Mapping Mobile Phone Network onto Urban Traffic Network

Mukta Ranjan Singha, Bichitra Kalita

***Abstract* -- Urban Traffic Network (UTN) can be represented as a directed graph say, G={V,E}, where V={v_1,v_2,v_3.....,v_m}, is a finite set of vertices and E={e_1,e_2.e_3,…,e_n}, is a finite set of edges. The vertices of UTN are the road junctions or terminals and the edges are road segments. The Mobile Phone Network (MPN) around the UTN can also be represented as a graph say $G^{/}$={T,E} with vertices T={t_1,t_2,t_3.....,t_l} and edges E={e_1,e_2.e_3,…e_n} . The vertices t_1,t_2, t_3.....,t_l are the points on the road segments nearest to Base Transceiver Station (BTS) Cell centre and the edges e_1,e_2.e_3,…e_n are the finite set of edges, same as the edges of UTN.**

In this paper, a method has been discussed to map a MPN onto a UTN. The mapping can be used for urban traffic management, such as counting the number of traffic users around a road junction. We have also stated and proved that "Any MPN graph can be constructed as an UTN graph". Further, we have used the application of the mapping in counting traffic users to find the traffic congestion levels.

***Index Terms:-* Mobile Phone Network, Traffic Congestion, Urban Traffic Network.**

I. INTRODUCTION

The main problem of Urban Traffic Network (UTN) is traffic congestion that occurs due to increased number of vehicles and their mobility on urban roads. Sometimes, road blockade occurs due to uncontrollable movement of the vehicles along the roads. In such case, an Intelligent Transport System (ITS) is necessary to manage and control the vehicles on urban roads. The wireless sensor supported system can provide real time mobility data of traffic users. Again, processing of real time data, the traffic scenario are analyzed and important information are retrieved for controlling the movement of urban traffic users. The important information includes traffic counts, route identification, user classification, traffic congestion and road blockade etc. The present day Mobile Phone Network (MPN) is built with the Second Generation (2G) or higher GSM network for voice and data communications. The GSM network has

been used in most part of the world and emerged as popular system of voice and data communication. We shall use the term UTN for urban traffic network, which constitutes urban roads, peoples and vehicles. The main goal of the urban traffic manager is to manage and control the movement of the traffic users without congestion. We shall also use the term MPN for Mobile Phone Network, which constitutes BTS and its connectivity, mobile phones and its users. The basic control station of MPN is BTS. The BTS is responsible for transmission and reception of radio signal to and from the Mobile Equipment. The short range BTS are installed at a short distance apart with another in urban areas. Whereas, in rural areas, long range BTS is installed. This is due to number of subscribers is dense in urban areas compared to rural areas. The area covered by a BTS is called a Cell. When a mobile phone user is in movement and enters or leaves a BTS Cell the action is recorded in a register in a database of MPN. Therefore, the traffic users who are the carriers of mobile phones and moving on roads can be treated as traffic users. Thus, the mobility of mobile phone users from one BTS Cell to another shows the mobility of urban traffics users from one place to another. Therefore, for the management of UTN, one can use the mobility record of mobile phone users from one BTS Cell to another. The advantage of using the MPN is that, it is already a created system in most urban areas in the world.

Therefore, we can consider the mobility of mobile phone users as the mobility of urban traffic users. The count and transition of mobile phone connection around the BTS Cells can be thought of as the count and mobility of urban traffic users around the urban road junctions.

The description of the sections of the research paper: The Section-I of this research paper is the introduction about the UTN and MPN. The GSM network has been discussed in brief at Section-II. Description of few previous research works, which uses the MPN has been discussed in the Section-III. The novel approach to map the MPN onto UTN has been discussed in Section–IV with an example. At the end of the Section-IV, we have stated a theorem on mapping MPN onto UTN. We have also described two algorithms viz. (1) algorithm for the mapping MPN onto UTN (2) algorithm for finding traffic user count and probable traffic congestion on urban road junctions in Section-V. The limitations and the conclusion are discussed in next consecutive sections.

*Attributes of UTN and MPN with few Properties***:** the Table-I describes the attributes of UTN and MPN network with their common properties:-

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Table-I **:** UTN and MPN attributes

Sl.	**UTN**	**MPN**	**Common property**
1	Road Junctions	Centre of Base Transceiver Station (BTS)	Represents vertices.
2	Road segment	Mobile Connectivity	Represents edges
3	Traffic users	Number of connected subscribers	Represents dynamic Weight.
4	Road Length and width	Signal Strength	Represents static weight.

Further, we can express that,

(i) The total count of active mobile users available within the range of a BTS Cell may be considered as probable number of traffic users on urban roads around the BTS Cell. By active mobile user, we mean that the mobile users who carry a mobile phone in switch on state and the mobile phone is within the range of any BTS Cell.

(ii) The mobility of mobile users shows the transition record of moving from one BTS Cell to another.

(iii) A point on the road segment nearest to the BTS Cell centre can be thought as a vertex for MPN, if there is no road junction inside the Cell. Otherwise, the UTN road junction may be thought of a vertex for MPN. In both the cases the vertices are within the BTS Cell.

(iv) For both the networks, the road segments are considered as edges.

II. THE MPN DATA COLLECTION SYSTEM

*The GSM network***:** The evolution of mobile phone has become popular with the use of Global System for mobile (GSM) technology and architecture. GSM has initially launched in Finland. Later on, GSM has been become popular and the most of the current telecommunication system in the world is based on GSM technology and architecture. In the GSM system, the total network area is called GSM service area [11]. The GSM service area is further divided into Public Land Mobile Network (PLMN) area. All incoming calls for a GSM/PLMN network are routed through a switching centre called Mobile Service Switching Centre (MSC). Call connections between PLMN and other networks must be routed through some designated MSC called gateway MSC. A group of BTS is controlled by a system called Base Station System (BSS) and all the BTS is connected to a Switching centre called Basic Switching Centre (BSC).

Mobile Phone Registration and its database: The basic service of a MPN is to give service to the customers when they are also in motion. An active mobile phone is always connected to a BTS with a radio signal, if it is within the range of the BTS. The local operator gives the network service to the mobile phone. The local operator in this case provides service inside the BTS Cell which always keeps the connectivity with mobile phone inside the Cell area. When the subscriber moves from one BTS cell to another the network keeps the track of the subscribers location is called location update. When a subscriber moves with their mobile phones from a BTS Cell to another, the Cell is connected through an air interface and the connection record is recorded in a database called Visitor Location Register (VLR). The VLR is integrated with the MSC. The home location of a mobile phone, where the mobile has been initially registered is maintained by a Home Operator. The Home Operator of the subscriber also keeps the track of the movement of the subscriber in a register, called Home Location Register (HLR). The VLR keeps the record of the subscribers currently under the VLR area. When the subscriber moves from one VLR to another, its data is erased from the old VLR and stored in new VLR. However, the HLR keeps the basic data of the subscriber on a permanent basis. Only variable information in the HLR is current location of the subscriber. The record of VLR address and the HLR address of the mobile phones shows the mobility record of the subscribers.

III. RELATED WORKS

The mobile phone network has now become an important tool amongst the researchers for urban traffic management. The method to track the vehicular speed has been discussed by Gayatri et al [3], where emphasis has been given to track the speed of traffic users along the urban roads. Further, in their findings Richard A Becker et al [1] discussed about the classification of urban routes and finding of traffic user volumes on urban roads. They used mobile phone handoff patterns, when the mobile is in call to find the traffic user count. In a research paper by Floritan Knorr et al [4] discussed the Vehicular Adhoc Network (VANET) as the data collection tool to inform the vehicle drivers about possible traffic breakdown. They shows that, with the help of the information received from their developed system, the drivers can slower the speed of the vehicles to avoid the congestion on urban roads. In discussing the data of urban traffic system Ke Jhang et al [5], has described about the spatio-temporal matrix and a traffic detection algorithm for the management of UTN.

The concept of Urban dynamics has also been used for the cellular census, which has been discussed by Jonathan Reads et al [8]. They used visual 3D plot during a gathering in Rome during a Madonna concert, where the data has been collected by the cellular networks. By giving emphasis on vehicular censor network Uichin Lee et al [9] discussed a method called MobEyes, which they used to summarize traffic data. Using Cell phones as traffic probes, Keemin Sohn et al [10] discussed a method to estimate the dynamic origin destination flow.

Most of the works described here are mostly uses MPN as their background data collection system.

IV. THE MAPPING OF MPN ONTO UTN

Let us consider the following figure labeled as fig-1 to describe a MPN and UTN together:-

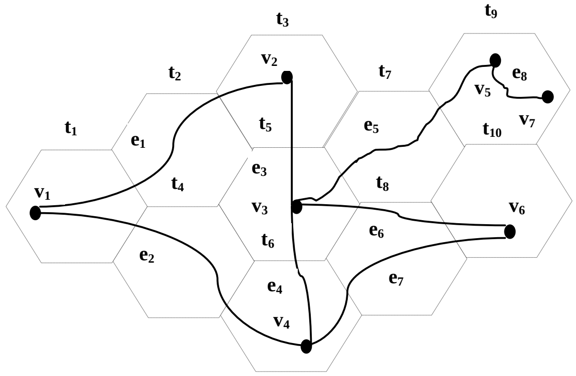

Fig-1 : An example of MPN and UTN together

The fig-1 contains BTS Cells, which are represented by hexagons with a cell name. Road junctions or terminals shown in dark ovals and the edges connecting the road junctions or terminals are shown as black thick lines.

*Separating the UTN***:** We can represent the UTN section of the graph as an incidence matrix A in fig-2 as follows:-

A=

	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
v_1	1	1	0	0	0	0	0	0
v_2	1	0	1	0	0	0	0	0
v_3	0	0	1	1	1	1	0	0
v_4	0	1	0	1	0	0	1	0
v_5	0	0	0	0	1	0	0	1
v_6	0	0	0	0	0	1	1	0
v_7	0	0	0	0	0	0	0	1

Fig-2 : UTN incidence matrix

The UTN graph found is also shown in fig-3:

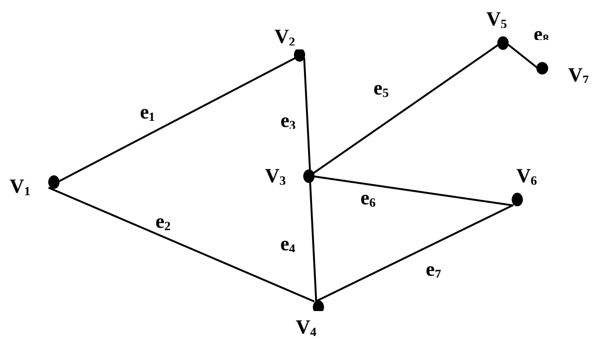

Fig-3 : The UTN Graph

Separating the MPN : Now, as shown in fig-1, we can also represent a matrix as shown in fig-4 showing connectivity of the road segments with the BTS Cells as a matrix B with the following assumptions :-

(i) The columns are represented by the graph edges which are same as UTN graph edges.
(ii) The rows are represented by the points to which the edges are connected inside the BTS Cells.
(iii) For the entries in the matrix, we denote the numbers 1, 2, 3, and so, which represents the connections to the BTS Cells with the road segment in consecutive way. As for an example, t_1, t_2 , t_3 BTS Cell connected an edge e1. We also consider other entries as 0's. These values of the matrix entries will help in further computations.
(iv) For a BTS Cell having more than two edges is represented by two rows. As for an example, the Cell t_8 has two edges inside it. Therefore, two rows are created as $t_{8,1}$ and $t_{8,2}$.

B=

	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
t_1	1	1	0	0	0	0	0	0
t_2	2	0	0	0	0	0	0	0
t_3	3	0	1	0	0	0	0	0
t_4	0	2	0	0	0	0	0	0
t_5	0	0	2	1	1	1	0	0
t_6	0	3	0	2	0	0	1	0
t_7	0	0	0	0	2	0	0	0
$t_{8,1}$	0	0	0	0	0	2	0	0
$t_{8,2}$	0	0	0	0	0	0	2	0
t_9	0	0	0	0	3	0	0	1
t_{10}	0	0	0	0	0	3	3	0

Fig-4 **:** The MPN represented in matrix form

The matrix B does not represent an incident matrix of a graph. Because, some of the columns of the matrix are having more than two entries; and for a graph, an edge must not be incident on more than two vertices [12]. Therefore, it cannot represent a graph.

So, initially we have converted the MPN matrix B into a MPN incidence matrix C without changing the property of the network. Later on, we have normalized the UTN graph to be isomorphic with MPN graph without changing the geometric property of existing edges and vertices. For this purpose, we shall only introduce few new vertices in the midst of the existing edges which also create some new edges. Thus, our aim is to find the isomorphism of MPN and UTN, such that, we can exploit the data collection system of MPN for the management of UTN.

Formation of MPN graph incidence matrix: The MPN matrix B in fig-4 has been converted and represented as an incidence matrix C of MPN graph as shown in fig-5. The algorithm of the procedure for the construction of incidence matrix C from matrix B is discussed in Section-V.

C =

	e_{11}	e_{12}	e_{21}	e_{22}	e_3	e_4	e_{51}	e_{52}	e_{61}	e_{62}	e_{71}	e_{72}	e_8
t_1	1	0	1	0	0	0	0	0	0	0	0	0	0
t_2	1	1	0	0	0	0	0	0	0	0	0	0	0
t_3	0	1	0	0	1	0	0	0	0	0	0	0	0
t_4	0	0	1	1	0	0	0	0	0	0	0	0	0
t_5	0	0	0	0	1	1	1	0	1	0	0	0	0
t_6	0	0	0	1	0	1	0	0	0	0	1	0	0
t_7	0	0	0	0	0	0	1	1	0	0	0	0	0
$t_{8,1}$	0	0	0	0	0	0	0	0	1	1	1	1	0
$t_{8,2}$	0	0	0	0	0	0	0	0	0	0	0	1	0
$t_{9,1}$	0	0	0	0	0	0	0	1	0	0	0	0	1
$t_{9,2}$	0	0	0	0	0	0	0	0	0	0	0	0	1
t_{10}	0	0	0	0	0	0	0	0	0	1	0	0	0

Fig-5 **:** The MPN incidence matrix

Procedure for formation of MPN graph: The MPN graph can be constructed with the incidence matrix as shown in fig-5.

However, the graph can also be constructed with the following procedure:

(i) If there is a UTN vertex inside the BTS Cell then create a vertex in the name of the BTS Cell. We have created the vertex t_1 in place of v_1 of UTN graph shown in fig-1.

(ii) If there is no UTN vertex inside the Cell, but the part of an edge is inside the Cell, than create a new vertex at a point on the edge. The position of the new vertex should be nearest to the centre of BTS Cell. In fig-1, as there is no vertex in BTS Cell T_2 and the edge e_1 crossing through this, therefore, we have created a new vertex t_2. Thus e_1 is divided into e_{11} and e_{12}.

(iii) If there are more than one UTN vertices in a BTS Cell then represent the vertices in the name of the BTS Cell with identifiable subscripts. In fig-1, BTS Cell t_9 has two UTN vertices v_5 and v_7 inside it, therefore two vertices are created as $t_{9,1}$ another is $t_{9,2}$.

The MPN graph constructed has shown in fig-6 :

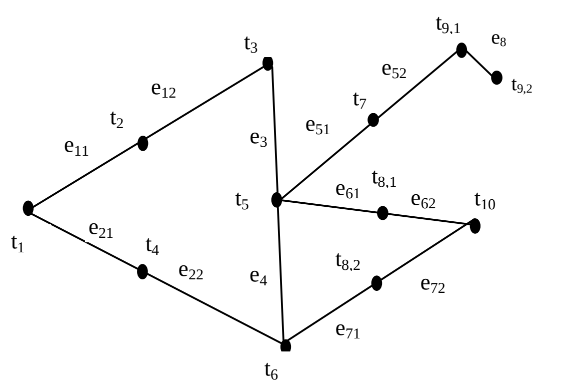

Fig-6 : The MPN graph

Normalization of UTN : We can convert the UTN graph shown in fig-3 to become an isomorphic graph represented in fig-6, by creating some additional vertex and edges without affecting the main feature of UTN graph as shown in fig-7:-.

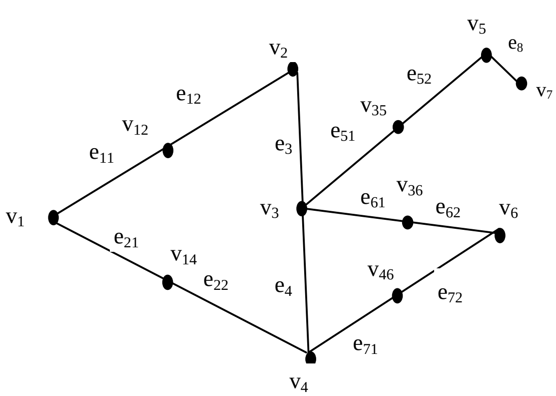

Fig-**7 :** The normalized UTN graph

The mapping of MPN graph vertices and edges with UTN graph vertices and edges has been shown in Table-II and Table-III.

Table-II
MPN-UTN Vertex mapping

MPN Vertex	UTN Vertex	BTC Cell involved
t_1	v_1	t_1
t_2	v_{12}	t_2
t_3	v_2	t_3
t_4	v_{14}	t_4
t_5	v_3	t_5
t_6	v_4	t_6
t_7	v_{35}	t_7
$t_{8,1}$	v_{36}	t_8
$t_{8,2}$	v_{46}	t_8
$t_{9,1}$	v_5	t_9
$t_{9,2}$	v_7	t_9
t_{10}	v_6	t_{10}

Table-III
MPN-UTN Edge mapping

MPN Edge	UTN Edge	BTC Cell involved
e_{11}	e_{11}	t_1 , t_2
e_{12}	e_{12}	t_2 , t_3
e_{21}	e_{21}	t_1 , t_4
e_{22}	e_{22}	t_4 , t_6
e_3	e_3	t_4 , t_6
e_4	e_4	t_5 , t_6
e_{51}	e_{51}	t_5 , t_7
e_{52}	e_{52}	t_7 , $t_{9,1}$
e_{61}	e_{61}	t_5 , $t_{8,1}$
e_{62}	e_{62}	$t_{8,1}$, t_{10}
e_{71}	e_{71}	t_6 , $t_{8,2}$
e_{72}	e_{72}	$t_{8,2}$, t_{10}
e_8	e_8	$t_{9,1}$, $t_{9,2}$

So, the graph shown in fig-6 and fig-7 are isomorphic to each other and we have found that MPN has been mapped into UTN. With these we can formulate a theorem as mentioned in theorem-1.

*Theorem-1***:** *Any Urban Traffic Network can be constructed as a Mobile Phone Network.*

Proof of the theorem: The proof of the theorem follows from the Algorithm discussed in Section-V.

*Useful attributes of MPN-UTN mapping***:** The data collected from the database of MPN can be used for UTN. The table-IV shows the usability of MPN data for UTN network:-

Table-IV **:** MPN data usability for UTN

Sl No.	**MPN data available**	**UTN data needed**	**Usability**
01	Number of subscribers in a BTS Cell	Number of traffic user on the road segment	Used for measuring traffic count
02	Changes in Signal strength of a mobile phone	Direction of movement of traffic user towards a road junction	Used for the direction of the traffic users
03	Uniform Cell coverage on a road junction	Uniform distance between two road junctions	Minimization errors in computation of direction and speed
04	Transition record of mobile phones	Different types of vehicle users	Classification of vehicle users

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V. THE ALGORITHMS

We shall discuss two algorithms in this research paper, (1) for mapping MPN onto UTN, (2) for computing traffic user count around a road junction and output the congestion levels depending on threshold values.

(1) Algorithm for mapping MPN onto UTN ;

Suppose the MPN matrix is $B_{L\times M}$ and the output incidence matrix is $C_{L\times M1.}$ Algorithm for construction of incidence matrix from MPN matrix is as follows:

Algorithm (Coded in Turbo C):

```
#include<stdio.h>
#include<conio.h>
void main()
{
int jj,tcol,v,l,m,n,x;
int mmm=0,i,j,k,p,b[10][10],c[20][20],colsum[10];
clrscr();
printf("Put the dimension of UTN matrix L and M\n");
scanf("%d%d",&l,&m);
p=l*m;
 printf("enter %d number of elements\n",p);
 for (j=1; j<=m; j++)
 {
 for (i=1; i<=l; i++)
 {
 printf("Input B[%d][%d]:",i,j);
 scanf("%d",&b[i][j]);
 }
 }
 /*Initilaise colsums*/
 for (j=1; j<=m; j++)
  colsum[j]=0;
  printf("\n");


/* Printing the UTN matrix*/
  for (i=1; i<=l; i++)
  {
  for (j=1; j<=m; j++)
  {
   if (b[i][j] > 0 ) { v=1; colsum[j]=colsum[j]+v;}
   }
   printf("\n");
  }
/* End of printing*/

   printf("\n");
   tcol=0;
   x=0;
   for (j=1; j<=m; j++)
   {
   if (colsum[j]<2) x=0; else x=1;
   tcol=tcol+(colsum[j]-x);
   }
  printf("\n\n");
  mmm=tcol;
/* Fill the MPN incidence matrix with 0's*/
 for (i=1; i<=l; i++)
 for (j=1; j<=mmm; j++)
  c[i][j]=0;

/*Start of Conversion*/
 k=0;
 for (j=1; j<=m; j++)
 {
 if (j>1) k=k+colsum[j-1]-2;
 for (i=1; i<=l; i++)
 {
 if (b[i][j]==0) c[i][j+k]=0;
  else
   if (b[i][j]==1) c[i][j+k]=1;
    else
     for (jj=2; jj<=colsum[j]; jj++)
     {
     if (b[i][j]==jj && colsum[j]>jj)
      { c[i][j+k+(jj-2)]=1; c[i][j+k+(jj-1)]=1;}
   else
       if (b[i][j]==jj) c[i][j+k+(jj-2)]=1;
      }
  }
  }
/*end of Conversion*/
/* Printing the normalised UTN matrix*/
 printf("\n\n The normalised incidence matrix is :\n\n");
 for (i=1; i<=l; i++)
 {
 for (j=1; j<=mmm; j++)
 {
 printf("%d  ",c[i][j]);
 }
 printf("\n\n");
 }
getch();
}
```

---

(2) Algorithm for finding congestion levels:

We have classified the congestion levels in three categories that may occur around a road junction. The congestion levels are level1, level2, level3. Occurrence of congestion and categorizing them in levels depends on a threshold values Threshhold1, Threshhold2, Threshhold3.

The steps of the algorithm:

1. Input the road junction number for a UTN graph (say v_1)
2. Get the road segments incident on v_1 (say e_i , e_2 , e_3 ….. e_n).
3. Set i=1, Total connections =0.
4. Get the number of mobile connections (say C_i) on the road segment e_i incident on the junction $v_{1.}$
5. Total connections = Total connections + $C_{i.}$

6. i=i+1.
7. If i<=n go to step 4
8. Total traffic user = Total connections
9. If Total traffic user => Threshhold1 and Total traffic user < Threshhold2 then the road junction has a congestion level1.
10. If Total traffic user => Threshhold2 and Total traffic user < Threshhold3 then the road junction has a congestion level2.
11. If Total traffic user => Threshhold3 then the road junction has a congestion level3.

Threshold value is defined as number of subscribers on incoming roads around a road junction.

VI. LIMITATIONS

The research paper is based on the mobile phone network data, collected by the system installed at the Mobile Service Switching Centre (MSC). However, now-a-days there are many mobile service providers who provide service for mobile phone users. Every service providers are having their own BTS for the management and control of mobile phone network. So, assembling all such data from all service providers needs strong co-operation from all the service providers.

Further, mobile phone transition records are confidential data. Because, the data of movement of high profile persons is a concern of privacy and security. Thus, privacy and security is to be maintained in handling these data.

If the UTN contains many edges crossing through a BTS Cell then the construction MPN graph matrix will be complex. However, it is assumed that there will not be more edges passing through the BTS Cell. If it passes also we shall consider the major ones.

VII. CONCLUSION

The mapping of MPN onto UTN have been discussed in this research paper with reference to the urban traffic management with which an ITS can be built for the management of the UTN. At this point a suitable policy and effort is necessary for the successful implementation of the system. If the data are collected from the mobile service providers then, an efficient urban traffic management system is possible for welfare of the society and mankind as a whole.

REFERENCES

[1] Richard A. Becker, Ramon Caceres, Karrie Hanson, Ji Meng Loh, Simon Urbanek, Alexander Varshavsky and Chris Volinsky, “Route Classification Using Cellular Handoff Patterns”, UbiComp’11, September 17–21, 2011, Beijing, China., Copyright 2011 ACM 978-1-4503-0630-0/11/09.

[2] Jorge Zaldivar, Carlos T. Calafate, Juan Carlos Cano, Pietro Manzoni, “Providing Accident Detection in Vehicular Networks Through OBD-II Devices and Android-based Smartphones”, 5th IEEE workshop on user mobility and vehicular networks. On-move 2011, bonn.

[3] Gayathri Chandrasekaran, Tam Vu Alexander Varshavsky, Marco Gruteser_,Richard P. Martin_, Jie Yang‡, Yingying Chen‡, “Tracking Vehicular Speed Variations by Warping Mobile Phone Signal Strengths”, 2011, IEEE Conference on pervasive computations and Communication (Percom) Seattle, (March 21-25, 2011)

[4] Florian Knorr, Deniel Baselt, Michael Schreckenberg, and Martin Mauve, “ Reducing Traffic Jam via VANETs”, IEEE Transaction on vehicular Technology, VOL, 61, NO 8, October 2012.

[5] Ke Zhang, Guangtan Xue, “ A real time Urban Traffic user detection algorithm based on spatio temporal OD matrix in vehicular sensor networks”, Scientific Research-Wireless Sensor Network, 2010, 2 668-674.

[6] Poonam kori, Dr. Sanjeev Sharma, 2012, An Effect of Route Caching Scheme in DSR for Vehicular Adhoc Networks, International Journal on Computer Science and Engineering (IJCSE), Vol. 4 No. 01 January 2012, ISSN : 0975-3397

[7] Fernando Losilla, Antonio-Javier, Garcia-Sanchez, Felipe Garcia-Sanchez, Joan Garcia-Haro, and Zygmunt J. Haas, 2011, A Comprehensive Approach to WSN-Based ITS Applications: A Survey, Sensors 2011, 11, 10220-10265; ISSN 1424-8220.

[8] Jonathan Reades, Francesco Calabrese, Andres Sevisuk, Carlo Ratti, 2007, “ Cellular Census: Explorations in urban data collection, Pervasive Computing, IEEE Computer Society, 1536-1268

[9] Ulchin Lee, Zhou and Mario Gerla, 2006, ” Mobeyes: Smart mobs for urban monitoring with a vehicular sensor network”, IEEE wireless communications, October 2006.

[10] Keemin Sohn and Dachyun Kim, “ Dynamic origin-destination flow estimation using celluar communication system”, IEEE Transactions on Vehicular Technology, VOl 57, No. 5, September 2008

[11] TES GROUP “B” COMPETITIVE EXAM-GSM & CDMA , SNEA (I) AP Circle – on behalf of Technical editorial Committee , SNEA (I) Central Head quarters , New Delhi.

[12] Narsingh Deo , “Graph theory with applications to engineering and computer science “ , PHI(EEE)