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Estimation of City Bus Travelers Using GSM Network

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Abstract — The mobile phone connectivity and its transition record can be used as useful information to estimate traffic users on urban roads. Mandatory use of a mobile phone dedicated to the city bus, can help in finding all other mobile phone users who are moving in the same city bus. Because, all the mobile phones will have same transition records with the mobile phone dedicated to the city bus. With this arrangement, at the background and Mobile Phone Network as a background data collection system, we have developed an algorithm to estimate the number city bus on an urban road and around a road junction at a particular time. The algorithm will also show the number of city bus users on urban road and around an urban road junction at a particular time. This estimate will help the urban traffic managers to optimize the city bus flow to minimize traffic congestion.

Keywords – City bus flow optimization, GSM, Mobile Phone network, Traffic estimation, Urban Traffic Management.

I. INTRODUCTION

Urban Traffic Management deals with efficient management of vehicle flow on urban roads without congestion. However, congestion on urban roads is sometimes unpredictable and thus unavoidable. The traffic congestion can be mitigated broadly in two ways – one is physical way another is logical way. The physical way refers to creation of additional roads, bridges, moderating existing infrastructure etc. The logical way refers use of Intelligent Transport System (ITS) facility blended with Information and Communication Technology (ICT). Both the system incurs cost and effort, which may sometimes not possible and unaffordable. Therefore, if we can use any existing system to control and manage the traffics then possibly it will be helpful to the traffic managers and as a whole welfare of the society. The Mobile Phone Network (MPN) is such a facility which can be used to the control the Urban Traffic Network (UTN). We can intelligently use the transition record mobile phones to classify the mobile users in a moving on urban roads [1]. The real time traffic information of the classified users may be useful again taking instant decisions by the traffic managers or same can be delivered to the traffic users to avoid congestion. The information can be delivered to the traffic users by bulletin boards, internet, mobile phones, roadside electronic boards etc. Mobile Phone Network can be mapped onto an Urban Traffic Network (UTN) [2] and information collection and organization on MPN mapped UTN network can be used as an important facility for the Urban Traffic Management System. The classification of mobile users has also been discussed in [1], however the classification and detection of the users who are moving together in a city bus will be more accurate if the city bus driver has been provided a mobile phone while driving around city roads. The mandatory carrying of mobile phone not only facilitate in estimating city bus users, but, it will also help the traffic managers in finding city bus density on a particular urban road, movement pattern of city buses, speed of travel, travelling on unassigned roads etc. Several tools on urban traffic management has been discussed with advantage and disadvantages in [3]. The tools may be used for urban traffic management are Magnetic loops, Pneumatic road tubes, Piezoelectric sensors. Wireless Sensors, Mobile phone networks, vehicular adhoc network, GPS, Car-to-car communications etc for the efficient management of traffic. However, out of these entire methods, mobile phone network is a facility that can be used for urban traffic management with less effort and cost. Because, the mobile phone network is already been an installed system in urban areas. City buses which travel around the urban roads are also a factor for the creation of traffic problems, because of its size and the travelers who are responsible for creation of the congestion problem on urban roads. At this point optimization of city bus movement with reference to the need of the city bus travelers at different points of time is necessary. We have studied the traffic problem around the urban roads of Guwahati city due to movement of the city bus. The uncontrolled growth of population in Guwahati city together with uncontrolled growth of city buses plays a major role in creation of congestion problems in and around Guwahati city. As per the statistics shown in the City Development Plan (http://www.jnnurm.nic.in/wp-content/uploads/2010/12/CDP_Guwahati.pdf) has shown the growth of transport in Kamrup District as shown in the table-1 below :

Table 1 : Growth of Vehicles in Kamrup District
(Courtesy : http://www.jnnurm.nic.in/wp-content/uploads/2010/12/CDP_Guwahati.pdf)

Year	Total Vehicles	Percentage of Growth
2001-2002	14431	--
2002-2003	16671	15.52214
2003-2004	18799	12.76468
2004-2005	29664	57.79563
2005- up to 31/12/05	25456	--

As discussed in [4], the transportation problem of the city of Guwahati can be minimized by changing type of the city bus, proper scheduling of buses, segregating the traffic. So for optimizing the movement of traffic we need a system through which we can study the demand of city buses around the urban roads, Moreover, a proper scheduling is necessary at this point to assign the city buses on the urban roads which may be possible in mitigating traffic congestion problem.

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II. RELATED WORKS

The prediction of urban traffics volumes is an important concern for the urban traffic managers to control the congestion on urban roads. In this connection prediction of urban traffic volume in single time series has been discussed in [5] which uses the heuristic approach to optimize the model. Waiting time minimization has also been discussed in [6] by Asad Salkham et al called Adaptive Reinforcement Learning–Collaborative Reinforcement Learning (ARR-CRL) approach. A comparable study has been done by Obafemi et al [7] to find the affects of congestion on some sample vehicles and it is found that congestion decreases vehicle utilization, decreases fuel efficiency, increase cost of fleet operation, shrink market coverage and increase cost of shipment. Affects of vehicle parking near road intersections increases traffic congestion and delays in the urban traffic networks has been discussed in [8]. The paper also suggested that if strict prohibition is applied for vehicle parking at road junctions then the traffic congestion and delay is reduced. Inlet and outlet factors analysis has been done by kenedy [9] to minimize traffic jam on urban roads. His paper suggested the co-ordinated traffic light to optimize the capacity of the roads by inlet and outlet analysis.

Hu Chunchun [10] proposed a new fuzzy clustering algorithm for road network traffic flow data. The method used to classify the road network into several zones for the management of urban traffic. Ryota Ayaki et al [11] described a combines sensor network system where they proposes to use mobile sensor relay nodes to collect data from fixed sensors for the collection of urban traffic data around urban traffic network. Circulation of mobile phones in china and its forecast has been studied by Xielin Liu et al [12] compared many techniques with estimates of determinants of diffusion rate and describes their method improves forecasting accuracy for mobile telephony diffusion.

III. GSM MOBILE NETWORKS OVERVIEW

Global system for mobile – GSM technology has emerged as the turning point of current data and voice communication system and most of the urban areas are facilitate with the GSM technology. At the same time mobile phone has become popular among the common people and has become the only mode of individual instant communication. People residing at every corner of the world communicates with other instantly only via mobile phones. The specialty of mobile phone is that the equipment can be used when the user is moving or travelling from one place to another. The GSM technology also facilitates the moving users the connectivity to the users without interruption within its network. The organization of the mobile phone networks starts from its Base Transceiver Station (BTS) which is responsible for signaling the information of mobile phones, its transition record of the mobile users to the Mobile Switching Centers (MSC). The visitor Location Register VLR and the Home Location Register (HLR) are two important data container of the mobile phone transitions may be used not only for the Mobile service providers as well other services like Urban traffic networks.

IV. DATA ORGANISATION

The transition record of mobile phones connectivity at mobile service switching station can be kept as a background data which will give the mobile phone users at a particular time at different locations in a urban traffic network. Moreover, the city bus operating from one location to another on various routes can also be represented in a database file. The assignment of dedicated mobile phone number will also be kept in separate table to know about the movement of city bus at different locations. The mobile transition record of the mobile phone allotted to the city bus driver and all other mobile phones which has the same transition record will represent the city bus travelers travelled from different traffic points at different times. The database tables with their relationships for the system are described in fig-1.

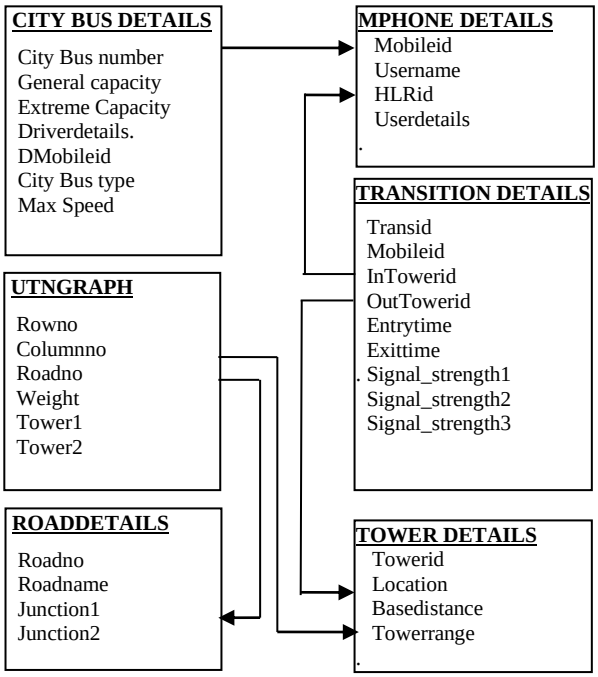

Fig-1 : Database tables and their relationships

Descriptions of database tables with the fields:

1. CITY BUS DETAILS

This table is used to keep the information of all city bus operated around the urban traffic network. The descriptions of the fields are:-

City Bus number : An unique number of the city bus.
General capacity : Capacity of the Bus in normal condition.
Extreme Capacity: Capacity of the Bus in extreme condition
Driverdetails. : Name and details of the driver.
DMobileid : Dedicated mobile id for the bus
City Bus type : Type of the City bus Deluxe / Normal etc
Max Speed : Max speed allowed on city road.

2. MPHONE DETAILS

This table is used to keep the information of the mobile phones registered around the Urban Traffic Network. The descriptions of the fields are:-

Mobileid : Identification no. of a mobile number.
Username : Name of the mobile user.
HLRid : Home Location Register id
Userdetails : Details about the user.

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3. TRANSITION DETAILS

This table is used to keep the transition details of the mobiles moving around the urban traffic network. The descriptions of the fields are:-

Transid : Transaction id of the mobile no.
Mobileid : Identification no. of a mobile number
InTowerid : Tower in which the mobile currently located
OutTowerid : Tower in which the mobile last located
Entrytime : Entry time at the current tower area
Signal_strength1: Signal strength from the left adjacent tower
Signal_strength2: Signal strength at the current tower
Signal_strength3: Signal strength at right adjacent tower

4. UTNGRAPH

This table is used to keep the UTN as a incidence matrix. The descriptions of the fields are:-

Rowno : Road Junction as incidence matrix Row No.
Columnno : Road Junction as incidence matrix Column No.
Roadno : Road Number connecting the junctions
Weight : Weight of the road in length
Tower1 : Corresponding tower of the first junction
Tower2 : Corresponding tower of the second junction

5. ROADDETAILS

This table is used to keep the details of the road of the urban traffic network . The descriptions of the fields are:-

Roadno : Road number (unique)
Roadname : Name of the road
Junction1 : Junction 1 connecting the road
Junction2 : Junction 2 connected the road

6. TOWER DETAILS

This table is used to keep the information of the BTS installed around the UTN. The descriptions of the fields are:-

Towerid : Unique BTS id
Location : Location of the BTS
Basedistance : Distance from the base Tower
Towerrange : Strength of the BTS.

V. METHODOLOGY

We shall discuss how we can count the number of city bus users on an urban road segment and urban road junction. We shall also discuss number of travelers on the bus at a particular time, based on transition record of mobile phones from one BTS to another. In computing these values we have to take the help of signal strength of mobile phone connections from the BTS Cell. We have used Signal_strength1, Signal_strength2, and Signal_strength3 which are the signal strengths of a mobile phone with three numbers of BTS located in consecutive way. With the help of the signal strength we can compute the position of a mobile phone on an urban road segment.

To understand the computation we shall take the help of an example as shown in Fig-2. It shows an Urban Traffic network with dark ovals as road junction and black thick lines as urban roads. The portion of the urban area is covered by a mobile phone networks with mobile towers T_1 to T_{10} as shown at the top of the cell in the diagram. The road junctions are numbers from V_1 to V_9.

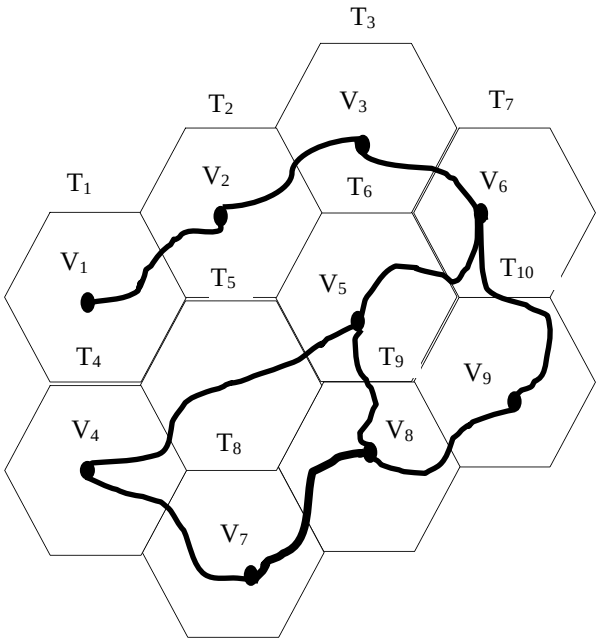

Fig-2: Mobile phone network and Urban traffic network

We shall use the MPN mapped UTN network as discussed in [1] to map the BTS with the urban road segment and we shall use the mobile transition record belongs to the mapped network.

The Fig-2 has been represented as a graph as shown in Fig-3

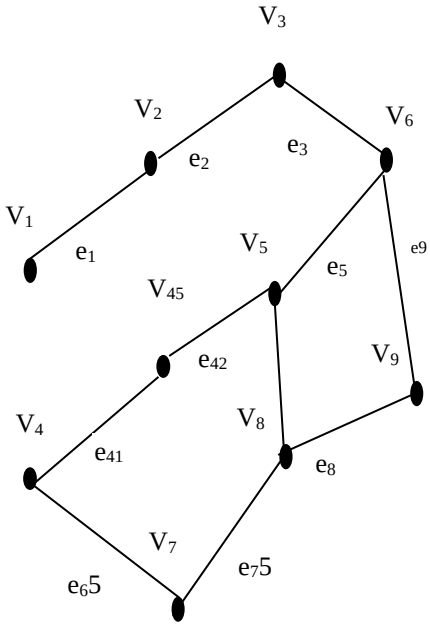

Fig-3: Graph representation of the mapped network

A mapping of mobile phone network onto the urban traffic network has been shown in Table -2 and Table-3. As there is no road junction at the tower T_5, we can create a dummy junction V_{45} for the mapping purpose.

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Table-2 : Road Junction mapping

MPN Vertex No.	UTN Vertex	BTC Cell involved
1	V_1	T_1
2	V_2	T_2
3	V_3	T_3
4	V_4	T_4
5	V_{45}	T_5
6	V_6	T_6
7	V_6	T_7
8	V_7	T_8
9	V_8	T_9
10	V_9	T_{10}

Table-3 : Road Segment mapping

MPN Edge No.	UTN Edge	BTC Cell involved
1	e_1	T_1,T_2
2	e_2	T_2,T_3
3	e_{41}	T_4,T_5
4	e_{42}	T_5,T_6
5	e_5	T_6,T_7
6	e_6	T_4, T_8
7	e_7	T_8, T_9
8	e_8	T_9, T_{10}
9	e_9	T_7,T_{10}

Suppose, we want to compute the number of city bus on the road segment e_2 traveling from V_2 to V_3. It is clear from the mapping information that road segment e_2 has crossed through the BTS cell T_2 and T_3. Therefore, we have to compute the number of city in these two portions e_2 (T_2) and e_2 (T_3) to compute total number of city bus on the road segment e_2 as shown in fig-3. However, on the road segment e_2 there are other city buses also which are moving from BTS Cell T_3 to T_2. So we have to distinguish the direction of the city buses and separate them while computing the numbers. Moreover, there are also other buses belongs to the BTS cell T_2 and T_3 but does not belongs to the road segment e_2.

At this point Signal strength of the mobile phone and the mobile tower can be used to compute the city buses belongs to the road segment e_2 designated by $e_2(T_1)$ and $e_2(T_2)$. We shall designate the portion of the road as "Right" if the portion is at right to the Cell centre and as "Left" if the portion is at left to the Cell centre as shown in the figure-3. The line divides the cell is a north to south line.

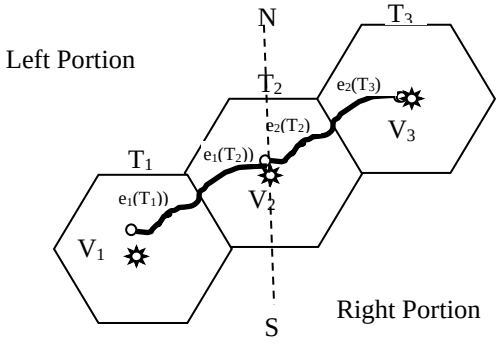

Fig 3 : A portion of UTN inside BTS Cells

(a) ***Computation related to road segment***: Initially, we shall find out the road segment with the help of signal strength then we shall find out the city bus as per direction according to our requirement in the computation. As for an example, the road segment e_2 in fig-1 has two parts e_2 (T_2) and e_2 (T_3) under two BTS cells T_2 and T_3. So we have four possible counts

(i) The City bus is at e_2 (T_2) towards junction V_2.
(ii) The City bus is at e_2 (T_2) towards junction V_3.
(iii)The City bus is at e_2 (T_3) towards junction V_2.
(iv) The City bus is at e_2 (T_3) towards junction V_3.

(b) ***Computation related to road junctions***: Initially, we shall find out the road junction for which the data to be computed, the information of the road junctions is available in the MPN mapped UTN. If we want to compute the number of city bus around the road junction. As for an example if we compute the number of city bus going out of V_2 or coming in into V_2, the need to compute the following with four possible options:

(i) The City bus is at e_2 (T_2) towards junction V_2.
(ii) The City bus is at e_2 (T_2) towards junction V_3.
(iii)The City bus is at e_1 (T_2) towards junction V_1.
(iv) The City bus is at e_1 (T_2) towards junction V_2.

VI. ALGORITHM

(a)Algorithm for counting city bus around a road junction together with number city bus travelers:

Steps:

1. Enter the Road junction around which the city bus and its travelers to be counted (say V_i)
2. Find the BTS Cell in which the road junction resides say (T_i)

/* Compute City bus in Road segment Portion-1 in Left and Right direction */

3. For BTS Cell T_i
4. Find out the portions of the roads on which the estimate to be done.(Say $e_j(T_{i1})$, $e_j(T_{i2})$)

/* Computation for left portion on the BTS Cell*/

5. For Road segment in the left portion ej(T_{i1})
6. Compute the dedicated mobile numbers on the road segment moving towards Right direction (say LN1)
7. Compute the number of the other mobile number having same transition record with the dedicated mobile numbers towards Right direction(say LNT1)
8. Compute the dedicated mobile numbers on the road segment moving towards Left direction (say LN2)
9. Compute the number the other mobile number having transition record with the dedicated mobile numbers towards Left (say LNT2)

/* Computation for Right portion on the BTS Cell*/

10. For Road segment in the left portion $e_j(T_{i2})$
11. Compute the dedicated mobile numbers on the road segment moving towards Right direction (say RN1)
12. Compute the number of the other mobile number having same transition record with the dedicated mobile numbers towards Right direction(say RNT1)
13. Compute the dedicated mobile numbers on the road segment moving towards Left direction (say RN2)
14. Compute the number the other mobile number having transition record with the dedicated mobile numbers towards Left (say RNT2)

/* Compute Total City bus around the Road Junction and Total City Bus Travelers in both direction)*/

15. Total number of city Bus Towards Road Junction NP= NL1 + RN2
16. Total number of city Bus Towards Road Junction NN= NL2 +RN1
17. Total number of city Bus Travelers Towards Road Junction , NTP= NLT1 + RNT2
18. Total number of city Bus Travelers Towards Road Junction, NTN= NLT2 +RNT1
19. Stop.

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(b)Algorithm for counting city bus on a road junction together with number city bus travelers:

Steps:

1. Enter the Road Segment on which the city bus and its travelers to be counted (say e_i)
2. Find the BTS Cell in which the road segment resides say (T_i, T_j)

/* Compute City bus in Road segment Portion-1 in Left and Right direction */

3. For BTS Cell T_i
4. Find out the portion of the road on which the estimate to be done.(Say $e_i(T_i)$)
5. Compute the dedicated mobile numbers allotted for the city bus on the road segment towards Right direction (say M1)
6. Compute the number of the other mobile number having transition record with the dedicated mobile numbers towards Right direction (say MT1)
7. Compute the number of dedicated mobile number on the road segment towards Left direction (say M2)
8. Compute the number the other mobile number having transition record with the dedicated mobile numbers towards Left (say MT2)

/* Compute City bus in Road segment Portion-2 in Left and Right direction */

9. For BTS Cell T_j
10. Find out the portion of the road on which the estimate to be done.(Say $e_i(T_j)$)
11. Compute the number of dedicated mobile numbers on the road segment towards Right(say M3)
12. Compute the number the other mobile number having transition record with the dedicated mobile numbers towards Right (say MT3)
13. Compute the number of dedicated mobile numbers on the road segment towards Left (say M4)
14. Compute the number the other mobile number having transition record with the dedicated mobile numbers towards Left (say MT4)

/* Compute Total City bus and its users */

15. Total number of city Bus Towards Right direction MR= M1 + M3
16. Total number of city Bus travelers Towards Right Direction MTR=MT1+MT3
17. Total number of city Bus Towards Left direction ML= M2 + M4
18. Total number of city Bus travelers Towards Left Direction MTL=MT2+MT4
19. Stop.

VII. GUWAHATI CITY - CITY BUS NETWORK

There are numerous city buses including Private and Government, operating daily on urban roads of Guwahati city. The introduction of JNNURM long city buses on the urban roads of Guwahati city has multiplied the problem of congestion. The city buses are operated in different paths and there is no optimized assignment of the buses on urban roads. However, if we can count the passengers who are availing the city bus facility at various stoppages at different time then it is possible to optimize the movements of the city bus. Moreover, assignments of city bus on an optimized way can minimize the problem of congestion.

VIII. FURTHER SCOPES AND CONCLUSION

Mobile phone network has tremendous scope for many applications including urban traffic management. Once the system is tuned for data collection system in an efficient manner, the stored data can be used for analysis purpose which may be used non-trivial information retrieval. It is also mentionable that the mobile phone network is already a readymade system at every city in the world; the infrastructure development cost for the system will be negligible in comparison to any other system. So people can use the mobile phone network system efficiently.

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