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Bus Coming: Description and Evaluation of Bus Tracking System for Rural Areas

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Abstract

The Bus Coming system provides bus location information to passengers taking into consideration the location of the bus as well as the location of the passenger. For rural areas this is an improvement over current bus stop based systems, given that bus stops are few in rural areas and many stops and pick-ups are made away from bus stops. The useful information provided in cities about buses with respect to a bus stop like bus's distance away, estimated time of arrival of bus, current location of the bus etc. can now be given to passengers of rural areas with the results being personalized to the passenger's current location. Bus Coming acquires both bus and passenger locations through the use of relatively cheap GPS location capable, internet connected mobile devices (mainly smart phones) which cannot be relied upon for accuracy. Bus Coming uses a Reference Point system to compensate for the inevitable inaccuracies of the locations received from the mobile devices. The accuracy of the association of raw location data received from the mobile devices to appropriate Reference Points is critical to the usefulness of the Bus Coming system. The core communication technology behind the system is based on Web Services and results demonstrate that this simple approach is accurate and appropriate for rural areas in Trinidad.

Keywords: *GPS; smart phones; rural areas; webservices.*

1. Introduction

Bus tracking services have recently (within the last 3 years) been introduced in some metropolitan areas. Chicago, Washington DC and London are a few cities that have implemented some form of advanced bus tracking services. These services are usually comprised of a GPS equipped fleet of buses and these locations are feed to a central server which then makes the locations available to different readers, web sites (basic lists or graphical representations like map overlays), electronic signs at bus stops, SMS for bus locations at particular bus stops and even mobile applications for smart phones that gives the location of buses on a particular route with respect to bus stops.

In rural areas there are limited bus stops, thus knowing where the bus is relative to a bus stop may not always be very useful. In rural areas knowing where the bus is relative to the passenger is much more useful. This type of passenger based information would be like, bus's distance to passenger, estimated time till the bus gets to passenger, has a bus already gone past a passenger and others. Bus location information can be personalized to better reflect the rural situation which is that, the bus stop is technically wherever the passenger is waiting. Passenger locations can be generated and provided by many connected mobile phones [1]. The locations generated by the mobile devices are associated with the reference point nearest it. This allows the system to be consistent with the points that are used to perform calculations like distance to passenger and estimations like time to passenger; while still being able to display visually consistent locations of buses on a Google Map

Transport in the West Indies is difficult for many especially for those that live in rural areas. Many people depend on Government provided buses to get to and from their homes daily. This bus service, however, is not reliable. Buses are scheduled to run at certain times of day but many issues can and usually do account for delays that then cascade down to other scheduled times causing predefined schedules to be useless. Routes to rural areas are assigned few buses and thus if there is a problem with a rural route bus, there are not many buses that can pick up the slack. Currently, there is no way for an individual in a rural area to access the bus transportation options available to him/her at any given time.

This lack of information can lead to long waits or worse, waiting in vain for a bus that never arrives. If passengers were provided with near real time information about the location and status of buses servicing their areas then these issues would be alleviated, improving the passenger's travel experience and allowing passengers to make more efficient use of their time.

Over the past two to three years, BlackBerry smart phones have been introduced to the West Indies on a large scale. Research In Motion (RIM) [2, 3] the company that manufactures BlackBerry smart phones also provides a developer platform that allows application developers to extend the functionality of the BlackBerry smart phone. This platform provides developers with access to built-in devices such as Global Positioning System (GPS) [4] receivers allowing them to utilize the functionality in the applications that they develop.

The Bus Coming system proposed in this paper uses the BlackBerry developer platform with the built-in GPS receiver in the BlackBerry smart phone to build a relatively cheap bus tracking system. The system will provide passengers with near real time bus location and status information with respect to the passenger's current location, not bus stops as is usually done. This will improve the travel experience of passengers in rural areas (where there are few bus stops) and allow them to make more efficient use of their time.

This paper is organized as follows: Section 2 gives a literature review of existing bus tracking systems in metropolitan countries and explains why such systems may be unsuitable for the West Indies; Section 3 explains the current bus tracking systems used in the West Indies; Section 4 describes the approach taken for development the Bus Tracking system which is based on both GPS mobile devices and the mobile cell phone network, as well as its showcases its development motivation; Section 5 describes and explains the methodology used to evaluation the Bus Coming System and Section 6 concludes the paper.

2. Literature Review

In Chicago, the Chicago Transit Authority (CTA) [5] provides a group of services to their passengers, this group of services is defined as CTA Bus Tracker. CTA Bus Tracker uses GPS devices placed on each bus to report bus location data (and more) back to their servers. They then provide real time services which allow passengers to know where buses are. CTA lets passengers know the location of buses via:

[1] "bus times" - A web page that lists estimated arrival times at designated bus stops. Figure 1 shows an example of the "bus times" Web Page.

[2] "bus map" - A graphical display of information about bus location relevant to selected stops. The map controls allow the user to provide information such as route and stop, then the system provides the relevant information to the user.

[3] "track by text" - This is a text messaging service that allows the passenger to text the bus stop number (shown on the bus stop sign) to a pre-defined number (41411 in CTA's case). Aresponse is then received by the passenger with information about the buses coming to the passenger's stop and the estimated time it will take the buses to get there.

[4] "subscribe" - This allows passengers to sign up for service updates and arrival alerts via email or text message

In Washington DC, the Washington Metropolitan Area Transit Authority (Metro) [6] provides a group of services to their passengers, this group of services is defined as Next Bus. Next Bus allows passengers to determine the next arrival time of all stops in the Metro bus system. Next Bus technology uses GPS to track buses on their routes every 120 seconds. Taking into account actual bus positions, intended stops and typical traffic patterns, the system estimates the bus arrival times. Next Bus is available to passengers via:

[1] "Desktop Web" - A desktop web interface that allows passengers to view current and coming arrivals at selected stops in three ways: Route Search, Route Live Map and Route Timetable. Figure 2 shows a sample of the "Desktop Web".

[2] "Mobile Web" - A mobile version of the "Desktop Web" that allows the user to select stop, route and route direction after which the system will provide the user with arrival information with respect to the selected stop.

[3] "Phone Calls" - Passengers can access bus stop arrival time information via phone calls to Metro Customer Service. This service allows the passenger to navigate an audio menu via the passengers voice or by touching numbers on the phone's keypad. The menu requests bus stop number and once said by the passenger the service responds audibly with the estimated arrival times at the stop indicated.

[4] "Electronic Message Signs" - Electronic message signs at metro stations let passengers know the length of time till arrivals and departures from stations. There are also signs installed in station corridors. Some signs are equipped with speakers to assist the visually impaired.

In London, Transport for London (TFL) [7] provides a service called Countdown. Countdown provides real-time arrival information for bus passengers at key stops throughout London as shown in Figure 3. When passengers arrive at these key stops they can view the estimated time to arrival of buses to that stop. TFL is also providing bus arrival time information via SMS (text messages) and Web.

The three systems described above are very useful within their environments, however, given an environment where bus stops are few and far between then their usefulness decreases. Instead of a bus and bus stop based system; a bus and passenger based system would be more effective.

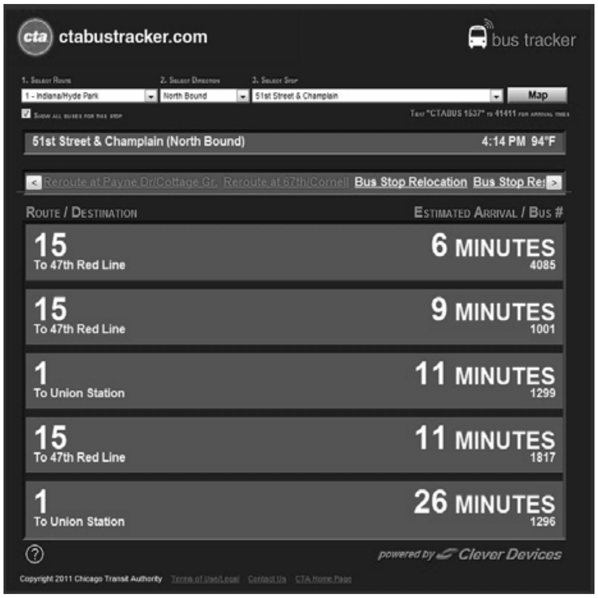

Fig. 1 CTA "bus times" Web Page

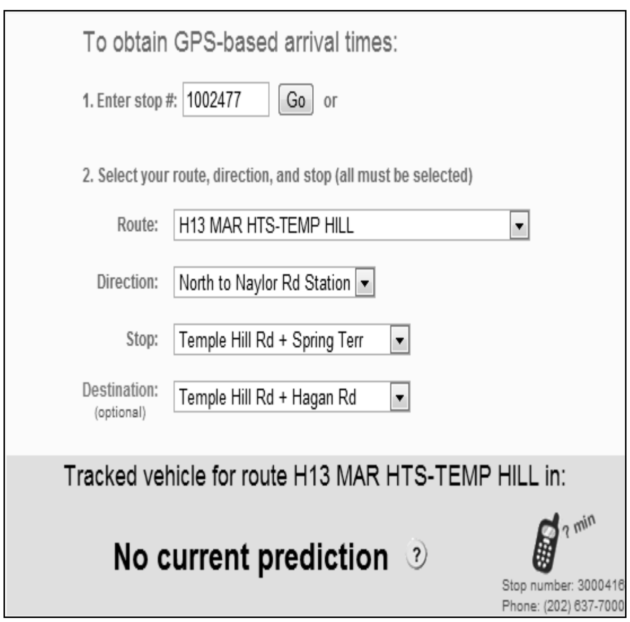

Fig. 2 WMATA "Desktop Web" Route Search

Fig. 3 TFL Countdown Signs

3. Lack of Bus Tracking in Trinidad

Territories like Jamaica [8], Barbados [9] and Trinidad and Tobago [10] have transport authorities that provide semi-static scheduling via hard copy or rarely updated websites. These schedules are seldom exact and thus cannot be relied upon. Especially in rural areas, where there is no assistance or information available from the transport authority about bus availability or location thus it is difficult to access bus transport in an efficient manner. The introduction of a system like the ones currently in use in Chicago, Washington and London to predominantly rural areas like those existent in the West Indies, may introduce problems. For example, passengers will not be able to get relevant information with respect totheir location, but with respect to a bus stop's location, that may be quite some distance away.

Systems like the ones in use in Chicago, Washington and London comprised of a GPS equipped fleet of buses and these locations are fed to a central server which then makes the locations available to different readers, web sites (basic lists or graphical representations like map overlays), electronic signs at bus stops, SMS for bus locations at particular bus stops and mobile applications for smart phones, that gives the location of buses on a particular route with respect to bus stops.

In metropolitan cities buses strictly stop at predefined bus stops, because of this the bus tracking systems implemented in these cities are focused on bus locations with respect to bus stops. In the West Indies, especially in rural areas, this approach will not work as designated bus stops are few and far between. It would not be practical to

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expect every person living in these areas to walk to the stop nearest them, as the nearest one can be kilometres away. Due to the scarcity and distance between bus stops, buses do not strictly stop at pre-defined bus stops, in many cases, a bus driver will stop for passengers at multiple non-bus stop locations along the route. The wait time for the bus to arrive at the next stop in these areas, is much less useful than the time for the bus to arrive at the passenger's location along the route. Therefore, building a bus tracking system based on each *passenger's current location* would be very useful for rural areas.

4. Proposed Solution

Internet access is a key component of this system. Trinidad and Tobago, like many other countries in the West Indies is seeing consistent positive growth in both fixed and mobile internet access. In Trinidad and Tobago, Q1 2012 over 50% of households have internet access, with 98% of those having broadband access, this is up 14% over the previous year. While mobile internet access is down 5% compared with last year, the recent and upcoming launch of local broadband mobile networks is expected to return positive growth to mobile internet subscribers. [10] With mobile internet coverage close to 100% in Trinidad and Tobago and general internet usage trending upwards, an internet based solution to the bus tracking problem in the West Indies is very feasible.

A system is needed that takes the passenger's location into consideration. In order to give information about the bus's location with respect to the passenger's location along the route, the passenger's current location along the route is required. The passenger's location along the route would be treated in much the same way as a bus stop would be, without having to erect an unreasonable number of stops along the route. With the passenger's location along the route, the system can tell the passenger the amount of time to the next bus or buses with respect to the passenger's current location.

GPS capable smart phones were used to provide near real time bus location information by placing a GPS capable smart phone on a bus and the phone would submit its current GPS location periodically.

4.1 Reference Points

Google Maps was used to provide a map with near real time bus location overlays. However when the GPS locations generated by the mobile devices were plotted directly onto the Google Map of Trinidad the results were inconsistent. Reference Points were used to help associate the GPS locations generated by the mobile devices with visually consistent positions on the Google Map.

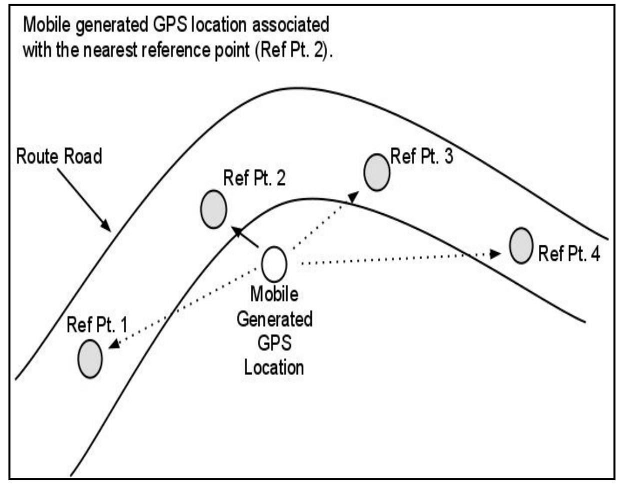

Fig. 4 Mobile GPS location associated with Nearest reference point

Reference Points are positions along each route that visually correspond to locations on a Google Map of Trinidad. The GPS locations generated by the mobile devices are associated with the reference point nearest it. This allows the system to be consistent with the points that are used to perform calculations like distance to passenger and estimations like time to passenger; while still being able to display visually consistent locations of buses on a Google Map.

Selecting the best reference point for given raw location data is the crux of the Bus Coming system. The fact that roads could double back in much like a horse shoe fashion, caution must be taken when assigning the closest reference point. For example, in Figure 4, no reference point of a route can be excluded from consideration when deciding the current closes reference point. A basic priority queue was used to accomplish this. The priority queue was ordered such that the reference point closest to the raw location data would be at the front. Once all reference points of a route have been added, the reference point at the front should be the one closest to the raw location data and thus the most appropriate representation of the bus's or passenger's location.

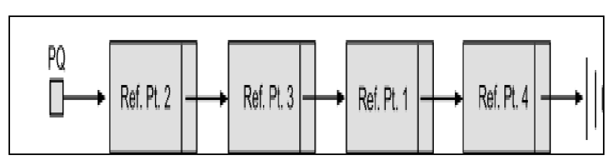

Fig. 5 Priority Queue

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Reference points provide a solution to the inconsistencies between mobile generated GPS locations and positions on a Google Map. They also provide two benefits as a side effect.

1) Easy calculation of distance between different positions along a route, since a straight line could be drawn from each reference point to the next without going off route. This provided a way of easily calculating distances along winding routes which are common in rural areas.
2) Easily calculate the availability status (coming or gone) of a bus with respect to a passenger along the route. If a passenger is associated with Ref. Pt. 2 and a bus is associated with Ref. Pt. 3, since 3 is greater than 2 we can let the passenger know that that bus has already gone.

The skills and technology required to produce a system that provides both passengers and bus operators with near real time bus location information can be built using readily available and relatively cheap technology involving programmable GPS devices (BlackBerry smart phones in this case, however any programmable GPS capable device would do, eg: Android, IOS, Symbian devices). The availability of fairly cheap programmable GPS enabled BlackBerry smart phones makes a bus tracking system implementable at a relatively cheap cost and in a relatively short period of time with minimal disruption to the current bus operations.

4.2 Components of the BusComing System

The proposed Bus Coming system consists of four components. Figure 6 shows how these components relate to each other.

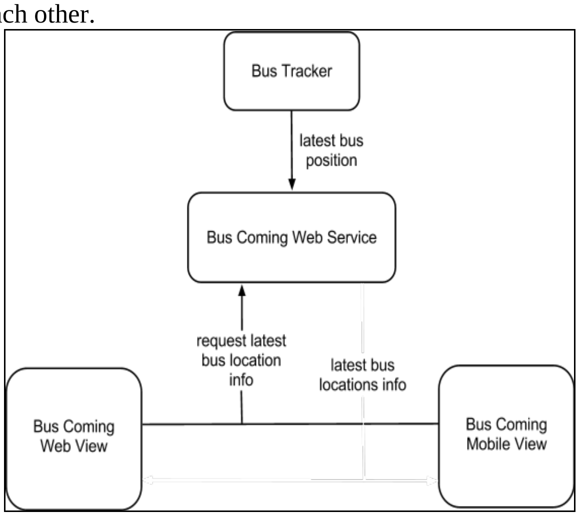

Fig 6 Bus Coming Overview

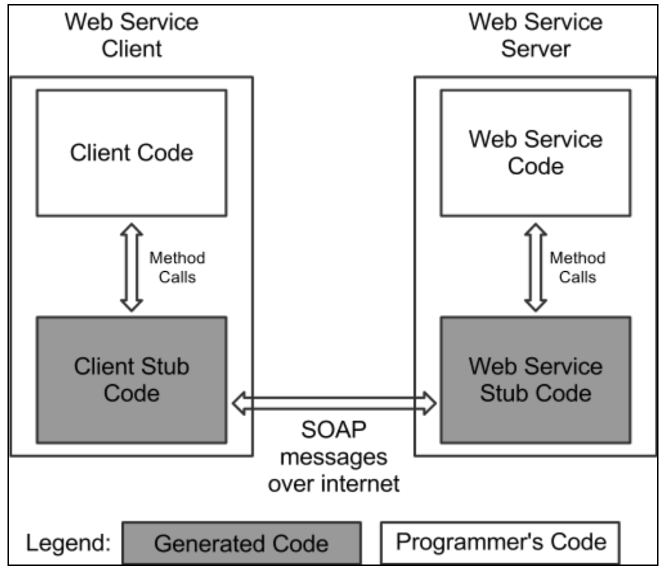

Fig 7: Bus Coming Overview

1) Bus Coming Web Service

This is a web service [11] that allows all other parts of Bus Coming System to submit information to the server (for example the Bus Tracker component submits information to this web service) or request information from the server (for example the Bus Coming Web and Mobile Views).
Standardised web services are used to provide the ability for multiple platforms to work within and around the system without any major changes. This accomplished with the use of the SOAP protocol as shown in Figure 7. The BlackBerry smart phones used could easily be replaced by one or more of many other web service compliant GPS capable devices.
Parts of the Bus Coming Web Service could be made public, allowing third party developers to use the data in interesting ways.

2) Bus Tracker

This is an application running on a GPS capable blackberry, the blackberry is placed on a desired bus to track its location. Figure 8, shows the Bus Tracker application and the interface where the bus driver selects the bus and route. Note that the tracker transmits the bus current location of the bus to the server via a web service periodically.

Operators expressed concern about the bus driver having to initiate the tracking along a journey, so considerations are being made to have the tracking remotely initiated by central operators.

Fig. 8 Bus Tracker Application

Bus Coming Tracker must be given some information before tracking can begin. Figure 9, shows a sequence diagram outlining the steps involved. The user that initiates the tracking (the bus driver) would set the bus name and route before the bus begins to move. Once the bus name and route are set and the bus driver is ready to begin the journey, the driver selects the "Start Track" button and then tracking begins. Bus Coming Tracker lets the Bus Coming Web Service know that it is starting to track by using the ***setBusRoute*** service, which sets the bus's current route and the time at which tracking has begun.

Once tracking has been initiated, Bus Coming Tracker frequently submits, every five seconds or so, the location of the BlackBerry device and thus the location of the bus, via its built in GPS receiver to Bus Coming Web Service via the ***busCheckIn*** service. These frequent submissions are used by Bus Coming Web Service to provide Bus Coming Web View and Bus Coming Mobile View with information about the bus's location.

3) Bus Coming Web View

This is a web view of all routes in the system and all buses on those routes. Figure 10 shows a Google Map web page of this component which is typically used by passengers using a home computer or can be used by the central control station of the bus service department. This web view is interactive and allows the user to view routes of interest. In addition, the site is updated in near real time as periodic AJAX[13] calls are made to the web service to get new data and update the web view accordingly displaying the position of buses as received by Bus Tracker.

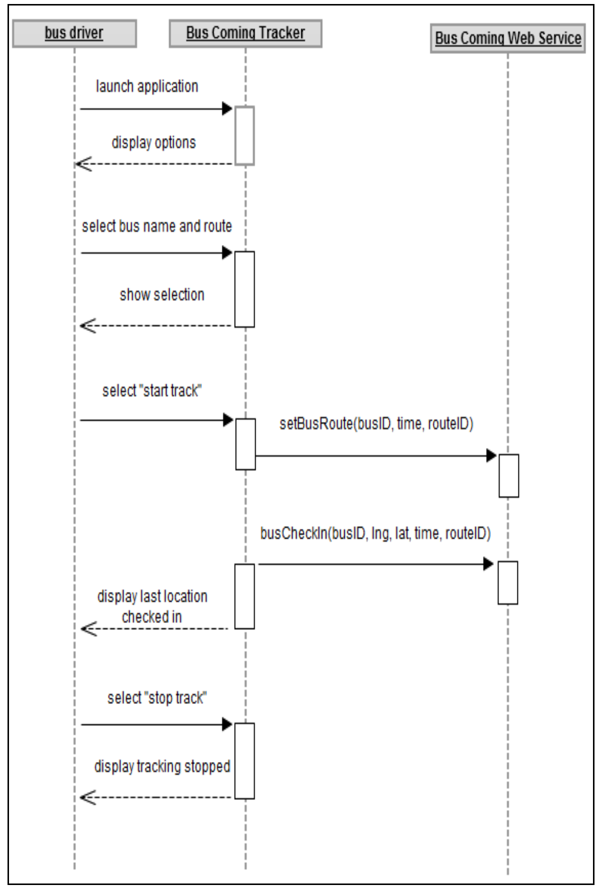

Fig. 9 Bus Tracker Sequence Diagram

Google provides API access to their Google Maps system. Through this API, developers can include Google Maps in their web applications. Overlays are added onto the Google Map to show a map with customized information on it, for example reference points along a bus route. Figure 12 shows a sequence diagram which illustrates how the ***getRefPoints*** capability of the web service is used by the web viewer to retrieve latitude and longitude of each reference point along a particular route.

Using the ***getBus*** capability of the Web Service, information containing the latitude, longitude and area of each bus currently on a particular route is retrieved. Google Maps is then instructed to display the bus.

4) Bus Coming Mobile View

This is an application running a GPS capable blackberry, the application allows the user to select a route and view all buses on the route and see whether or not those buses are coming towards them or if they have already gone past. Figure 11, illustrates that the bus is 20 minutes away from the position of the passenger who requested the service.

Fig. 10 Google Map showing Bus Locations

Fig. 11. Mobile View for Passengers

From the list of routes the passenger can select the route that the passenger is on. Once the route selection has taken place Bus Coming Mobile View will get the passengers location from the GPS receiver, this location along with the ID of the selected route is submitted to Web Service using a call to ***getBusesOnRoute***. The Bus Coming Web Service then returns a string array containing information about all the buses currently servicing the selected route. This information is initially displayed to the passenger as a button list with the name of the bus and its coming or gone status on the button. If one of the buttons representing a bus is selected more detailed information about the bus will be presented to the passenger with respect to the passenger's current location. This detailed information includes the current area of the bus, the bus's distance away from the passenger, the bus's current speed, the estimated amount of time it will take the bus to get to the passenger, the distance of the bus from its final destination and the estimated amount of time it will take the bus to get to its final destination.

The location of the passenger that is calculated by the device's GPS receiver and submitted to Bus Coming Web Service, is, as with buses, associated with the closest reference point along the route. All calculations with respect to the user are really taking place with respect to a reference point along a selected route. As with buses this is done to account for any inaccuracy of the GPS receiver. If a passenger lives down a street of the route and uses Bus Coming Mobile View, the passenger will get information as if the passenger was standing on the route at the top of the passenger's street.

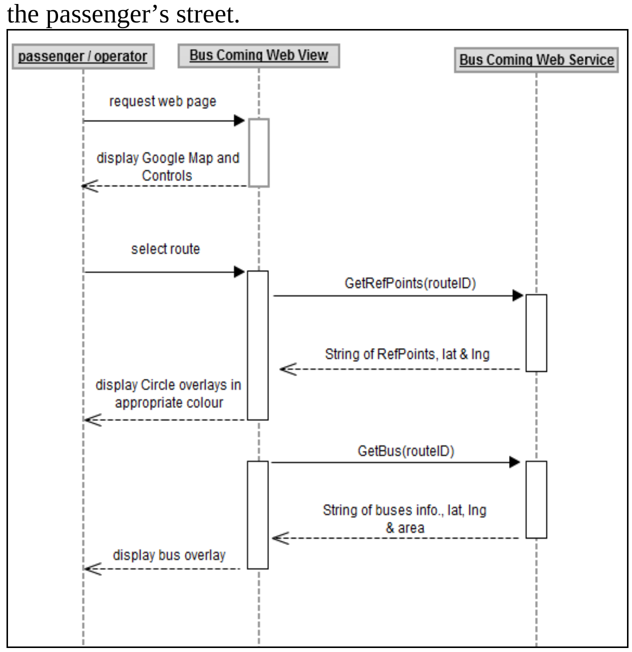

Fig. 12 Bus Coming Web View Sequence Diagram

4.3 Bus Coming Data Model

Bus Coming Web Service runs on top of a MySQL database, this provides storage and retrieval of data required to respond to requests. The Bus Coming data model consists of the following entities:

- bus - This stores basic information on buses within the system, as well as the current route of all buses. The lastupdate field of the bus entity is set when a bus is put on or taken off a route, this field is used to ensure that the speed calculation does not take into account old location values of a particular bus.
- position - This stores all of the position data submitted by the Bus Coming Tracker running on a smart phone device on each bus. The position of a bus is never destroyed so that it can be used later to trace the historical movements of a particular bus. These values are also used to calculate a bus's speed and thus time to destination.
- refpoint - This stores the exact location of all points along all routes. Since the values of latitude and longitude returned by the GPS receiver are not always accurate, reference points each called refpoint is used to associate the location returned by the GPS receiver with an actual location along a route. This will allow for more accurate calculations of distance and speed. Also refpoints allow the Bus Coming Web View to show the location of buses along the route and not have buses being shown over houses and buildings.
- route - This simply stores the name and id of the routes in the system.

5. Evaluation of BUS COMING Project

To test the distance accuracy of the Bus Coming system the physical locations of fixed reference points along a given route were identified. The route was then travelled in a given direction and this was considered a pass. Several passes were made along the same route. Along each pass known reference points were identified and the time at which the test vehicle arrived at each known point was logged. For example, Table 1, shows examples of known reference points and their locations along the test route. The tracker application was adjusted to submit locations as often as possible. The tracker locations would then be associated with a reference point and it will be noted whether or not the reference point selected by the system matched the reference point logged – the travelling speed was also recorded.

Since we expect the tracker to sometimes provide inaccurate location information we would like to see whether or not the inaccurate locations were being associated with the correct corresponding reference points. Table 2 shows a set of passes for each reference point along the route. The column legend for Table 2 is:

a – Pass number
b - Time of Manual Location
c - Expected Ref Point association
d - Best Time of Tracker Location
g - Actual Ref Point association
h - Distance between raw location values and expected ref point location

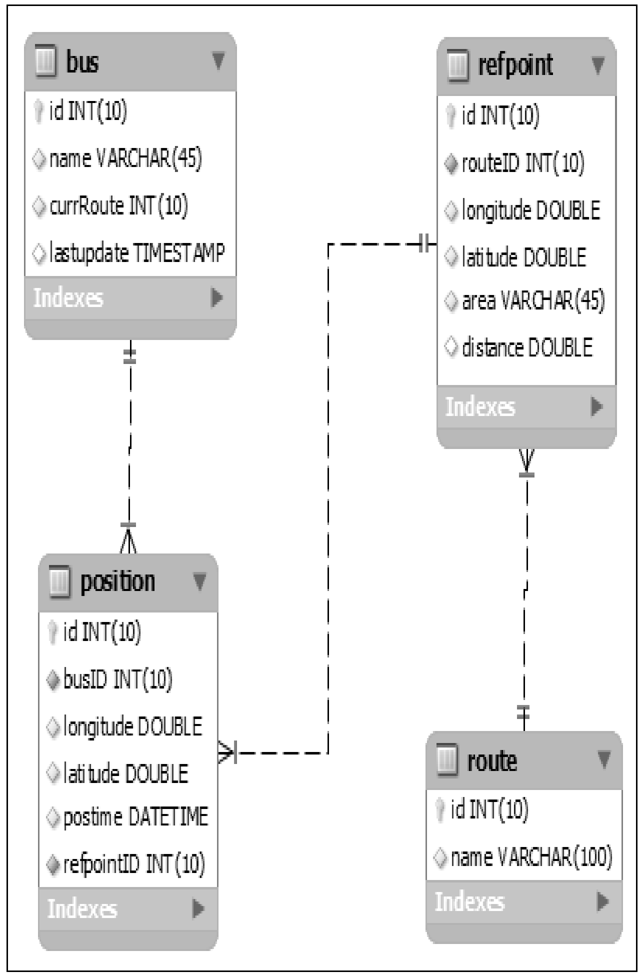

Fig. 13: Bus Coming Data Model

4.1 Analysis of Results

From Table 2 it can be seen that 94% of the reference points were correctly associated with the fixed locations. The only exception was the second row in the table. In

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addition, if we look at the compensations made by the system to associate the raw location data with reference points, it can be seem that the average distance required for compensation was 26.5m, thus reference points should be placed at least this distance apart to ensure the system shows correct direction of travel. Figure 14, shows another view of the information presented in Table 2.

During pass 2 the tracker stopped submitting locations shortly after crossing the third known reference point, thus only 3 locations were reported on for pass 2. Also during pass 4 the tracker stopped submitting locations shortly after crossing the first known reference point, thus only 1 location was reported on for pass 4.

While some known reference points were not reported on during pass 2 and pass 4, this does not affect the usefulness of the reported locations during these passes, therefore the results of these passes were kept.

There seemed to be no relation between speed and accuracy. The most accurate reading was from pass 2 at reference point 819 whose raw location data indicated a location 3.7m away from the actual location. This reading was submitted while traveling at 85 KM/h.

The second most accurate reading was from pass 2 at reference point 827 whose raw location data indicated a location 5.95m away from the actual location. This reading was submitted while traveling at 94 KM/h.

The least accurate reading was from pass 5 at reference point 827 whose raw location data indicated a location 32.88m away from the actual location. This reading was submitted while traveling at 95 KM/h.

The second least accurate reading was from pass 1 at reference point 819 whose raw location data indicated a location 31.45m away from the actual location. This reading was submitted while traveling at 70 KM/h.

More data may bear out a more identifiable trend, however given the current data no relation can be found between speed and accuracy of the location data.

Table 1: Examples of known Reference Points

Reference Point Number	Latitude	Longitude
793	10.528088	-61.409417
818	10.546233	-61.412893
819	10.546728	-61.412981
827	10.552659	-61.414057
837	10.560683	-61.41554

Table 2: Data from each pass made along the same route

a	b	c	d	g	h
1	22:22:04	793	22:22:04	793	37.65 m
1	22:23:52	819	22:23:52	818	31.45 m
1	22:24:27	827	22:24:27	827	30.03 m
1	22:25:17	837	22:25:17	837	15.11 m
2	15:54:40	793	15:54:40	793	21.09 m
2	15:56:17	819	15:56:17	819	3.7 m
2	15:56:47	827	15:56:47	827	5.95 m
3	16:32:21	793	16:32:21	793	29.47 m
3	16:33:45	819	16:33:45	819	13.62 m
3	16:34:15	827	16:34:15	827	24.86 m
3	16:34:52	837	16:34:52	837	26.94 m
4	16:59:25	793	16:59:25	793	19.63 m
5	17:28:52	793	17:28:52	793	28.42 m
5	17:30:10	819	17:30:10	819	20.23 m
5	17:30:34	827	17:30:34	827	32.88 m
5	17:31:13	837	17:31:13	837	22.83 m
6	17:47:53	793	17:47:53	793	16.73 m
6	17:49:15	819	17:49:15	819	15.05 m
6	17:49:41	827	17:49:41	827	19.57 m
6	17:50:21	837	17:50:21	837	16.62 m

6. Conclusion

Typical bus tracking systems perform real time collection of the positions of buses by GPS and bus system operators use this information to manage its operations and provide customers with the positions of buses, expected arrival times and other information. These systems typically require a lot of capital to implement and are better suited for metropolitan cities where there is a dense network of bus stops. However, given an environment where bus stops are few and far between, their usefulness decreases. Instead of a bus and bus stop based system this paper presents a bus and passenger based system which is more applicable for the West Indies where there are many rural communities.

The Bus Coming tracking system proposed in this paper has shown to be capable of effectively compensating for the inaccuracies associated with raw location data generated by consumer level mobile devices (smart phones). Thus even very low cost devices without accurate location capabilities can be used within the Bus Coming system to extract accurate location data.

Given the accuracy of the Bus Coming system, rural areas should look first to a bus and passenger based bus tracking system thereby providing more useful information than a bus and bus stop based bus tracking system.

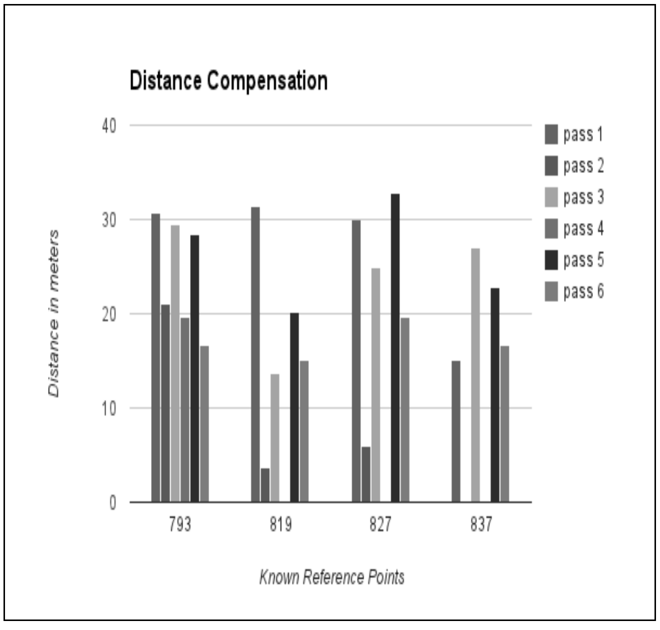

Figure 14: Data from each pass made along the same route

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