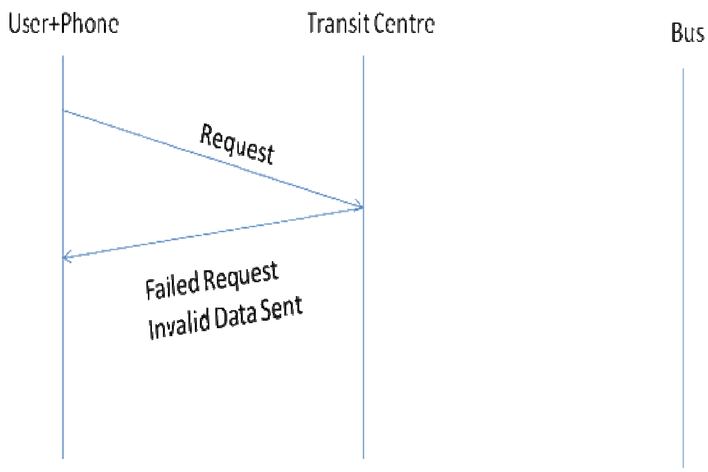

Figure 14: Incorrect Data Sent Scenario

Description: User sends a request for 'pick-up' with invalid information. Transit Centre could not recognize the request therefore delivering a message back with "negative acknowledgement".

Bus Unavailable

Case 1: Bus breaks down.

If bus breaks down in the middle of the route, transit centre will be notified to send another bus. Therefore, *Bus Delay Scenario* applies.

Case 2: BC transit cancels bus route

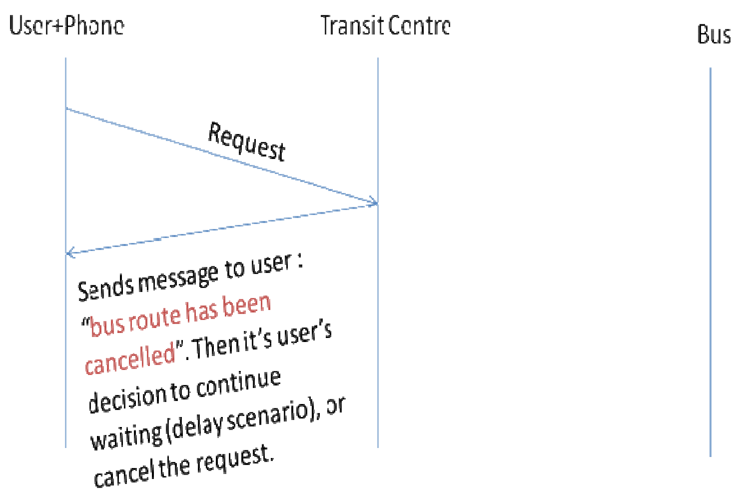

Figure 15: Bus Unavailable Scenario Case 2

Description: User proceeds to send a 'pick-up' request to the transit centre. Transit Centre recognized the bus route has been cancelled and will send a message "bus route has been cancelled" to user with two options:

1. Continuing Waiting (Delay Scenario)
2. Cancels the request

Case 3: Bus Detour

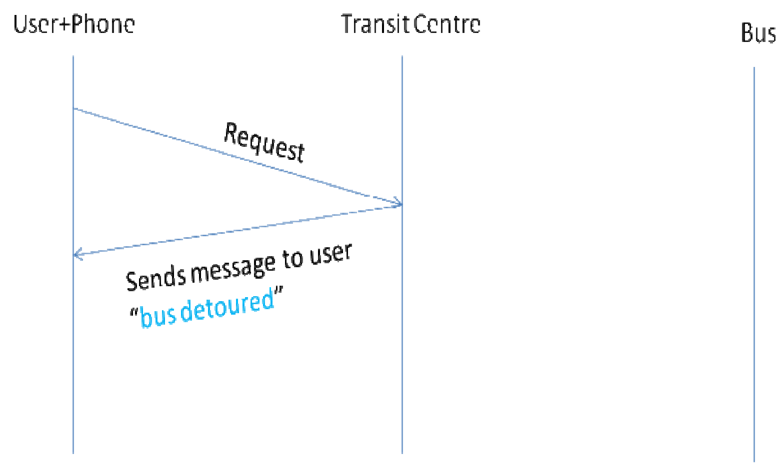

Figure 16: Bus Unavailable Scenario Case 3

Description: User proceeds to send a 'pick-up' request to the transit centre. Transit Centre recognized the bus is detoured and will send a message back with "bus detoured."

5.2.6 Web Service (API)

In the proposed Smart Bus System, a transit web service (API) will be established as a hub to connect the three components in the public transportation system: buses, bus stops, and Smartphones via 3G networks. Connected to a real-time transit database, this web service will process requests and responses within the bus system. The API will allow developers access to real-time transit data such as bus schedule, bus capacity and bike rack availability. Developers can use the API to write cool and customized new Smartphone apps to enhance rider experience. Research has been conducted on popular protocols and data formats used in Transit APIs. As shown in Figure 17 and Figure 18, REST and XML are the most used protocol and data format respectively. Hence, a RESTful web API that receives and returns XML data is proposed for the Smart Bus System.

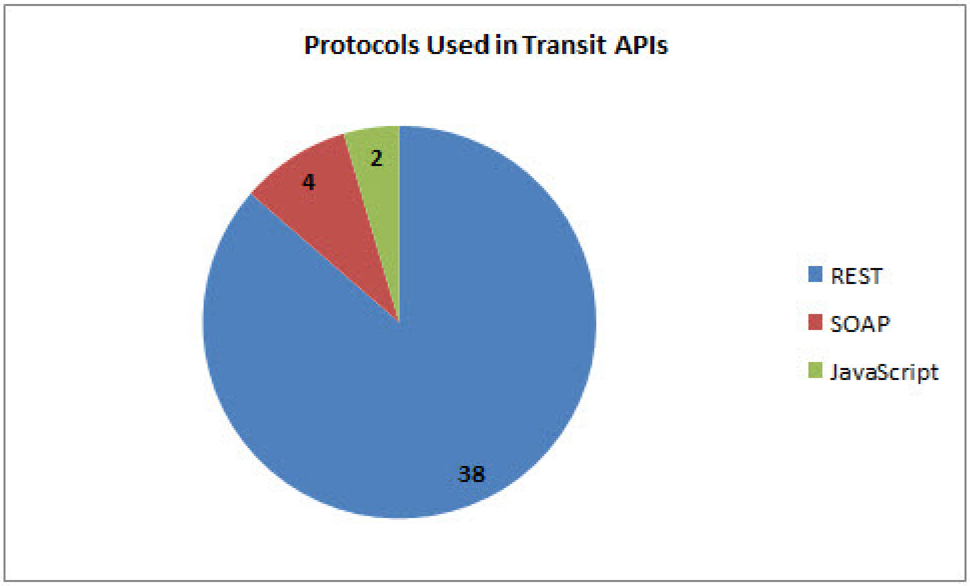

Figure 17: Transit API protocols

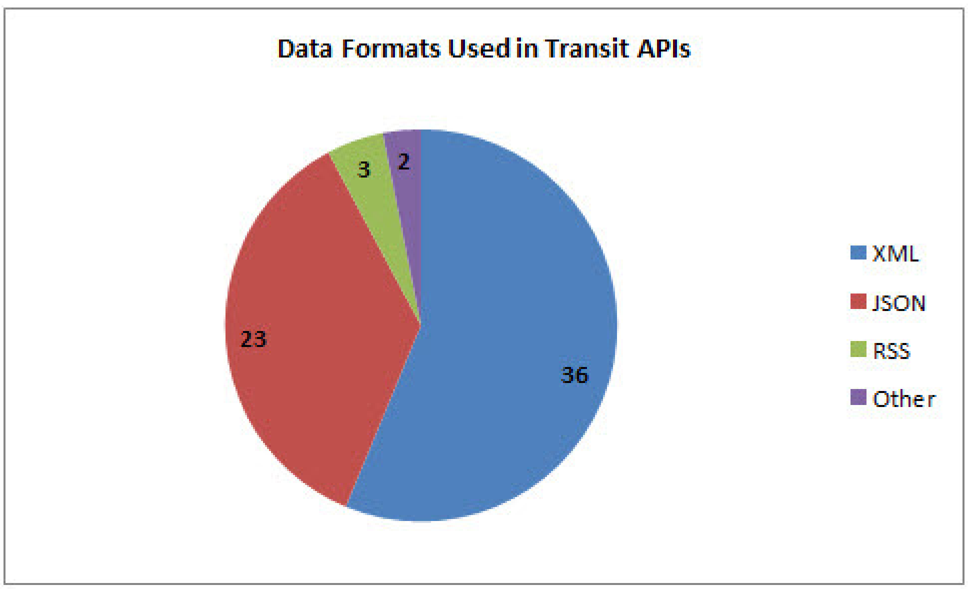

Figure 18: Transit API data formats

Among a number of RESTful API frameworks for PHP, the Slim micro framework is chosen for its simplicity and comprehensive Features include: RESTful routing, Named routes, Route passing, Route redirects, Route halting, Custom views, HTTP caching, Signed cookies, Custom 404 page, Custom 500 page, Error handling and Logging. At the mean-time, an API has been set up on the authors' localhost IP address with an Access database that "fakes" BC Transit database. The data stored in the database are downloaded from the static schedule data and associated geographical datasets on BC Transit's website. The files contain schedule times, stop locations and route information in GTFS format which stands for General Transit Feed Specification.

Some proposed API methods are listed below.

- /routes/:lat/:lon - get routes near a location.
- /stop_details/:stop_id - get details of a bus stop.
- /stops_at_location/:lat/:lon/:radius - search for bus stops near a location.
- /stops_on_route/:route_id - search for stops on a certain route.
- /trip_details/:trip_id - get details of a trip.
- /trip_for_bus/:bus_id - get trips for a certain bus.
- /trips_at_location/:lat/:lon/:radius - get trips near a location.
- /trips_on_route/:route_id - search for trips on a certain route.

So far one method is coded which returns the bus arrival times at a certain bus stop within the next hour.

5.3 Cost Analysis for Bus Stop Prototype

5.3.1 Microcontroller

One of the steps in developing a smart bus system is to determine the suitable microcontrollers. Research was done to determine the microcontroller requirements. The system requires having a GPS microcontroller to locate the position of buses and a general microcontroller to handling the other features.

Three microcontrollers are listed as the considerations for this project: Arduino mini USB extension, Arduino Duemilanove and Arduino Mega2560. In order to meet the requirement for transferring data with 3G network, the microcontrollers are required to have the feature to connect with 3G. The purchasing costs and vendors can be found below in

Table 11 and

Table 12.

Table 11: Purchasing costs and vendors

	Price (CAD/piece)	Microcontroller chipset	Vendor	Addition required parts
Arduino mini USB extension	20.41	ATmega168 or ATmega328	Robotshop/ Arduino	3G router, 3g communication board
Arduino Duemilanove	24.29	ATmega168 or ATmega328	Robotshop/ Arduino	3G router, SM5100B, 3g communication board
Arduino Mega2560 controller	59.78	ATmega2560	Robotshop/ Arduino	3G router, SM5100B, 3g communication board

Table 12: Microcontroller price list

Type	Price (CAD/piece)
ATmega328	3.08 (appx/ must purchase 10 at least)
ATmega168	3.99 (appx / single available)
ATmega2560	15.21

Purchasing microcontroller chipset and developing our own microcontroller set would save up to 44.57 dollars maximum. However, the time for delivery might need to be considered.

Arduino Duemilanove and Arduino mini USB extension have similar setup and features, but Duemilanove have 3 ways of power connection: USB, Power connector, or VNN ground pins.

ATmega 328 and ATmega168 have identical flash memory, but the ATmea 328 max operating frequency which can potential process the data faster. ATmega 2560 provides higher flash memory space (256 Kbytes) compare to the other two which can store more information in the controller without clearing the memory.

Based on the price and performance, the suggestion would be to purchase the Arduino Duemilanove with ATmega328 microcontroller, which can provides enough features, but not overpriced.

5.3.2 LED Display

For demonstrating the smart bus stop to display the real-time data, an LED display would need to be purchased. The LED display must be for outdoors and programmable. Three companies were examined for their signs as shown in Table 13.

Table 13: Comparison of LED display companies

Brand/Company	Type	Programming Options	Power	Dimensions
Mandex Motion Displays	M-EXL Series	- central information source - subscription feed - local/Ethernet ASCII - bitmap feeds	100/120 VAC, 60HZ No built in power switch	5.25"H. X 3.00. variable length 2.5lbs
PCM Electronic Signs	Starfire	- programmable fields - conditional programming		Selection
aesys	LED Bus stop sign	- optional push button for audio voice announcement	Solar	Custom

PCM has various types of signs, but the software is very limited for what can be displayed.

Figure 19: PCM Electronic Designs

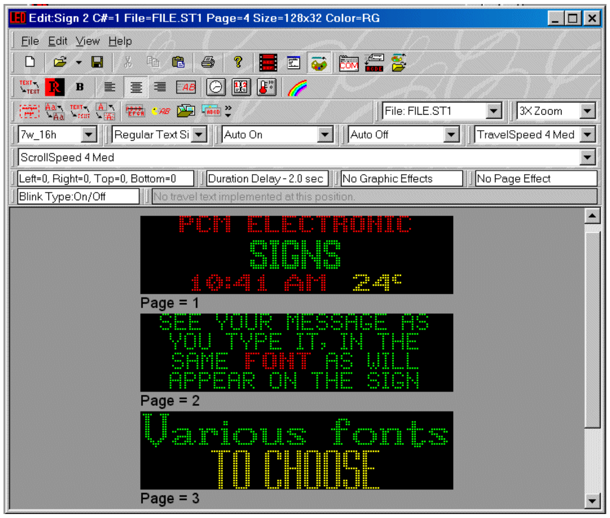

Figure 20: PCM Electronic Software

At aesys, the bus stops LED signs are wired and wireless. They can communicate with the transit center for real time information. Aesys has their own fleet management system using GPS, but it is not sold in North America. The site did not provide enough information about customizations to linking data to the bus stop. Future inquiries would be needed for gathering more information. Fortunately, the company has an office location in Ontario.

Figure 21: aesys bus stop design

Figure 22: aesys bus stop design power by a photovoltaic panel

Besides looking at specific LED models for bus stops, the research revealed companies who have various options for on-board bus equipment. Specifically, Industrial LCD Pro who designs an overall bus system was examined. They build and install a monitoring system that could be put into the bus system. The system has two options for displaying the information. First, the data can be provided by an USB stick. This system can be updated to a 3G/GPS unit to update the content. It is nice that the GPS is an optional requirement for the display system.

Overall, several LED companies build digital outdoor signs, but the level of programmability is still a question. As well, for pricing information, most companies require quotes and do no freely show costs. Based on a report from LEDs magazine, the installation of 1000+ solar LED-illuminated bus stops in London, England cost around 1.6 million CAD which is roughly $1600 per bus stop. Due to the high cost of the ideal bus stop, a mock up LED display from a whole sale online store would be selected instead. The LED display ranges in prices from ~$250-$1000. The downside to buying not from a known or respectable company is one will not know if all the required features will be there when the product arrives.

5.3.3 Part List – Bus Stop Prototype

The following table is an overview of the parts required to build the bus stop prototype.

Table 14: Bus Stop Parts List

Parts	**Model**	**Price**
Microcontroller	Arduino Duemilanove with ATmega328 microcontroller	$ 44.57
LED display	LED display from a whole sale online store	Varies from $250-$1000
3G router	TBD	$50

Chapter 6. Summary and Future Works

This report provides the ground work for the team to carry on to the ELEC/CENG 499 project. The team researched on the smart bus system including on-board technology and smart bus stop technology, and came out with a preliminary Smart Bus System (SBS) design. The parts list including all costs and descriptions can be found in section

5.3 Cost Analysis for Bus Stop Prototype. To date, a Slim-frame RESTful API has been set up on the authors' localhost IP address connecting to an Access database that simulates the BC Transit web service.

Further work is needed to complete the transit web service (API) to process requests and responses within the bus system. Research needs to be conducted on a programming language to develop a smartphone app that will meet the minimum requirements. In addition, the team will need to investigate the network security and privacy issues.

A partnership or sponsorship with potential involved parties should be established by the team in order to reach the final goal of this project. Based on the budget and sponsorship that the team receives for the ELEC/CENG 499 project, the team will be able to determine the possibility of developing smart bus stop prototype (see section 5.2.3 Bus Stop). The bus stop will be built and demonstrated at the presentation site if the budget allows. The demonstration will use the static bus schedule if BC Transit does not release real time schedule data.

Overall, the final demonstration and presentation will include the following items: a digital schedule bus stop, a transit web service, and a smartphone application.

Appendix A. Textbook Review

In the "Systems Analysis & Design" textbook, Part 4 discusses the implementation phase where the system is built and put into operation. The implementation phase looks at the transition from the design phase to implementation and the development of objects.

Chapter 12 examines how a project group changes focus to the tasks related to building the system ensuring the system will perform as desired and creating the associated documentation. The programmers of the team begin the process of writing programs and the system analysts prepare to tests to check system performance.

A project manager assigns the programmers with various tasks. The goal is to assign the minimum amount of tasks to complete the project. This way there is less coordination problems to deal with when working with a small team. The best way to coordinate is scheduling regular meetings, ensuring standards are followed and using computer aided engineering software tools effectively. In addition, the project manager manages the schedule and accounts for delays. Two common delays are scope creep and minor slippages. Scope creep occurs when new requirements are added to the project after the system design has been finalized. Minor slippages include tardiness of completion tasks that add up. The goal is to ensure these small setbacks do not accumulate.

Before testing starts, the tests must be carefully planned to reduce future costs of fixing bugs after the system has been installed. A test plan includes several tests that examine different components of the system. A test will check various test cases specified and reviewed by the testers. Some types of test are a unit test, integration test and a system test. A unit test looks at a module or program within the system. An integration test checks how well several modules work together using use scenarios and physical data flow diagrams. Lastly, a system test reviews the system as a whole in a broader sense. The final stage of testing is acceptance. This involves users who determine if the system is acceptable to them (beta testing).

Finally, documentation must be created for both the user and the system. Online documentation is becoming more commonly used. There are three types of user documentation: reference documents, procedure manuals and tutorials. Reference documents help the user learn how to perform a specific function. Procedure manuals describe how to perform business tasks. A tutorial teaches a person how to use the system. It is useful to implement documentation navigation controls into the documentation.

Chapter 13 examines the activities needed to install the information system and successfully convert the organization using it. As well, post-implementation activities like system support, system maintenance and project assessment are reviewed. Installation and availability are relatively simple, but the training and organizational issue create the complexity of the process. The transition to a new system follows a model called Lewin's three-step model of organization change. The stages are freeze, move and unfreeze. To help unfreeze attachment from the current system, activities can be added to the systems analysis and design. The migration plan guides the movement from the as-is to the to-be system. Through support and maintenance the new system can refreeze it into everyday use.

A migration plan incorporates a number of elements that guide the transition from the old to the new system. Using selected and business contingency planning the organization's readiness can be developed. Through hardware and software installation and conversion of the data, the technology is prepared. People are ready to accept and use the new system through many channels. The channels to enforce the change are management policies, adoption motivation techniques and training.

The migration plan will be successful if the system analysts understand the sources of resistance to change and know the costs and benefits for the users.

Once implementation is complete, post work takes place. System support is done by the operations group who give online and help-desk support to the users. The support is divided into two levels. The first level staff deals with the majority of phone questions. Level 2 support staff follows up on challenging problems and sometimes generate change requests for bug fixes. Change requests are mainly focused on by system maintenance. The requests come from system support staff, other development project teams, senior management to fix the bugs and improve the business value. The goal of project assessment is to understand what is successful about the system and the project activities and what needs to be improved. The project team reviews focuses to the way that the project team carry. Finally, system review looks at understanding the extent to which the proposed costs and benefits form the new system that were identified during project initiation.

The last chapter, Chapter 14, discusses the encompassing of object-oriented concepts and techniques in systems analysis and design. Object-oriented system means a system that is viewed as a collection of self-contained objects that put together to form a system. The objects have both data and processes. They can be a person, place or thing that the user wishes to capture. All objects have unique attributes that describe the object. They are grouped into classes that are arranged into a hierarchical format. Polymorphism allows a message to be interpreted differently by different kinds of objects. This allows the objects to be treated as black boxes and ignore the detailed system. Encapsulation and information hiding allow an object to conceal its inner processes and data form the other objects. If object-oriented analysis and design use UML, the analyst can decompose complex problems into smaller manageable components. As well, using

UML allows the analyst to interact with the user employing objects from the user's environment rather than a set of separate processes and data. The object-oriented analysis and design can be modelled in one of four ways: use case diagram, class diagram, sequence diagram or behavioural state machine diagram.

A use case diagram demonstrates the main system functions and the different kinds of users that interact with it. The diagram includes actors and use cases which are separated by a system boundary and connected by lines representing associations. The actors are the people or things that derive value from the system and sometimes are specialized versions of general actors. Building a use case diagram requires five steps: identify the use cases, draw system boundary, add the use cases to the diagram, identify the actors and add appropriate associations to connect use cases and actors.

A class diagram shows the classes and relationships among the constant classes in the system over a period of time. The main building block of the diagram is a class. The class stores and manages information in the system. They have attributes that capture information about the class and about the operations (class actions). There are three types of operations: constructor, query and update. The classes are related to each other with an association. The association has a name and multiplicity that indicates the maximum and minimum instances that participate in the relationship. Special types of association include aggregation or generalization. They are used when classes comprise other classes or when one subclass inherits properties and behaviours from a superclass. The diagram is first created by identifying the classes and their attributes and operations. The relationships are then drawn among the classes to show associations. For the special associations, special notations are used.

A sequence diagram is a dynamic model that illustrates instances of classes that participate in a use case and message that pass between them over time. These diagrams are helpful for understanding real-time requirements and for complex use case scenarios. Objects are placed horizontally across the top of the diagram, each having a lifeline vertically below. The lifeline is just a dotted connecting line. The focal of control is represented by a thin rectangle. It is placed over the lifeline to show when the objects are sending or receiving messages. A message is a communication between objects that conveys information with the expectation that activity will ensue. They are drawn as an arrow connecting two objects that points in the direction the message is being passed. To start the diagram, first identify the classes that participate in the use case. Afterwards, add the messages that pass among them. Lastly, the lifeline and focus of control need to be added.

The final model is the behavioural state machine diagram. It shows the different states that a single instance of a class passes through during its life in response to events, along with responses and actions. A state is a set of values that describe an object at a certain point in time. It represents a point in an object's life where it satisfies a condition, performs action or waits for something to happen. An event is something that takes place a specific point in time and alters a value that describes an object, changing the object's state. Objects undergo transitions as they move from state to state. When drawing the diagram, rectangles with round corners are placed on the model to represent the various states that the classes will take. Next, arrows are drawn between the rectangles to show the transitions. Finally, event labels are written above the arrows to describe the event that triggers the transition.

References

[1] Arduino Mini USB Extension Board. *RobotShop.* [Online] [Cited: August 2, 2012.] http://www.robotshop.com/ca/productinfo.aspx?pc=RB-Ard-01&lang=en-US.

[2] ArduPilot Mega 2560 - Arduino Compatible UAV Controller. *RobotShop.* [Online] [Cited: August 2, 2012.] http://www.robotshop.com/ca/productinfo.aspx?pc=RB-Spa-701&lang=en-US.

[3] Arduino Duemilanove. *Arduino.* [Online] [Cited: August 2, 2012.] http://arduino.cc/en/Main/arduinoBoardDuemilanove.

[4] ATmega328. *Atmel.* [Online] [Cited: August 2, 2012.] http://www.atmel.com/devices/atmega328.aspx.

[5] ATmega168. *Atmel.* [Online] [Cited: August 2, 2012.] http://www.atmel.com/devices/atmega168.aspx.

[6] ATmega2560. *Atmel.* [Online] [Cited: August 2, 2012.] http://www.atmel.com/devices/atmega2560.aspx.

[7] *SBS Transit.* [Online] [Cited: August 2, 2012.] http://www.sbstransit.com.sg/.

[8] BC Transit Corporation. handyDART. *BC Transit.* [Online] 2009. [Cited: August 2, 2012.] http://bctransit.com/regions/cfv/accessible/handydart.cfm.

[9] Aesys S.p.A. Stationary Systems. *Aesys.* [Online] 2012. [Cited: August 2, 2012.] http://www.aesys.com/products-solutions/bus-systems/stationary-systems.

[10] Carmanah Gets Orders for LED Signs and Bus Stops. *LEDs Magazine.* [Online] May 2006. [Cited: August 2, 2012.] http://ledsmagazine.com/news/3/5/20.

[11] Mandex Motion Displays. Expandable and Flexible LED SIGNS. *LEDsignage.* [Online] 2011. [Cited: August 2, 2012.] http://www.ledsignage.com/flexible.

[12] PCM Electronic Signs. *PCM Signs.* [Online] [Cited: August 2, 2012.] http://www.pcmsigns.com/.

[13] PCM Signs. *STARFIRE LED Sign Specifications.* [Online] [Cited: August 2, 2012.] http://www.pcmsigns.com/starspec.htm.

[14] Winnipeg Tranist. *Winnipeg Tranist.* [Online] 2012. [Cited: August 2, 2012.] http://winnipegtransit.com/en.

[15] Winnipeg Transit. Innovation in Motion. *Winnipeg Transit.* [Online] [Cited: August 2, 2012.] http://winnipegtransit.com/en/inside-transit/innovation-in-motion/.

[16] Viswanathan, Priya. 3G Vs 4G – Which is Better? *About.com.* [Online] [Cited: August 2, 2012.] http://mobiledevices.about.com/od/carrierfaq/a/3g-Vs-4g-Which-Is-Better.htm.

[17] Santos, Wendell. 45 Transit APIs: Yahoo Traffic, SMSMyBus and BART. *Programmable Web.* [Online] February 14, 2012. [Cited: August 2, 2012.] http://blog.programmableweb.com/2012/02/14/45-transit-apis-yahoo-traffic-smsmybus-and-bart/.

[18] Lane, Kin. Short List of RESTful API Frameworks for PHP. *Programmable Web.* [Online] September 23, 2011. [Cited: August 2, 2012.] http://blog.programmableweb.com/2011/09/23/short-list-of-restful-api-frameworks-for-php/.

[19] The OneBusAway RESTful API. *OneBusAway.* [Online] May 11, 2012. [Cited: August 2, 2012.] http://developer.onebusaway.org/modules/onebusaway-application-modules/current/api/where/index.html.

[20] E-BUS Bus Dynamic Real-Time Information System. *AsiaTEK.* [Online] [Cited: August 2, 2012.] http://www.asiatek.com.tw/products/products-software-detaildfb4.html?ID=1.

[21] Upton, Chad. Posts Tagged 'nfc' - NFC vs QR Codes. *YYZ New Toronto Group.* [Online] December 4, 2011. [Cited: August 2, 2012.] http://www.newyyz.com/ntgsite/tag/nfc/.

[22] Wozniaki, Tanya. NFC versus Bluetooth. *Near Field Communication NFC.* [Online] 2012. [Cited: August 2, 2012.] http://www.nearfieldcommunicationnfc.net/nfc-vs-Bluetooth.html.

ELEC/CENG 399 Design Project I Final Project Report Evaluation Form

To be filled by students:

Project title:___ Design a Smart Bus System ___________________________

Group #:___6____

Group members:_ Benson Hung, Emily Huang, Lara Juras, Xiaoya Guo, _____

Supervisor(s):___ Dr. Fayez Gebali, Dr. Kin Fun Li, Dr. Michael McGuire __

To be filled by the supervisor(s):					
Progress report distributed to the supervisors for grading: Friday, August 3, 2012					
Please complete the progress report grading by: **Friday, August 17, 2012**					
Please refer to the rubric for grading.					
Topics					Grade [%]
[5%]Chapter 1, Goals :					
[10%]Chapter 2, Progress Overview:					
[25%]Chapter 3, Detailed Project Description:					
[25%]Chapter 4, Workload Distribution and Achievements:					
[10%]Chapter 5, Project Discussion:					
[5%]Chapter 6, Summary and Future Works:					
Subtotal [80%]:					**0.0**
To be filled by the instructor:					
[20%]Appendix A: Textbook Review	[10%]Write the textbook review in a clear				
	[10%]Meet minimum page requirement (2 pages):				
	Subtotal [20%]:				**0.0**
Total [100%]:					**0.0**

Comments by the supervisor: