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Predicting Bus Arrival Time based on Traffic Modelling and Real-time Delay

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***Abstract*—To know the arrival time of bus to a bus stop is the basic information every transit users want to know. Waiting for a long time at a bus stop discourages the people to rely upon public transports. In this paper, we present a system which can predict the arrival time of bus to a particular bus stop considering the real time parameters that affects the travel time of bus. With bus module, the real time parameters that affect travel time are continuously collected and used to predict the bus arrival time at various bus stops. A mobile application is developed in order to assist the querying users in getting the arrival time of bus to a particular stop. As there will be delay in travel time due to the vehicles on road, road traffic is modeled using M/M/1 queuing theory in order to calculate the delay caused by the other vehicles travelling in the same road. Server predicts the arrival time based on real time information updated by bus module and the information present in the database of server. Server is coded such that it sends the predicted arrival time of bus to the queried user's cell phone at every bus stop it passes till it reaches the stop queried by user. Updated arrival time received by users helps the transit users to plan their schedule and reach the bus stop in time. Such a predicting system motivates the non users of public transport systems to use them and reduce the usage of private vehicles in their day to day life.**

Keywords: Bus arrival time prediction, real-time delay, traffic modelling

1. INTRODUCTION

Use of Public transport services and minimizing the use of private vehicles reduces the overall fuel consumption and also reduces traffic congestion. People tend to use private vehicles instead of public transport in order to save the time of travel. Time of travel means the time one waits for a transport medium added with the time required to travel to a certain destination. Instead of spending time waiting for a public transport to come, people rely on their private vehicle to move from one place to another. If every person in a city uses private vehicles, it results in traffic jam or traffic congestion. Traffic congestion is a term used to express a situation where there are more vehicles on a road than the number of vehicles that should be there for free flow of the vehicles on the road.

In situation of public bus transport system, passengers normally want to know the accurate time at which the bus reaches bus stop which is nearby to them. These days most of the bus operating companies provides the schedule of buses on their websites which are freely available for the passengers. But these provide only limited information such as operating hours, time intervals, etc. which is not timely updated. Even though they provide useful information they are far from acceptable level of the public transport users. Schedule of a bus may be delayed due to many unpredictable factors such as harsh weather conditions, more number of passengers at the bus stop, breakdown of the bus, traffic conditions.

Accurate arrival time of the bus is important to the bus operation control and the passenger information system. This accurate arrival time is necessary for the transit users to respond to the unexpected delay of a bus. By this the transit operators can plan their schedule and make efficient use of time. They can also take some other means of transport in case the bus arrives too late. However the overall quality of transit service can be improved by providing such information to the transit users.

In this system transit users are provided with the arrival time of a bus for a particular bus stop. This information is sent to the cell phone of transit user who had requested the system to do so. Whenever a user wants to use the public transport system, he sends query to the predefined number of server from which he gets back the arrival time of the bus as a reply.

This system consists of three major components querying user, bus module and the backend server.

(1) Querying user: One who queries the arrival time of the bus using a mobile phone.

(2) Bus module: Using which the details of the parameters that cause delay are reported.

(3) Backend server: Collecting the information reported by the bus module and intellectually processing the information so as to predict the bus arrival time.GPS is not used to acquire the physical location inputs.

Such an arrival time predicting system has the advantage compared with other approaches. First, compared to conventional approaches (e.g., GPS supported ones) this is system is energy friendly. Second, sending continuous updated arrival time to the queried user makes the information more accurate. Designing such a system has a few challenges:

(1) Modeling the traffic, delay in the bus arrival is also caused by the vehicles in the road, so it is necessary to model the road traffic.

(2) Bus route and classification and bus stop identification is also necessary. There will be many buses in a public transport system so it is necessary to classify the routes of the buses based on bus stops the bus passes through.

In this arrival time predicting system road traffic is modeled using M/M/1 queuing model and the parameter that causes delay for the bus arrival are collected from bus module and is sent to server. Based on the accumulated information, both the historical knowledge of the road and the real time parameters we are able to predict the bus arrival time and send the arrival time of bus to a specified bus stop, queried by the user.

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2. RELATED WORKS

Many scholars, researchers have put forward many ideas, theories and systems in order to predict the accurate arrival time of bus. Intelligent transport systems (ITSs) are gaining recognition all over the world. Research has been going on all over the world for developing an ITS which can predict the arrival time. Many systems and prototypes are being developed. A system is also developed in which they have presented a bus arrival time prediction system based on participatory sensing using cell tower sequence matching [1]. In this system they have used the mobile phones of transit users to approximate the bus travelling routes and to predict bus arrival time at the bus stops.

Artificial neural network (ANN) model for predicting bus arrival times was proposed [2]. ANN models require extensive testing and training in order to find the right network structure and determine the best parameter values. Arrival time is predicted based on the data accumulated by the GPS device mounted on the bus in order to get the real time location of the bus [3].

P2P overlay network was used in a arrival time prediction system **[**4]. Here they have proposed a method of combining a P2P overlay network and WSN to develop a bus arrival time prediction system. In this a single WSN network was formed which consists of a bus and a bus stop. In order to predict bus arrival time and transmit real-time bus information, P2P overlay network was formed by connecting all bus stations and bus terminals.

A real time passenger information system (RTPIS) [5] was developed in which they have used tracking devices to get GPS data of bus location and depict it in the approximate geographic positions on the route map. Main purpose of this system were to display the arrival time of bus at bus stops, web based interface for control room to monitor buses in real time and mobile application for end users.

Another Arrival time prediction model was proposed in which they have predicted the accurate arrival time of bus using Kalman filter model [6]. In order to predict the arrival time of bus to a particular bus stop, they have used the traffic information from social networks updated by people who have witnessed events and updated their social media accordingly. They have verified the results with a corresponding SUMO simulation.

3. SYSTEM OVERVIEW

We have developed an arriving time predicting system which predicts the time for which the people at the bus stops has to wait. The architecture of the system is shown in figure 1.This gives an account of the major components of the system design and how each of the sections in the system works.

The system mainly consists of three major components

- Querying user
- Bus module
- Backend server

3.1 Querying user

Querying user is the one who wants to get some information. In this system querying user is the one who wants to know the accurate arrival time of the bus for a particular bus stop. The querying user uses his cell phone to send the query request to the server by a message through GSM network.

3.1.1 *Bus Module*

Bus arrival time depends on many factors such as weather conditions [7], number of travelers, traffic congestion etc. resulting, delay in the predefined schedule of the bus and inconvenience to the travelers waiting at the bus stops. For a bus arrival time predicting system it is necessary to know the real time location of bus. Not only the location of bus helps in predicting time, but the total number of travelers also helps in predicting the delay time of the bus. However, some of the information required to calculate the delay time has to be sent to the server from the bus. In order to get the data required to calculate delay the bus should be equipped with certain equipments based on the data required by the server.

The bus module contributes the information collected within the module to the backend server as shown in Fig 1 (left side).

Bus module consists of two components

1. RFID reader
2. Ticket machine

3.1.2 *Server*

Server is a software application that accepts the requests from the clients and responds to the requests accordingly. Generally a backend server is the unit in a system which will be out of user interface but handles the user input. Most of the computation complexity is shifted to the Backend server where the information from all the modules in the system will be stored.

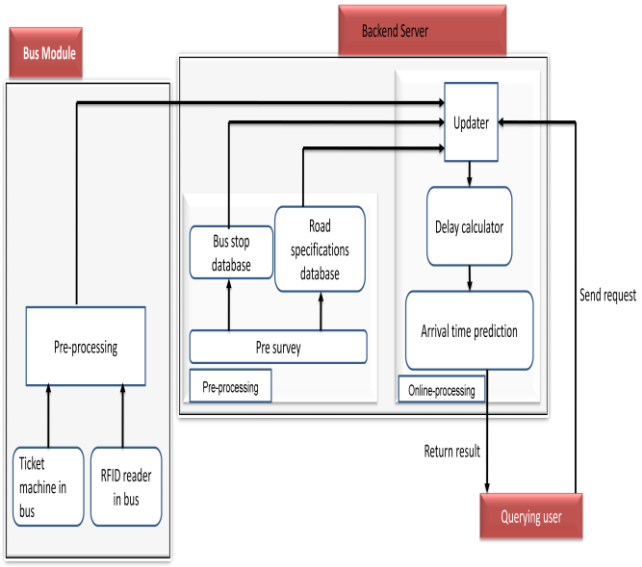

Fig 1. System architecture

We have developed a server in which the querying user gets the response as soon as the user sends the query to the server. The database of the server includes the road specifications and the bus stop details and the online processing part have the updater, delay calculator and the arrival time predictor in it. The GSM module of the server collects the query from the user and the data from the bus module and sends to the updater for the arrival time prediction.

4. TRAFFIC MODELLING

Traffic congestion of transport system is a phenomenon of increased disruption in traffic movement on a road. It is observed when number of vehicles approaches or exceeds the capacity of road. Traffic congestion depends on the arrival rate of vehicles, service rate of the road, spacing between the vehicles, deviations from the

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road and many more aspects add to congestion. Traffic congestion is one of the main reasons that affects the commute time of vehicles. So the modeling of traffic is important to calculate the time required by the vehicles to reach from one point to another.

Simulation has been done for real situations using the traffic simulator, simulation in urban mobility (SUMO) which is capable of simulating real world road traffic using digital maps and realistic traffic models [8].

M/M/1 queuing theory model is one of the approaches that are used for traffic [modeling and it has been used in many system designs and researches [9] [10] [11].

4.1 *M/M/1/α Queuing System*

M/M/1 queuing system refers to a system which has negative exponential arrivals and service times and a single server. It is a better approximation for a large number of queuing systems. Since a single road is considered, this queuing theory suits the consideration. For instance, a single link fed by a single transmit queue qualifies as a single server and can be modeled as an M/M/1 queuing system. Here:

M = Arrival or Departure distribution which is a Poisson process.

1 = Number of server (number of roads).

4.1.1 Queue discipline

Discipline of a queuing system means the rule that server uses to choose the next customer from queue when server completes the service of current customer. Queue discipline used here is "first in- first out" abbreviated as FIFO. This discipline serves one customer at a time.

4.1.1.1 Performance parameters of M/M/1/α queuing system

The equations describing M/M/1 queuing system are simple and easy to use.

Performance measures [10]

The average waiting time of a bus in the system (W) is given by

$$W = \frac{1}{\mu - \lambda} \qquad 1$$

Where, W = Waiting time of the vehicle

μ = Service rate of the road
λ = Arrival rate of the road

Once arrival rate and service rate of the road is determined. The delay due to traffic in the system (road under consideration) is calculated. As arrival rate will be updated from stop to stop the accuracy of prediction also increases.

5. ARRIVAL TIME PREDICTION

In this section, arrival time is predicted based on the discussed theories in chapter 3 and other parameters that cause delay of the bus. The database, that is the information such as distance between the bus stops, Poisson arrival rate of each of the roads including the roads that converge, service rate of main road (road at which the arrival time is to be predicted), average delay per person in getting in and out of bus, average speed of vehicles is collected. This data is necessary for backend server to calculate the arrival time. Parameters that influence the calculation of arrival time of bus are number of people, commute time, traffic congestion.

5.1 *Number of people*

Passenger is one of the important segments of a public transport system. In this section we calculate the delay time based on number of passengers who get in and out of the bus.

As soon as tickets are issued, the ticket issuing machine updates the count of people who get in at a particular bus stop and get down at the upcoming stops. Based on this information the delay time D_N is calculated deterministically. The delay time D_N refers to time delay caused by the passengers.

$$D_N = N \times d \qquad 2$$

Where, N = Number of people
d = Average delay per person

This delay time is added to commute time to increase the accuracy of prediction and this delay time (D_N) and count of people is updated to the server from stop to stop as the people get in and out at every stop.

5.2 *Commute time*

Commute time refers to the time taken for a person to move from one place to another. Whenever a vehicle moves from one place to another, it has to move with some speed. This speed of the vehicle will not be same all through the distance, sometimes it moves with more speed and sometimes in less speed (based on the road conditions and other factors). So the average speed of vehicle needs to be considered to predict the commute time of bus.

By knowing the distance travelled by the vehicle and the time consumed by it to travel that distance, it is possible to calculate the average speed of the vehicle as follows:

$$\text{Average speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

The average speed for vehicles on that particular road will be fixed. [4].

To calculate commute time of the bus, current location of bus is to be known. Once the location of bus is known, distance from the bus and destination bus stop can be calculated (based on the survey results which are done to calculate the distance between bus stops). In order to know the location of bus and to predict the time, the update time of bus at one of the bus stop in the route it travels is considered.

If querying user is at Q and the last or recent update was from stop X, Assume that the bus has passed bus stop Q at time T, query has been received at time T_1. Then:

$$time(t) = \frac{\text{Distance between stop Q and X}}{\text{Average speed}}$$

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$$Commute\ time\ (D_C) = t - (T - T_1)$$

6. *Delay due to traffic*

Delay due to traffic is calculated based on the theory discussed above. From equation 1, average waiting time of a vehicle in a queue is

$$W = \frac{1}{\mu - \lambda}$$

M/M/1 queuing theory can be applied to the road traffic [11] in order to find the delay due to more number of vehicles in the queue of the main road. W in M/M/1 queuing theory refers to the waiting time of bus in queue which is the delay due to traffic.

Delay due to traffic (D_T) is given

$$D_T = \frac{1}{\mu - \sum_{i=0}^{n} \lambda_i} \qquad 3$$

Where, n = number of intersections.

6.1 *Arrival time*

Arrival time of bus to the bus stop queried by user is delayed due to traffic and the number of passengers as calculated in the previous sections. Total delay time of a bus to reach the bus stop requested by the querying user will be the sum of D_N, D_C and D_T.

$$\text{Total delay time} = D_N + D_C + D_T$$

$$\text{Arriving time of bus} = \text{Queried time} + \text{total delay time}$$

This arriving time is sent to queried user by a message through GSM network. Since the arriving time is sent from stop to stop to queried user based on the changes in number of people and also the Poisson rates, prediction time sent to the querying user will be more accurate.

7. SYSTEM IMPLEMENTATION

Arrival time predicting system for a bus is designed using,

- Cell phone.
- Bus module-RFID reader, Ticket machine, GSM device, microcontroller.
- Server- Microcontroller, laptop, GSM device.

Querying user sends the query request to server by a message through GSM network. Server has a GSM module in it, which can receive data sent by querying user and the bus module. Data received by the GSM module of server is read by a microcontroller. This microcontroller is connected to the laptop using a USB to UART cable. Laptop displays the data received by microcontroller. Microcontroller is coded in such a way that every message received by the GSM module of server is read and updated.

RFID reader reads the tag (bus stop) details and ticket machine gets the count of people at every bus stop. RFID reader, ticket machine and bus GSM module of the bus are controlled by a microcontroller of the bus module. Whenever a bus reaches the bus stop, real time information from the RFID reader and ticket machine is read by the microcontroller of bus module which is then processed. Microprocessor prompts the GSM device of bus module to send processed data to GSM module of the server.

Once the parameters necessary for calculating delay is received by the GSM module of server, microcontroller within the server reads these data and displays them in the laptop. Updater unit of server updates these data within it and passes the data to delay calculator which calculates the delay. Arrival time for the queried bus stop is calculated based on this delay calculated. The microcontroller connected to server is then prompted to allow the GSM device of the server to send the predicted arrival time to queried user by a text message through GSM network.

7.1 *Assumptions and considerations*

- Server gets updated as soon as the bus reaches any bus stop (including people count).
- Bus travels in a fixed route. There are no diverging deviations from the main route. Some other roads with different Poisson arrival and service rates will join the main route.
- Single lane road is considered which means that vehicles cannot overtake other vehicle in a queue and one vehicle is serviced at a time. Figure 2 shows the queue system along with the service station.
- Interval for calculating Poisson arrival rate (λ) and service rate (μ) is "1 minute" [10].
- Sum of Poisson arrival rates will be less than the service rate of the main road.

Bus travels in a pre-defined average speed all through the distance.

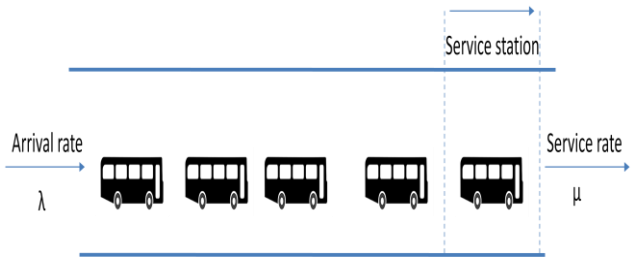

Fig 2. Queue system along with the service station

7.2 *Mobile Application*

Mobile phone which we used here is an Android smart phone which is installed with a mobile application coded using java language and developed under Android platform by using Eclipse tool. Screenshot of mobile application developed is shown in Fig 3(a), (b). Purpose of using this application is to send querying request to server in a format that could be understood by server and the other thing is that by using a specified format of request, unwanted messages which are sent to servers by other people can be filtered out. The communication link between cell phone and server is through AirTel GSM network.

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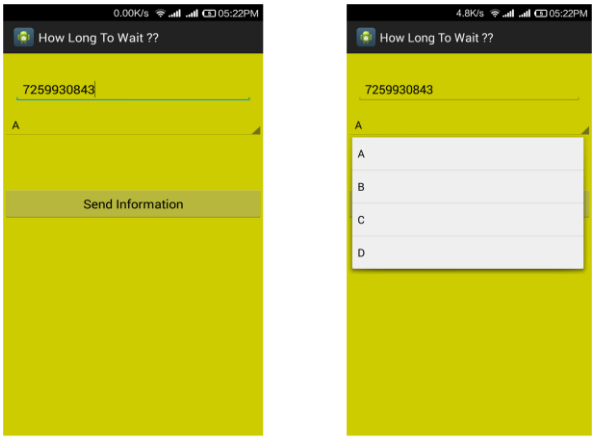

Fig. 3. Screenshot of the mobile application

7.3 *Bus module*

Bus module consists of the RFID reader, ticket machine, pre-processing unit and a GSM device.

7.3.2 RFID reader and tag

RFID readers are generally used to detect the objects which have RFID tag in it. Here each of the bus stops is assigned with a unique RFID tag. Whenever a bus approaches any bus stop, RFID reader is supposed to detect the bus stop (tag). For this purpose RFID reader is embedded into the bus module so that it can detect the details of bus stop it passes by.

This reader collects the information of bus stop and passes to the pre-processing unit. Pre-processing unit converts the collected data to the format that could be understood by server. The information of the bus stop will be collected automatically by RFID reader without manual interpretation. The functionality of RFID reader, GSM device is controlled by the microcontroller of the bus module.

Details about RFID reader used in project

- 125KHz frequency
- Passive readers and Tags
- Wireless distance range (3-5) cm

7.3.3 Ticket machine

As soon as the passengers get into bus at each bus stop, tickets are issued to the passengers through a ticket vending machine. This ticket vending machine within bus module stores the count of people who got into bus at that particular stop and who will get out of bus in the coming bus stops. Here in the implementation part, use of ticket machine is not done but the data that is supposed to be sent by ticket machine is assumed to have reached the server. This data is entered directly at the frontend of server as a user input.

7.4 *Backend server*

Backend server is implemented in Microsoft visual studio running on a Lenovo G500 laptop which has 2GB inbuilt RAM and INTEL CORE i3 processor. Dot net language has been used for coding server. Functionality of the GSM device of server and bus module, handling of incoming queries to server and incoming data from the bus module is efficiently done by a Renesas 64 pin IC, whose brief operation is explained as follows.

Backend server has database which is obtained by the survey of road and bus stops, updater, delay calculator and arrival time predictor. Survey data includes data such as bus stop IDs, Poisson arrival rate and Poisson service rate of the individual roads, total number of intersections of the roads to main road.

Information received from bus module is updated in server .Once the querying user sends query request to server by specifying the bus stop, server fetches the data which was already stored in server and calculates the delay time .This delay time is used to calculate arrival time of bus to the bus stop specified by the querying user and sends this time to the user using GSM device of server.

7.4.2 Online processing

Online processing unit of server processes the real time data that are available from bus module and information from database. Information that is sent to server is updated in updater unit of server. Screenshot of server in figure 4 shows the screen in which the count of people, last update time of bus, the query message are displayed and updated.

As arrival time prediction includes the calculation of delay due to traffic congestion, real time delay due to number of passengers, accuracy in the arrival time predicted will be more and could be used for implementing in public transport systems.

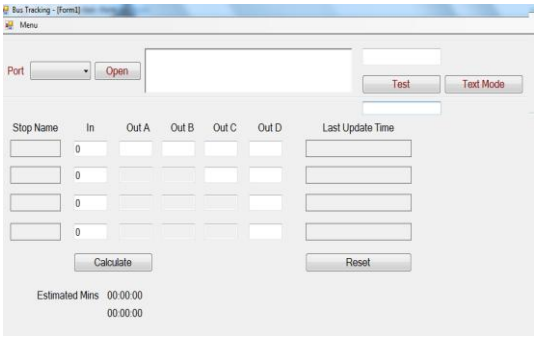

Figure 4 Screen shot of the online process

8. RESULTS AND CONCLUSION

Server responds to the queried user by text messages. GSM module of server sends the arrival time of bus to the queried user's cell phone. Along with sending the arrival time it also sends the updated arrival time at every bus stop it reaches. This increases the accuracy of prediction. Screenshot of updated arrival time received as text message by the queried user is shown in Fig.5.

Arrival time predicting system has been designed which considers real time parameters that causes delay such as number of people and also results of traffic modeling. This system updates the arrival time of bus to queried user based on his query. It sends the updated arrival time to user whenever bus reaches the bus stops of predefined route until bus reaches the stop queried by user.

This system uses the location update of bus only when it reaches the bus stops of predefined route in order to predict the arrival time. But for higher accuracy of arrival time prediction it is necessary to track the bus (location of bus) continuously all along the route travelled by bus. Continuous tracking of bus helps to predict précised arrival time of bus.

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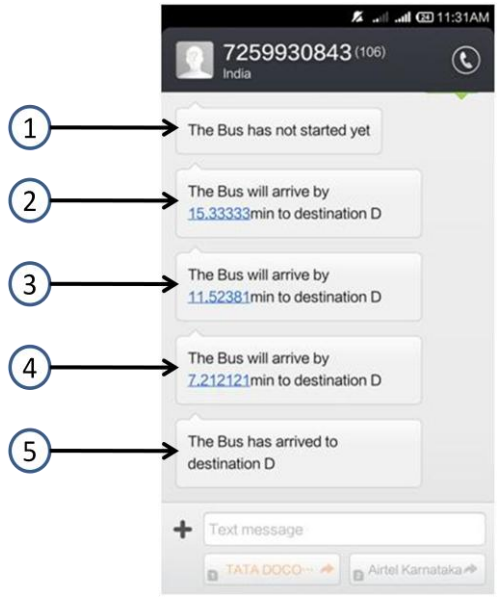

Fig.5. Screenshot of the received arrival time of bus

Road transport services can use this system for implementing in real time so that, updated arrival time received by users helps the transit users to plan their schedule and reach the bus stop in time. Such a predicting system also motivates the non users of public transport systems to use them and reduce the use of private vehicles in their day to day life.

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