A Mobile Application Implementing Hybrid Method for Localization for Public Bus Service Using Multilateration and Fingerprinting Technology

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Abstract – In this paper, our main aim is to track the public buses in an area and update the information about the whereabouts of the buses to passengers using GSM-based hybrid localization, that is multilateration and fingerprinting technology. A GSM modem will be able to get the CELL’s location and extract the received signal strength from the neighboring cells. By using the multilateration concept the localization error can be reduced to a range of less than 50 meters. The difficulty in solely using multilaterating method using Signal Strength (SS) is in determining a way to convert SS to Transmitter-Receiver (T-R) distance accurately. So along with multilaterating method, fingerprinting concept is also applied which is to, initially, establish a database that contains the measurements of wireless signals (that is, the SS) at some Reference Points (RP). Then the location of the Mobile User (MU) can be identified by comparing their Signal Strength (SS) measurements with the reference data. This concept can be used for public bus tracking system instead of currently tested GPS tracking system as this will be very much cost effective. Knowing the whereabouts of the bus, the people waiting in the bus stops can be alerted and the estimated time of arrival of the bus can be displayed. In this paper we have enhanced the above mentioned feature by creating a mobile application the makes the users clearly informed about the arrival of the next bus for the same route thereby predicting their travel.

Keywords – Time Difference of Arrival (TDOA) , Angle of Arrival (AOA) , Trilateration , Location Based Service (LBS).

I. INTRODUCTION

To see a group of people waiting at a bus-stop, having impatient looks on their faces, looking anxiously at their watches, pacing around the bus stop is a very common sight in today’s world. Everyone will be looking into the far distance hoping their bus will eventually appear in sight, oblivious to the time of arrival of the bus.

The awkward physical experience of waiting for a public bus on a hot summer day is soon to be a thing of the past. The advent and progressive developments in mobile telecommunication, the Internet and WWW technologies have together simplified and facilitated man’s desire to be in touch and contactable anytime, anyplace.

The set up technologies could be achieved using various already existing mechanisms, following a number of ways.

Bus is a very common public transport in most countries. For the past years, Public Bus service Operators have been thinking of different ways in improving their services. One of the most important services is providing bus service information to commuters. With the fast advancing rate in technologies, more advanced ways are been considered in providing the information.

II. OBJECTIVE

- To provide real time bus service information
- To be able to handle emergencies in bus services (breakdown, accidents, etc.)
- To ensure tracking of bus services using GSM effectively
- To familiarize with GSM communication network
- To establish communications via GSM mobile


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III. CONCEPT

GSM is a widely spread wireless network to allow mobile users to communicate wirelessly. The concept of Location Based Service (LBS) comes into the picture when we talk about localization. LBS is used to find the area of location of the GSM receiver.

The Base Station measures Time Difference Of Arrival (TDOA), Angle Of Arrival (AOA) in order to calculate the location of the GSM receiver. By using the TDOA the base station can calculate the difference in time $\Delta t$. The distance from the base station can be calculated by using the formula

$$r=\Delta t \times C$$

Where $C$ is the velocity of the light and $r$ is the distance calculated from the corresponding base station. By knowing the angle and distance from the base station, we are able to find the location of the GSM receiver.

This system is not effective enough in localization. Here the error of approximation more than 200 meters which is too large to be accepted.

In order to reduce the problem of error in approximation, the concept of multilateration can be used by calculating the distance $r$ from many different neighboring base stations. Here we have considered three neighboring base stations. The calculation of distance from three neighboring base stations would result in an error approximation of less than 50 meters, which is at an acceptable range.

This error of approximation can further be reduced by using fingerprinting technology at specified location points. In this we pre-calculate the TDOA and AOA of certain Reference Points (RP) and maintain the database. This forms the training phase.

During the Positioning phase the TDOA obtained will be compared with the database and the location is obtained. This concept can be implemented for tracking the fleets of the Public Bus Transportation System. The location of each and every bus can be tracked and the information about the arrival of the bus can be displayed at the corresponding bus stops.

IV. ORGANIZATION OF THE SYSTEM

- Base Stations to Calculate the TDOA and AOA of the GSM Transceiver present in the Bus
- Using Multilateration to find the location of the bus to be tracked
- The error in location is further reduced by using fingerprinting technology
- A supervisory system coordinates tracking of every bus and displays the corresponding information to the subsequent bus stops of the corresponding bus

V. MECHANISM

1.) Mechanism of obtaining TDOA and AOA:

Every Bus is fixed with a GSM modem such as GM28 Sony Ericsson Modem as shown in Fig. 1. Each modem will be able to transmit signals to all its neighboring base stations. A typical modem will be able to communicate with 6 to 7 base stations around it.

The Base stations are fixed with timed and directional antennae. Since the modem communicates with many base stations, all of them will be able to obtain their corresponding TDOA and AOA.

![Fig. 1: GM28 Sony Ericsson Modem](image)

2) Mechanism Of Multilateration

The distance of the GSM receiver from the different base stations are calculated by using the TDOA. We need at least 3 such values so as to apply multilateration concept and locate the position.

![Fig. 2: The concept of trilateration.](image)
In trilateration, a circle is drawn with one of the distance $r_1$ calculated with that base station as centre. This is shown in Fig. 2 (a).

Supposing that the distance calculated from second base station is $r_2$, a Circle with radius $r_2$ and centre as base station 2 is drawn and it is seen that it intersects the previous circle at two points. This is shown in Fig. 2 (b).

Similarly, let the distance $r_3$ be the distance from base station 3 and a circle drawn with $r_3$ as radius meets the previous two circles at a point. This is shown in the Fig. 2 (c).

The concept of multilateration brings down the error of approximation in localization. We are able to reduce the error of localization from a range more than 250 meters to an acceptable range of less than 50 meters. This concept can be used in tracking the bus fleets in Public Bus Service.

The buses need to simply be affixed with a GSM modem for tracking its location. By knowing the whereabouts of the bus, the information regarding the expected time of arrival of the bus can be displayed in the corresponding bus stops.

Here, the error of approximation is about 50 meters. But such an error is within acceptable limits for the case of bus localization. This is because that the distance of 50 meters is just equivalent to about 5 seconds in real time. Thus the error of 5 seconds in predicting the expected time of arrival of a bus in a bus stop would not be a draw back.

3) Mechanism of Fingerprinting Technology

The concept of fingerprinting can be incorporated with this system to get enhanced performance and reduced error of localization.

The fingerprinting technology consists of two phases. The first phase is the Training phase and the second phase is the Positioning phase.

a) Training Phase

In training phase we determine the location of the GSM transceiver at certain Reference points (RP) and store the corresponding TDOA and AOA measured by the various neighbouring base stations and store this data in a database. This database would contain the name of the reference point and the corresponding TDOA and AOA values measured by the base stations neighbouring the reference point.

The number of reference points can be increased to decrease the error of localization. For the public bus service system, we maintain a large number of reference points in the routes of the bus, so that the location and tracking of the bus are done more precisely. The training phase mainly deals only with managing the database for a number of reference points.

b) Positioning phase

During the positioning phase, the position of the GSM receiver can be calculated easily just by comparing the values of the TDOA and AOA measured by the neighbouring base stations. If the values match, then we can be sure that the localization of that user is precise. The Positioning phase mainly deals with comparing the measurements obtained with the database and finding the reference point.

The location of the Bus can be easily defined by this method, because the reference points are mainly located along the route of the bus. By increasing the number of reference points, the bus tracking system for Public service might be very well accomplished.
4) \textit{Mechanism of Information Passing to Subsequent Bus Stops.}

On finding the whereabouts of the bus by the GSM network, the subsequent stops are informed about it and the expected time of arrival of the particular bus at that specific stop is displayed. This message passing between the GSM network and the Bus Stops can be done by sending an SMS to the corresponding stops. The message is sent only to the Bus Stops of the particular route of the bus.

This information can also be made available to the public when they request from their mobile phones. This feature would be similar to the present service where a user requests for a score, and the network replies. In this case the user would request for a particular Route, and the network would reply with the corresponding information.

VI. \textbf{ADVANTAGE OF GSM OVER GPS SYSTEMS}

- The presence and wide spread availability of GSM
- Accuracy can be adjusted by modifying the database properly and increasing the number of reference points.

\textit{Coverage:}

Low Set up cost as the main framework is already available due to the use of multi-lateration, quite a large number of reference points are being used. This is will cover a wide area providing very accurate results. as most of the mobile companies provide GSM facilities, this can be used by large number of users.

\textit{Low Cost:}

Since GSM technology is widely used across a large number of mobile devices, this positioning technology is very cheap. This primary challenge is the installation and calibration cost.

\textit{Low Effort:}

Large amount of calibration needs to be collected and maintained in order to have higher accuracy.

VII. \textbf{IMPROVEMENTS}

- The system can be enhanced further by, recognizing the place from where emergency call has been raised to a particular bus.
- Also, public can get know the arrival of the next bus in the same route by creating an mobile application which can track public transports like buses so that, they can get to their places on time.

VIII. \textbf{FUTURE SCOPE}

- The increase in the number of reference points will not only make the database accurate, but also make the database static and this information could be of immense help in tracking any place.
- The accuracy of the system can further be improved by extending tritilateration to multilateration.

IX. \textbf{CONCLUSION}

This system would accurately pinpoint all the buses that operate in a particular area and supplies reliable information to all the parties involved and including the passengers. The vehicle-tracking system of the invention can provide a simple and economical way to track vehicles on a route without requiring a subscription to a GPS service or expensive vehicle detection equipment at each street corner.

The public transportation routes in most cities have cell phone coverage and this vehicle-tracking system can utilize that existing communication network. The system is automatic and run by computers and therefore requires no human data input or manual data transmission.

The data collected can be compared to stored route and schedule data by the data storage and processing device to determine whether a vehicle is on-route and on-schedule. The comparisons and calculations made with this data will generate results that can be displayed to public transportation users and managers so they can easily determine whether a bus is running on schedule and when it will arrive at other stops on its route. This displayed information can be updated real-time based on the actual time of the network and the system-determined location of the bus.

By implementing this system in a city to track public bus locations, dispatchers will also have a visual way to locate buses without disturbing the drivers. By providing an effective and easy-to-use public transportation system, a city can increase the number of people that choose to use the transit system instead of driving, therefore decreasing traffic and pollution.

The bus locations are also known in the event of an emergency where rerouting becomes necessary. In addition, data collected by the system over time can be used to detect scheduling problems where buses consistently run late and route schedules or bus routes therefore need to be changed.
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