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Using Mobile Phone Network for Urban Traffic Management

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ABSTRACT
The transition record of mobile phones across Base Transceiver Stations can be used as useful data for urban traffic management. While, most of the urban traffic users are mobile users, thus the count of such users can be used as a count of traffic users on urban roads. Using this mobile phone transition records, we have developed a system to classify the mobile phone users in different categories. We have developed algorithms to classify the mobile phone users, such as static users, pedestrians users, slow moving vehicle users, city bus users, car or bike users, daily travelers, users of a large gathering, non-resident users. This classification will help the urban traffic managers to control the traffics and congestion on urban roads.

General Terms
Urban Traffic Management, Wireless Sensor Network, Intelligent Traffic System, Vehicular Adhoc Networks

Keywords
Intelligent Transport System, Mobile Phone Network, Urban Traffic Congestion, Urban Traffic Control, Urban Traffic Network.

1. INTRODUCTION
Traffic congestion is a phenomenon that is faced by the urban traffic users travelling on foot, or on vehicles. The traffic congestion spoils valuable time, fuels and money which create unexpected situations on the roads. In present day situation advanced technologies like wireless sensors [1], vehicular ad-hoc networks [2], car to car communications system etc are used to manage the urban traffics. These technologies also help to control the traffic congestion or to inform traffic users about probable congestion or road blockade by collecting and analyzing the real time traffic data. However, highly populated cities where Intelligent Transport System (ITS) facility is not available, the commuter has to suffer with severe traffic congestion problems. Sometimes the urban road traveler faces rigorous traffic problem when they are carrying serious patients, though there are alternative free roads to travel.

The advent of mobile phone is a boost of the communication technology for modern day civilization. Now-a-days people communicate with each other with mobile phone when they are apart. They also communicate using mobile phones when they are in the same building premises, because the cost of call becomes cheaper and affordable. Urban areas are generally having thick population of peoples as well as having lots of vehicles moving through roads. The mobility of people around urban road is a concern of urban traffic network, because of growing congestion on urban roads. People moves on foot or with several kinds of vehicles such as carts, bicycles, rickshaws, city bus, cars, bikes etc. for different purpose. The people who move around urban roads are the carriers and users of mobile phones, and thus the mobile phone network can be used as a tool for counting traffic commuters on roads to control traffic congestion or traffic jam. If we can compute the real time traffic situation with the help of mobile phone network then the same can be intimated to the traffic users to avoid the traffic congestion. With the help of the mobility record of each mobile user we can also plan for other activities such as route planning for city bus which ultimately help the management of urban traffics.

Urban traffic network where there is no ITS facility available, the mobile phone network can be used as a background and real time data collection system to collect the mobility of traffic users on the urban roads. In such circumstances, mapping of Mobile Phone Network onto an Urban Traffic network [3] is an important technique to exploit. So the mobile phone network can be exploited as a background data collection system to control the Urban Traffic Network. The active mobile phone registration database and the active mobile phone transition record can act as an agent to control the traffic jam as well other traffic management issues.

Several tools have been used to collect the data of urban traffics where most of them use the Conventional in Situ Technology or Floating Car Data (FCD) [4]. The Conventional in Situ Technology may be Magnetic loops, Pneumatic road tubes, Piezoelectric sensors. On the other hand FCD uses wireless sensor network, vehicular adhoc network, GPS, Car-to-car communication, Mobile phone networks etc for the efficient management of traffic. All other systems apart from the Mobile Phone Network are the facilities specially created for Urban Traffic Management which needs more or less equipments, manpower, and maintenance. Therefore the installation of such facilities needs extra effort and cost. On the other hand, we can use the readymade system – mobile phone network facility in such situation as a key facility without extra effort and cost.

2. MOBILE PHONE NETWORKS
Global System for mobile (GSM) network- With the passage of time, the mobile phone technology has become remarkably advanced, and many tools and utilities come up to solve the communication problem. The second generation (2G) of mobile communication system appeared as Global System for Mobile (GSM) without causing major usability changes of Public switched telephone networks (PSTN). In GSM the network has been divided into the partitioned area like GSM service area, PLMN service area, Mobile service switching centre (MSC) Service area, Location area (LA), and Cells. The lowest level of area that is maintained under a GSM is a cell, which is an area is connected to the other areas via a mobile

antenna or tower. To connect a mobile phone from a cell by another mobile phone the GSM system should know the location of the mobile phone to be connected. Therefore it is necessary to keep track of subscriber's location with the help of various databases more precisely the subscriber's identity module (SIM), the Visitor Location Register (VLR), the Home Location Register (HLR). When a subscriber switch on his mobile phone with an authenticated connectivity the presence of the mobile phone is recorded in a database from the area called Visitor Location Register (VLR). The Visitor Location register is integrated with the Mobile Services Switching Centre (MSC). The home operator of the subscriber keeps current location of the subscriber in HLR database together with the basic data of the subscriber on a permanent basis. In general when the subscriber moves to another VLR area, the data is erased from old VLR and stored in the new VLR.

The mobile phone constantly receives information from the network. This information includes the identification area (ID) of the VLR area where the mobile phone is currently located. Every time the network broadcasts the information and the mobile updates the ID of the VLR area. When a mobile phone moves to a different VLR area the ID of the VLR area changes. Thus the ID broadcasts by new VLR area will differ therefore the mobile sends a request to the network for a registration enquiry in the VLR database. Therefore the mobile transition record is reflected in the VLR database for the time when mobile is under that VLR area. It is also possible to transfer these transition log information in a separate database to keep track of changes in locations of the mobile numbers across the mobile towers from the VLR database then it can be used for intelligent urban traffic control and management. The VLR record from each MSC can be collected for the urban mobile network and can be processed further to retrieve intelligent information.

3. RELATED WORKS

Detection of vehicles on roads, its classification and count are some important task for smooth management of urban traffics. Numerous types of vehicle detectors with their detection ability and performance have been discussed by Yuxin Liu et al [5] . In their discussion they mentioned about several equipments to detect on road vehicles with its advantage and disadvantages. Coil detectors, video detectors, microwave detectors, laser detectors, infrared ray and ultrasonic, magnetic detectors are few examples have been discussed with comparison. Again, Vehicular adhoc network (VANET) has also been discussed as a key data collections facility for the urban traffic management. Florian Knorr et al [6] has discussed a system that can count number of vehicles on a road segment and the time taken to cross a road segment. It has been found that a method have been developed to control the vehicular congestion by sending warning signals to the drivers to keep a larger gap amongst the vehicles on highways to prevent the occurrence of traffic breakdown. Again, Wi-Fi enabled buses and stops has been discussed in [7] in a paper by Utku Günay et al as a backbone of metropolitan delay tolerant network. They proposed a routing algorithm to minimize the traversal time for the buses and thus improvement of the traffic condition. Ke Zhang et al [8], discussed a method to detect traffic rate based on a spatio-temporal original destination matrix, their paper also discussed the vehicular sensor network created by the GPS system. But the paper does not emphasize on the origin of data and collection method which is an important issue in urban traffic network. Because, the background data gives the original traffic information to be processed for further information. Transforming GIS data for road maps of the urban area has been discussed in [9] which has been used to provides road features for traffic simulations,

Collection and distribution of the information through internet has become a common task amongst the common peoples. Internet has become now the primary source of information. In this context, Joshua Hare et al [10] discussed a method stating that the population of mobile phones and Internet connectivity can be exploited as a data collection and deployment facility in many applications including the urban traffic control. It has been discussed by Gayathri et al [11], about a method to tracking vehicular speed by an algorithm called DDTW (Derivative Dynamic Time Warping). Further, Richard A. Becker et al [12], described a method how the mobile phone handoff pattern can be used to classify the routes of a city traffic network and thus finding the traffic volumes on urban roads. They also explained and compared to find similarity in their computed data with the data published by the transport authority. However, their work is on mobile phone handoff patterns and when the mobile is in call. It is not necessary that a mobile phone user will call his mobile during his journey on urban roads. Jorge Zaldivar et al [13] , 2011, in their paper discussed about a method to inform the authority about the vehicular accidents within 3 sec with the help of an Android based application which monitors the vehicle through an on board diagnostics interface. The device is capable of detection of accidents with the triggering of the devices with triggering if airbags after accidents. Moreover, M R Singha et al [3] described a method to map a mobile phone network onto urban traffic network to make data collection and processing system easier for the control of the urban traffic networks.

. Considering the mobile phone networks with other techniques we can explain that the mobile phone network can be used as a facility with minimum installation cost. Because, most of urban areas are installed with the mobile phone networks for data and voice communications. Moreover, as we have seen that there are many providers of the mobile phone networks , so, failure of one cannot stop the data collection. So, the mobile phone network is more effective in reliability and performance in comparison to other systems like closed circuit TV's, wireless sensor networks, RFID etc. Moreover, other system needs not only huge installation cost but it needs daily rigorous maintenance. In such circumstances the mobile phone networks which has been already used for data and voice communication purpose can be used as a useful tool for managing traffic on urban roads, which does not need extra equipment and installation cost.

4. BACKGROUND DATABASE

Mobile transition data should be collected from the mobile service providers. The VLR database or the HLR database can give the information of mobile transitions from one location to another. The transition records are collected and stored into a table (refer the table-1 for MTRANSITION table). As soon as the data is inserted in the MTRANSITION table a ***trigger*** will wake up for updation of data in MPATH table. In MPATH table the path sequence for a mobile phone will be updated. E.g. suppose a mobile number has initially recorded with an area '1', after that it has moved to a different area say '2' so the path sequence will be 12. Moreover, the time slab for completing the sequence will also be added, the time slab will give information like time taken to complete the path or at what time the mobile phone has completed the path etc. The trigger will change a logical value of a field value *pathisroute* depending on the *pathsequence* completes a route or not.

There are two additional tables specifying the ROUTE in a city traffic network. The no. of routes depends on no. of road junctions considered in the UTN and number of edges presents connecting the vertices of the network. The data processing complexity will increase, with the increase in number of vertices and edges. The E-R diagram and the relational schema for the background database have been discussed next.

4.1 The Entity-Relationship (ER) diagram

The following is the E-R diagram for the system. The E-R diagram has shown only by entities. Attributes are described in **Table-1**.

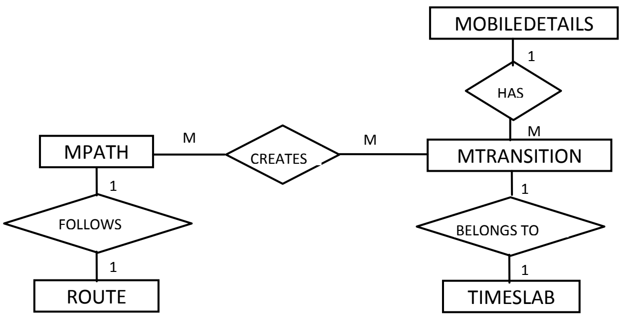

Fig 1: E-R Diagram

4.2 The Relations and their attributes

Table-1 : Relation and their attributes

SL	TABLE NAME AND DESCRIPTION	
1	MOBILEDETAILS	
	The table contains the mobile numbers and their Home location Register details with following fields:	
	Mobileid	Mobile no. of a user(Integer)
	Username	Name of the user (Text)
	HLR_id	Home location register id(Integer)
	User details	Details of the user(Text)
	Cofidentiality_level	Level of confidentiality Char(1)
2	TOWERDETAILS	
	The table contains details about mobile towers with the following field values:	
	Towerid	Transaction created at Tower (Integer)
	Location	Location of the Tower (Text)
	Base_distance	Distance from a Base Tower (Float)
3	MTRANSITION	
	The table contains the base data records generated at the BTS with following field values :	
	Transid	Transaction ID as Primary key(Integer)
	Mobileid	Mobile no. created transaction (Integer)
	Towerid	Transaction created at Tower (Integer)
	Entrytime	Entry time (dd/mm/yy:hh:mm:ss)
	Exittime	Entry time (dd/mm/yy:hh:mm:ss)
4.	MPATH	
	The table contains the updated data by a database trigger that keeps the information of a mobile path during particular time duration (say 8.00AM to 8.00 PM). The table contains the following fields immediately updated from the MTRANSITION table:-	
	Mobileid	Mobile ID (Integer)
	Pathsequence	Sequence of Paths in order (Text)
	Tdate	Date of occurrence (dd/mm/yy)
	STslab	Starting time slab (Text)
	ETslab	End time slab (Text)
	Tduration	Duration of time in the slab (Float)
	Pathisroute	Logical (True or False)
	Mobileclass	Mobile belongs to a Class (Character)
	Towers	No. of towers in the transition (integer)
5.	ROUTE	
	The table contains the information about an urban route followed by a path sequence. The fields of the table are :-	
	Routeno	Route no. (Integer)
	Pathsequence	Sequence of Paths in order (Text)
	Distance	Total Length of the Path(Float)
	Nj_Walktime	Normal Journey time(Float)
	Nj_Rikshawtime	Normal Journey time(Float)
	Nj_Busttime	Normal Journey time(Float)
	Nj_Carbiketime	Normal Journey time(Float)
6.	TIMESLAB :	
	The time slab maintained for a day. The fields are:-	
	Tslab	ID of the time slab(Integer)
	Timefrom	Start time of time slab(HH:MM:SS)
	Timeto	End Time of time slab (HH:MM:SS)

4.3 The actions to be initiated with triggers

We shall discuss few actions or triggers should be initiated on insertion of a transition record in MTRANSITION table which will further help in the algorithms described in sixth section. The triggers are basically used to compute the values for few fields in MPATH table depending on some conditions.

Pathsequence : This is field related to the path travelled by a mobile user described by a sequence of places traveled by a mobile user. If the transition record of a traveler starts with the place 1 and then 2 and then 4 then path sequences will be 124. This is concatenated string defines the path sequence of a user. The field Tdate defines the date of travel and STslab defines time slab when the pathsequence starts and ETslab is the time slab when the pathsequence ends.

TDuration : It is the time duration for completing a particular pathsequence. If Tduration exceeds the normal journey time for the pathsequence then there is chance of congestion.

Pathisroute : All the considerable roots of urban traffic network will be stored in a table called ROUTE. We shall keep only those routes we are interested for study. If a pathsequence is equal to any route in the **ROUTE** table then Pathisroute field is True otherwise False.

Mobileclass : This is a field which shows in which class the mobile belongs to. The Mobileclass will be computed by few algorithms described in sixth section.

5. MOBILE USER CLASSIFICATION

We shall initially discuss the classification of mobile users and the algorithm to classify the mobile phone users into the classes static users, pedestrians, user of slow moving vehicles, users of city bus, car or bike travelers, daily travelers, users of a large gathering and non-urban users.

5.1 Class hierarchy with DAG

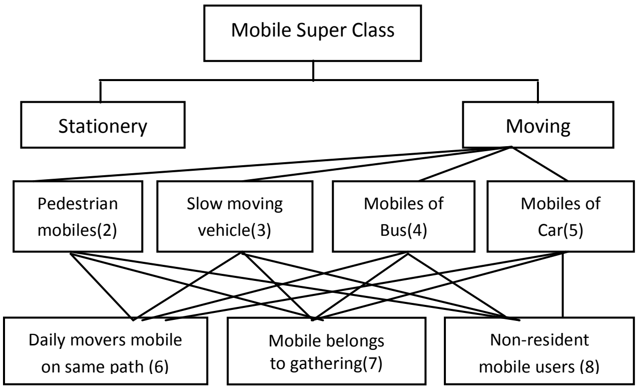

Fig-2 : Directed Acyclic Graph

5.2 Classification of Traffic Users

The classification of users described above follows some meaning as the mobile numbers classified as shown in **Table-2**.

Table-2: User Classification details

SL	MOBILE USER CLASS	MOBILITY PROPERTY
01	Stationery or household mobile phone.	Mobile phone which does not move from one location and the connection has no transition record from a long time.
02	Very Slow movers mobiles-Pedestrians	Mobile phone or user which moves from one location to another location has transition record of moving slowly and steadily from one location to another. The users will not have long distance covered on the journey.
03	Slow movers mobiles-Slow moving vehicles (such as Rickshaw, Horse cart etc)	Mobile phone or user which moves from a location to another location has transition record of moving faster than pedestrians from one location to another. If some transitions take longer time the it requires than there may a larger waiting time and congestion.
04	Fast movers mobiles-City bus users	Mobile phone or user which moves from a location to another location has transition record of moving faster at least from one location to another. It may take long time compared to normal time, to cross a road, which we may consider as larger waiting time and congestion.
05	Very fast movers mobiles-Car or bikes users	Mobile phone or user which moves from a location to another location has transition record of moving faster than city buses at least from one location to another. It may take long time to cross in few of the transitions, which may be considered as larger waiting time and congestion.
06	Daily travelers	A group of travelers who has similar transition records for the weekdays can be considered as daily travelers on same path.
07	Mobile belongs to a gathering	A group of users who has mobility as well stationery at a place for a long time (the place is a field or a large auditorium , cinema hall etc),
08	Nonresident mobiles users	The mobile numbers which has few transition records in the urban area but most of the transition records outside the urban area can be considered as non-resident users.

6. THE ALGORITHMS

We shall discuss the few algorithms related to the triggers described in previous section together with an algorithm which classifies the mobile users 01 to 06 as described in **Table 2**.

The algorithms are as follows.

6.1 *Algorithm for detecting Pathsequence and Tduration , STslab, ETslab, Tdate on a particular day:*

Steps :

1 : Arrange the data for MTRANSITION table sorted as per *mobileid* and *towered, entrytime* and *exittime*.
2 : Concatenate the ordered *towerid*'s as for a particular *mobileid* on a particular day called the ***Pathsequence***.
3 : Set ***STslab***=entrytime of the sequence.
4 : Set ***ETslab***=endtime of the sequence.
5 : Set ***Tdate*** = Date of occurrence of the path sequence.
6 : Compute the time taken to complete the path sequence by the mobile number which will be called ***Tduration***.
7 : Store ***Pathsequence, STslab, ETslab, Tdate, and Tduration*** in MPATH table as per mobile number and date.
8 : Complete the steps (a)-(d) for all *mobileid*.

6.2 *Algorithm to compute Pathisroute* :

Steps :

1 : Get a ***pathesequenc***e of a mobile number for a particular day.
2 : If MPATH.***pathsequence*** matches with any of the ROUTE.***pathsequence*** then the MPATH. ***Pathisroute*** = .True. otherwise MPATH. ***Pathisroute*** = .False.
3 : Compute the step (a) – (c) for all pathsequence in MPATh table.

6.3 *Algorithm to compute Mobileclass :*

Steps :

1 : Get a record of MPATH table with ***mobileid.***
2 : Compute travel speed. (say V= ROUTE.distance / MPATH.Tduration)
3 : If the mobile number has no transition records then classify the mobile number as "01: Stationery Mobile".
4 : If the mobile number has a transition record of travel as pedestrian then classify the mobile number as "02:Pedestrians Mobile".

5 : If the mobile number has a transition record of travel as slow moving vehicles then classify the mobile number as "03:Slow movers Mobile".
6 : If the mobile number has a transition record of travel as fast moving vehicles then classify the mobile number as "04:Fast movers Mobile".
7 : If the mobile number has a transition record of travel as very fast moving vehicles then classify the mobile number as "05: Very fast movers Mobile"
8 : Otherwise classify the mobile number as " Mobile number cannot be classified"
9 : Compute steps (a) to (h) for all mobileid from MPATH table.

6.4 Algorithm to find Daily travelers :

Steps :

- I Get all records from MPATH table for a ***mobileid*** and ***pathsequence*** .
- ı If the path sequences are nearly same for all the days then classify the mobile number as "06: Daily travelers.

7. TRAFFIC CONGESTION

Traffic flow and density can also be computed from the classified users classified by the above algorithms. Traffic density of an urban road may depend on number of mobile users on the road. The density of mobile users can give the picture of congestion on the urban road. In this case the statistical data computed for a year may be used to predict the traffic volume on a road. Say the statistics shows that if number of mobile users on a particular time slab on an urban road segment shows a congested road condition then we can conclude that "The road is congested".

8. THE LIMITATION

The data collection and the procedures described in this paper have some limitations. One of the limitations of the system is collection of mobile transition data. There are many mobile service providers in and around the urban traffic network. Every mobile service providers are using their own antennas for communication except for few. So merging all the data with each and every tower will be a complex task for the system. Moreover, maintaining privacy for the mobile phone transition is also necessary. Since, mobile transition can show the transition of a mobile phone at different places. So the VIPs or VVIPs movement who are carrying mobile phone also reflect in the transition database are to be maintained with privacy.

However, the predictions or the information retrieved from the system can be used as base information or as a help. Where there is no ITS we can surely expect the mobile phone network there. Thus the system can be implemented with low cost. The ingenuity is that the existing mobile network is to be set up for the collection of the record related to MTRANSITION table defined earlier in section 4.2.

9. FUTURE SCOPES

There is tremendous scope for the authority who deals with Urban Traffic Management activities. The mobile phone network can be exploited to develop an Intelligent Transport System (ITS) where there is no other facilities such as sensor based networks, or GPS or VANET. The UTN authority can approach the existing mobile service provider authorities for the basic data needed for the system. Apart from some other data can also be collected from Government or Non-government sources such as daily traffic users, daily pedestrian count, and daily city bus users. number of private cars on road. City buses and the route distribution etc which will help in urban traffic management for blended with mobile phone connectivity records.

10. CONCLUSION

Mobile phone network is a facility which is already available with every city around the world. Thus the mobile phone network and its connectivity record can boost the Urban traffic management system not only at the urban places where the ITS is not available but also where ITS is available and can be a source of added sub system for the urban traffic management.

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