Design and Implementation of Transportation Management System

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Keywords: Intelligent Transportation System (ITS), Arrival Time Prediction, Neural Network, Android Application.

Abstract: This paper proposes an effective method of transportation management system. This proposed system is designed to interconnect public transport vehicles and bus stations to "Central Room" to monitor the vehicles & traffic status. Based on the collected data and via analyzing road condition, estimated arrival times are computed and transmitted to all relevant stations. The main structure of proposed system consists of Bus unit, station unit and main control centre with servers. Bus and station unit can be hardware unit or mobile android unit. Monitoring Busses based on GPS and GPRS applications. The data transferred between Bus units, station units and the main servers are managed via GPRS/UMTS link. At the server (Central Room) and based on the collected data from buses and via analyzing road condition, accurate arrival times will be computed (Via Neural network (NN) / Kalman Filter (KF)) and transmitted to all relevant stations. In this paper, we proposed a modified technique to predict bus arrival time depending on the two algorithms (NN & KF) simultaneously to take advantage of historical data (NN) with current data (KF). Achieving these main features will cause major improvements in public transport convenience and safety. Field tests were performed under real traffic situations in order to test the system.

1 INTRODUCTION

Intelligent Transportation Systems (ITS) domains include many areas as public transportation control framework, road traffic management and the application of traffic control. Vehicle monitoring and transportation management systems fall under the category of (ITS).

Many previous studies and systems have been addressing intelligent transportation and vehicle monitoring systems (Han and Huh, 2011; Doğan et al., 2010; Hickman and Hanowski, 2011). Intelligent transportation systems enable various technologies to be applied in management of transportation and is defined as the use of information and communication technologies to collect, process, and transmit traffic data to transport users and operators (Qin et al., 2008). Vehicle monitoring systems, however, only take vehicles into account; for example, auto-positioning systems can be applied to vehicle monitoring, vehicle control, and vehicle management. Addressing the problem of public transportation commuters in Egypt waiting for long time piling at the middle of the streets, struggling to catch a bus with all the suffering they meet, the delay they cause and the accompanying traffic digestion.

When travelling with buses, the passengers want to know the predicted bus arrival time at the bus stop. Long waiting time at bus stops may drive away the anxious travellers and make them reluctant to take buses. Accurate arrival time of next bus will allow travellers to take alternative transport choices instead, and thus mitigate their anxiety and improve their experience.

Towards this aim, many commercial bus information providers offer the real-time bus arrival time to the public. Providing such services, however, usually requires the cooperation of the bus operating companies (e.g., installing special location tracking devices on the buses), and incurs substantial cost (F. Li Y. et al., 2011; Pengfei et al., 2012; Dihua et al., 2007). Many research on implementing tracking systems based on android applications (Manav and Anupam, 2012; Ruchika and BVR, 2011), but most of them concentrated on tracking system not fully management transportation system and estimate arrival time predilection espials in countries complicated in traffic as Egypt. Our proposed system can be implemented based on hardware units or mobile application units.

The proposed transportation system is designed to interconnect public transport vehicles and bus stations to "Central Room" to monitor the vehicles &

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traffic status. Monitoring vehicles based on GPS and GPRS applications. Via analyzing and processing the collected data at the control center, we can predict the bus arrival times at relevant stations.

The prediction times to the next bus will be announced on screens to passengers on the bus stops. The next bus stop will be notified to the passengers in buses using visual & audio announcements. Achieving these features of the proposed system will cause major improvements in public transport convenience and safety, especially in Egypt and countries like Egypt in transportation. Most vehicle arrival time prediction in intelligent transportation system depend on many parameters like: Bus speed, occupancy, traffic flow, traffic incidents, weather conditions, daily, weekly and seasonal and many other parameters which can affect on quality of prediction times. These large number of parameters make bus arrival time predictions very complex and difficult to reach optimal accuracy. Some of these parameters can be classified as on line predictions like Bus speed, occupancy, traffic flow, traffic incidents, weather conditions and other parameters can be classified as history like daily, weekly and seasonal.

The proposed algorithm for prediction times relies on real-time location data (Kalman filter) and takes into account historical travel times (Neural Network) as well as temporal and spatial variations of traffic conditions as presented in our paper (M. Zaki et al., 2013). Although the two separated algorithms gave us accepted results as shown in our paper (M. Tantawy and M. Zorkany, 2014), but still the two algorithms work individually.

In this paper, we proposed a modified technique to predict bus arrival time depending on the two algorithms (NN & KF) simultaneously to take advantage of historical data (NN) with current data (KF). So the proposed prediction time method is a hybrid scheme that combines a neural network (NN) that infers decision rules from historical data with Kalman Filter (KF) that fuses prediction calculations with current data.

This paper is organized as follows. The proposed Transportation management system is presented in Section 2. Communication Protocols and Frame Structure are given in Section 3, System based Hardware units is presented in section 4, System based Android applications is presented in section 5. Arrival time prediction is proposed in section 6. Simulation results are discussed in section 7 and finally conclusions are drawn in Section 8.

2 PROPOSED TRANSPORTATION MANAGEMENT SYSTEM

The proposed main structure of transportation management system are given in figure 1, where data transferred between the buses, the main servers, and the end users are managed via mobile networks and Internet. The hardware and firmware units in the busses collect, control, and process the data while hardware and firmware units at bus stops “Bus station Unit” controls and display data received from server. The bus and station units can be a hardware-based unit or Android-based unit. The servers host the system management and processing algorithms, system database, and web applications. A portal is included to give the necessary information to the end-users.

For In-Bus units and Station Units, Our proposed system can be implemented based on hardware units (In-Bus & Station units) or mobile Android units (Android unit as In-Bus unit and Android unit as station) or mix units (hardware and Android).So the proposed system could be presented in the market in two different versions: System based customized Hardware and System based Android application.

At server and based on the collected data from buses, bus arrival times will be computed (Via Neural network / Kalman Filter) and transmitted to all relevant stations. the prediction time for the next bus(s) to arrive will be displayed on screens on the bus station. The proposed system is composed of three main parts: Servers, In-bus unit and Bus stop (Station) unit.

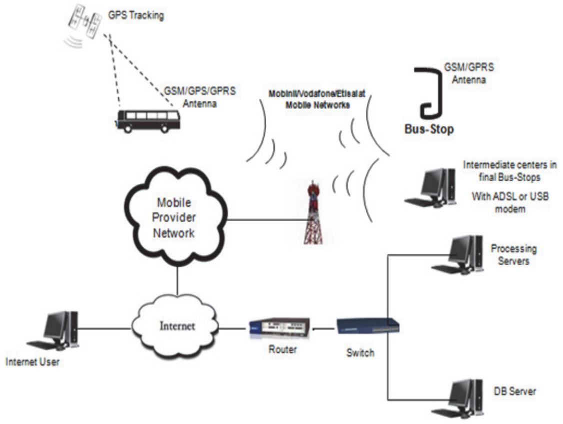

Figure 1: Main structure of proposed system.

2.1 Proposed Network Infrastructure

The proposed framework uses a layered or modular approach to communications standards, similar to the layering approach adopted by the Internet and the International Standardization Organization (ISO).

In general, data communication between system units in buses, stations, and servers in "Central Room" can be considered to involve the following primary levels: Information level, application level, transport level, sub-network level, and plant level. These levels can be compared to both of ISO open system interconnection seven layers model and The American National Transportation Communication for ITS Protocol (NTCIP) framework published by American Association of State Highway and Transportation Officials (Aashto, 2009).

The proposed framework extends beyond the communications stack to include informational data and interfaces to physical communication infrastructure. Figure 2 shows how the proposed framework relates to the OSI model.

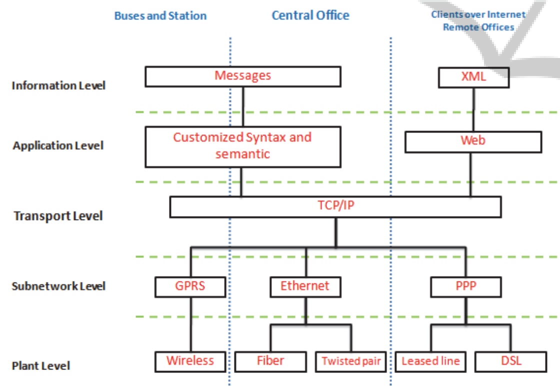

Figure 2: Proposed Protocol Architecture.

2.2 Communication Sequence

Figure 3 shows the communication sequence for the proposed system. After system initialization, the system admin customize the processing servers by entering the routes, the stations, the authenticated International Mobile Equipment Identifier (IMEI) for every Bus/station unit.

When the bus/station units registered to the processing server in the central room the processing server can upload the required audio files to the bus-units. Then location, velocity and other information for all buses are forwarded to the processing server in the central room.

The server processed the received information, using neural network and Kalman filter, and estimating the arrival time, sending the results to the database server, the corresponding stations, and to the portal web site.

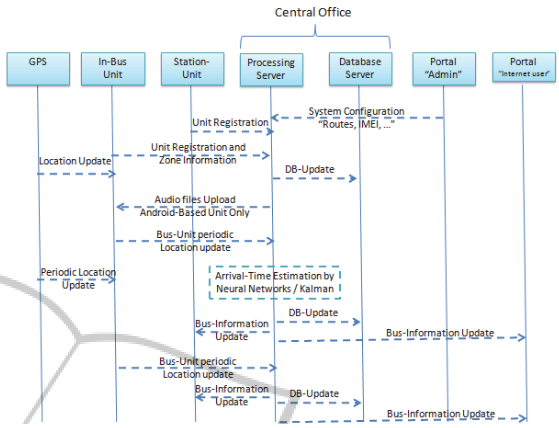

Figure 3: Proposed Communication Sequence.

3 COMMUNICATION PROTOCOLS AND FRAME STRUCTURE

In general, data communication between in-bus unit and servers in "Central Room" uses TCP/IP suite, which run over a GPRS mobile operator network and higher technology as UMTS. The transmitted frames to/from the server and busses are classified into three types of packets.

3.1 Frames between Buses and Server

In the proposed system, three packet frames are used for communication between buses and sever; bus registration frame from bus to server, bus route frame from sever to bus, and bus periodic frame from bus to sever. The following figure demonstrates the communication sequence between buses and server.

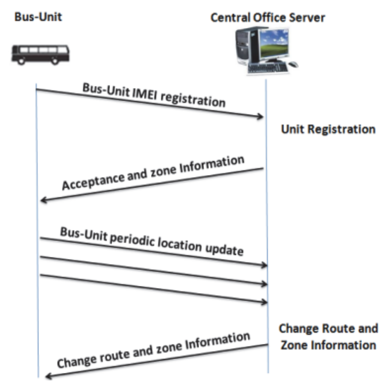

Figure 4: Sequence diagram of bus unit and server.

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3.1.1 Bus Registration Frame

In the designed system all busses are defined in the server database though the admin GUI using the IMEI of the GSM module of unit installed in each bus. The IMEI is the unique GSM serial code that can be extracted through android applications. IMEI is typed by the manufacturer on the GSM module and can be used as the in-bus unit serial number.

This proposed method gives ease for remote and flexible control and management of all busses in the designed system. All buses in the designed system remotely load and save the route stations data which gives the following privileges:

- Reducing sever processing overhead as the calculation of the bus station zone is done in each bus through in-bus unit.
- Optimizing the use of the network capacity as the announcement and display of the stations through in-bus display interface and audio system is done automatically through the in-bus unit.
- Overcome problems due to network connection failure as in-bus units, in this case act as a stand-alone system that can announce and display the bus route stations directly as the processing is done through the in-bus unit.
- Sending bus periodic package frame (explained below) to the sever directly as the bus enters a station without waiting for the fixed periodic delay which could result is bad system accuracy (bus can enter and leave the station before the next periodic frame). This is done as the calculation of the bus station zone is done automatically via the in-bus unit.
- In the beginning of operation the route stations of each bus is loaded remotely using the following bus registration request frame.

3.1.2 Bus Route Frame

This frame is sent to the bus either as an answer to request due to start of operation bus request as shown in the previous section or directly from the sever in case of admin request of bus route change (i.e. the bus route is changed remotely according to admin requirements). Bus route frame given below contains all bus route stations data; namely; stations coordinates (longitude, latitude), names, and audio codes.

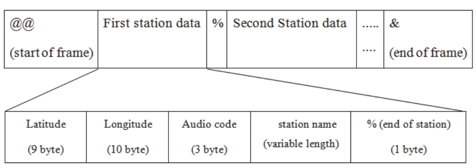

Figure 5: Bus route frame.

3.1.3 Bus Periodic Frame

These periodic packets are sent from bus to server with constant delay, unless bus enters a station zone. The periodic packets are sent directly without delay within station zone. This frame is used to manage buses and process and calculate the bus arrival time. The following frame shows the designed bus periodic packet format example sent from the buses to the server. and table 1 shows each field indication and size of each field.

B1,I352134010613025,s00064*{103032.000t,A,3002.6816 ,N,03119.3300,E,45.98v,8S, 062000.000 ,001#

Table 1: Bus periodic frame packet fields.

Field & Length (Byte)	Indication
B1	Start of Packet / Bus Number
I352134010613025	Identification number of GSM module
s00064	packet sequence
*{	start of GPS data
103032.000t	Time
A (or V)	Status: data valid (A) or not valid (V), (valid if number of satellites ≥ 3)
3002.6816,N	North (Latitude)
03119.3300,E	East (Longitude)
45.98v	Velocity
8S	Number of satellites
062000.000	Time2: time of first station in Route
001	Audio Code
#	End of Packet

3.1.4 Connection between Server and Stations

The connection between stations and server is constructed via web page design application. The server can detect each zone of station and automatically open the web page of this station to display the prediction times of busses of this station. Using this type of connection, we didn't need and extra connection between server and stations as connection between buses and servers.

4 PROPOSED SYSTEM UNITS

The proposed bus and station units can be a hardware-based unit or Android-based unit. The system based hardware is divided into two entities; one in the moving buses and one at the Bus station. The exact functions performed by the In bus unit are different from those performed by the Bus station unit.

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4.1 In-Bus Unit

The "In-Bus Unit" basic function is tracking the bus during motion by sending periodic messages (every 30 seconds) to the main processing server, including its new location; unit is divided to sub-units as shown in Figure 6, where the display system is optional for the In-Bus unit. Figure 7shows our In-Bus unit which fully designed and implemented at NTI by the project research team.

Operation of In-Bus Unit:

Main controller communicates with GSM/GPRS via AT commands. The GSM/GPRS module is configured to define the mobile service provider access point, connection selection (TCP/IP), and server IP address and port. Each unit has a unique ID which is the GSM/GPRS module IMEI (International Mobile Equipment Identity). The ID is sent by the In-Bus Unit after connection with server is established.

For a first time attachment on the system network, the main processing server will send all information about the route which this bus belongs to including an ordered list of the coordinates of all bus station on the route; the microcontroller will save this information in the main controller ROM for further calculations.

GPS module scans the satellites and finds the real-time coordinates then these coordinates are compared with the pre-stored coordinates of the respective bus stations. If the coordinates match, the result is shown as Station Name on LCD display and also announcement using the speakers. At the same time these coordinates send to the main processing server using GPS/GPRS module.

Due to the problems that have been noticed due to GPRS link failure according to signal coverage which required the use of dual SIM card holder controller design to switch between different GSM service providers in case of link failure

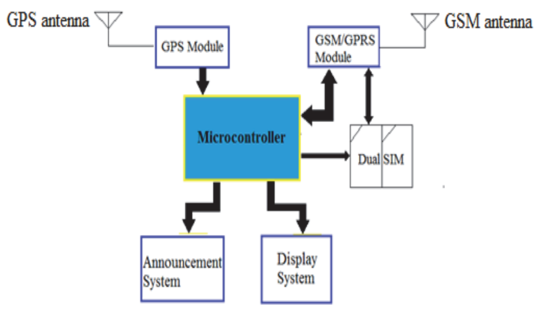

Figure 6: Block Diagram of in-bus unit.

Figure 7: In-Bus Unit.

4.2 Bus Station Unit

The "Bus Station Unit" is installed inside public bus stations to display a list of the new arriving buses and the expected time to arrive at. This list is received from the main server after gathering information from the bus fleet and making prediction calculations. The unit is divided to sub-units. The Bus station Unit and the In-Bus Unit are the same; nevertheless the In-Bus Unit has GPS and the announcement system circuits. The main processing server can send the arriving buses list to the concerned station after registering its IMEI number.

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5 SYSTEM BASED ANDROID MOBILE APPLICATION

a new features was added to the system by developing In-Bus and station units redesigned based on Android mobile application. In general, data communication between electronic android units in buses, stations, and servers in "Central Room" uses TCP/IP suite which run over GPRS/UMTS mobile operator network. The following subsections show how re-implement system based android application.

5.1 GPS Implementation on Android GPS

Location-based services or LBS refer to 'a set of applications that exploit the knowledge of the geographical position of a mobile device in order to provide services based on that information.

LBS can be classified in three categories: Public Safety / Emergency Services, Consumer Services and Preferred Location Search.

There are two methodologies to implement LBS on android applications:

- To process location data in a server and to forward the generated response to the clients.
- To find location data for a mobile device-based application that can use it directly.

The location of Android unit can be computed by 3 methods:

1) Mobile Phone Service Provider Network-
Using cell ID.
2) GPS Satellites
Using GPS satellites system.
3) Assisted-GPS (A-GPS)
Integrates the mobile network with the GPS to give a better accuracy.

In Android, location-based services are provided by the Location Manager class located in the android. location package. Using the Location Manager class, we can obtain periodic updates of the device's geographical locations as well as fire an intent when it enters the proximity of a certain location. Location-based service is another key functionality that gets used in smart phone applications. It is often combined with maps to give a good experience to the user about their location [18].

5.2 Display Android Phone's Screen on Monitors

A popular feature on several Android phones is the ability to connect the phone to an High Definition Multimedia Interface (HDMI) monitor. The phone must have an HDMI connector, and need to buy an HDMI cable.

6 PROPOSED ARRIVAL TIME PREDICTION

This proposed transportation system presents an effective method to predict the bus arrival time at individual bus stops along a service route. This method depend on famous methods in prediction domain, Kalman filter and Neural Network. The proposed method combines Kalman Filter (KF) that fuses prediction calculations with current GPS measurements with a neural network (NN) that infers decision rules from historical data.

The proposed algorithm relies on real-time location data (Kalman filter) and takes into account historical travel times (Neural Network) as well as temporal and spatial variations of traffic conditions as presented in paper (M. Zaki et al., 2013).

Although the two separated algorithms gave us accepted results as shown in paper (M. Tantawy and M. Zorkany, 2014), but still the two algorithms work individually.

In this paper, we proposed a modified technique to predict bus arrival time depending on the two algorithms (NN & KF) simultaneously to take advantage of historical data (NN) with current data (KF). In the proposed method, we used three available previous data from the buses in the same period and the same link and the fourth data from learned neural network to predict time using Kalman filter algorithm.

According to Kalam filter prediction algorithm [11-12], the prediction time t(k+1) depends on four pervious data (t(k), t(k-1), t(k-2), t(k-3))

$$t(k+1)=f\,(\,t(k),\,t(k-1),\,t(k-2),\;t(k-3)\,) \qquad (1)$$

In the proposed method, we replace t(k-3) by estimated time computed from neural network. and the equation (1) will be:

$$t(k+1)=f\,(\,t(k),\,t(k-1),\,t(k-2),\;t(NN)\,) \qquad (2)$$

As well as if the previous data are not available, we can replace it by learned neural network in Kalman filter algorithm. For example, if two previous data are available only, we use the other two data from learned neural network as shown in equation (3).

$$t(k+1)=f\,(\,t(k),\,t(k-1),\,t(NN),\;t(NN)\,) \qquad (3)$$

7 SIMULATION RESULTS

7.1 Network Traffic

The network traffic is estimated mainly as a result of bus periodic frame (from bus to sever). All other frames do not represent any load on the network because they will be sent either at the beginning of the operation or in case of changing bus route. The effect of this frame on network traffic is given as the following. According to the periodic packet format from bus to server, the total traffic per bus per packet is given by:

$$\text{Total traffic per bus per packet = IP packet payload + IP packet header} \qquad (4)$$

$$\text{IP packet payload = Total application packet length + TCP segment header} \qquad (5)$$

Where:

IP packet header = 20 bytes

Total application packet length = 91 bytes (Table (1))

TCP segment header = 20 bytes

As IP packet payload should be divisible by 8, extra zero pads are added (in our case = 1 byte is added)

Then: The Total traffic per bus per packet = 132 byte

Figure 8 and figure 9 show the average IP traffic transmitted from one bus varying with the intertransmission period and the total traffic received at the server versus number of buses respectively.

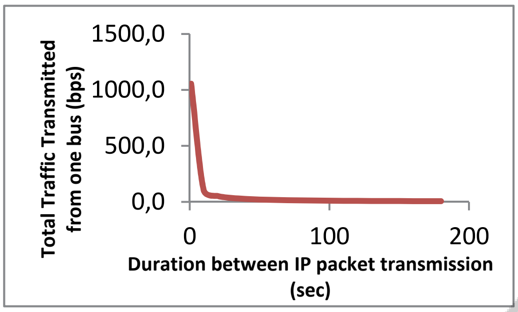

Figure 8: Average IP traffic transmitted from one bus vs. duration between IP packets transmission.

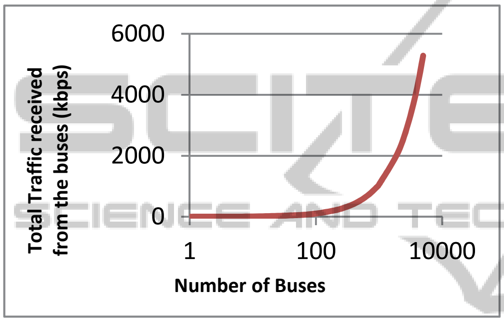

Figure 9: Total traffic received at the “Central Room” server vs. number of buses.

It should be noted that the real data traffic will be slight higher than that in Figure 6 and figure 6 due to GSM/GPRS overhead and the acknowledge packets transmitted back from the server to the bus.

7.2 Testing Bus Arrival Time Prediction Technique

The proposed prediction time algorithm was tested based on the available data, which was collected during more than three months for units have been installed in three Busses of the lines of NTI fleet (Our Institute) in different three routes (about 18 stations). Taking into account that these lines in different areas to cover different cases of traffic in Egypt.

For Example, figure 10 shows prediction arrival time calculation result between two stations "Ahmed badawy and Massara station" using Kalman Filter, Neural Network and Hybrid method. Where, RMSE "Route mean square error" =1.28 mint for Neural network, 1.92 for Kaman filter and 1.44 for hybrid.

A comparison between arrival time prediction algorithms (Kalman filter, neural network and Hybrid NN&KF) for some stations is summarized in Table 2 and figure 11.

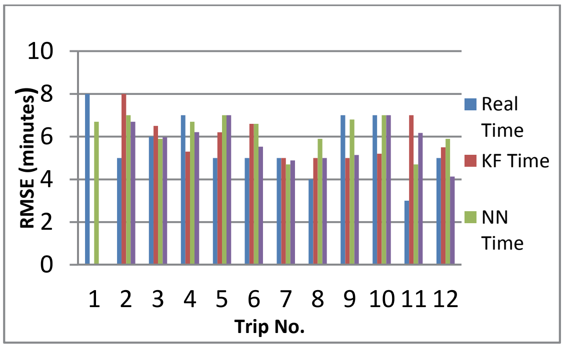

Figure 10: Arrival Time Prediction between two stations.

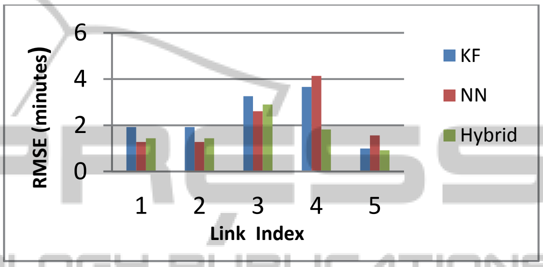

Figure 11: RMSE for KF, NN and Hybrid NN&KF.

Table 2: RMSE (Root-Mean-Square Error).

Station No	KF	NN	Hybrid
1	1.92	1.28	1.44
2	2.65	1.96	2.20
3	3.26	2.61	2.9
4	3.66	4.14	3.29
5	0.99	1.56	0.92

From the field test results using NTI fleet (low trip rate), it can be noted that calculating the arrival time using neural network algorithm gives us better results than Kalman filter algorithm in most different conditions. Nerveless Kalman filter has show negligible improvement than neural network algorithm in some stations under test. In case of heavy daily trip rates the kalman filter algorithm shows better results.

8 CONCLUSIONS

This paper presents the Transportation Management system. The system was designed and implemented based on Hardware units and redesigned using Android based mobile application.

Based on the collected data from buses and via analyzing road condition, accurate arrival times computed (Via Neural network / Kalman Filter) at the

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server and transmitted to all relevant stations. The network traffic is estimated mainly as a result of bus periodic frame (from bus to sever). All other frames do not represent any load on the network because they will be sent either at the beginning of the operation or in case of changing bus route. A Comparison between implementing transportation system based on hardware unit viruses Android unit are presented. The system was tested using NTI Fleet for a field test.

From the field test results using NTI fleet (low trip rate), it can be noted that calculating the arrival time using neural network algorithm gives better results than Kalman filter and hybrid algorithm in most different conditions. Hybrid neural network with Kalman filter give better results than Kalman filter. In case of heavy daily trip rates the hybrid algorithm shows better results

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