A Model Based Connectivity and Localization Strategy for Vehicular Ad hoc Networks

Devjeet Choudhary[2,] Dushyant Yadav[2,] Jetendra Joshi[1], Manash Deka[1] and Saurabh Jha[2]

[1]Department of Electronics and Communication
[2]Department of Computer Science
NIIT University, Rajasthan, India

Abstract — **Nowadays, researchers have performed extensive experiments to study the feasibility and Connectivity of vehicle access. We investigate connectivity in the ad hoc network formed between vehicles that move on a typical highway. We use the common model in vehicular traffic theory. Since a vehicle spends a large portion of the connection time in this poor link quality area, "No GPS Zone" the data throughput can be significantly reduced. Relative location information is an important aspect in vehicular Ad hoc networks. It helps to build vehicle topology maps, also provides location tracking of nearby vehicles. In this paper, we propose a protocol of localization using VANET where no GPS information is available based on clustering and link prediction and also has the advantage to use a single coordinates system. Using the network simulator NS-2 and also checked the mobility scenario in SUMO by implementing the above protocol.** *(Abstract)*

Keywords - VANET Localization; road-side Access Points (APs); NS2; SUMO-MOVE; Vehicular Ad-hoc internet; localization; data fusion; protocols. (key words)

I. INTRODUCTION

With the generation moving towards smart technology and the introduction of VANETs in transportation system, a great opportunity and need of research have arose from it. The integration of Cloud computing with VANET is the next big thing in this field. In VANETs, the vehicles moving in a network communicate with each other forming the Vehicle-to-Vehicle (V2V) model and with the fixed infrastructures i.e., with roadside units (RSU's) forming the Vehicle-to-Infrastructure (V2I) model. The integrated model of Cloud computing with VANET has a similar architecture where three clouds are involved. Vehicular Cloud (VC) where in the vehicles form clusters and communicates with each other in the vehicular cloud. The Roadside Cloud (RC) where in the vehicles communicates with the RC and the RC's in return provide the VC's with information and also forward the data to the Central Cloud Server (CCS). In the CCS, the data is segmented on the base of the area and stored respectively. The CCS smartly monitors the data and keeps it authentic and secure. This information can be very useful for vehicle tracking and accident detection etc. The most widely used technology for vehicular tracking is Global Positioning System (GPS). But, the GPS technology fails to provide the data when the device enters a tunnel or any far of places that go out of the connectivity and range of the satellites. This paper

mainly focuses on providing service to the vehicles that get stuck in the tunnels where there are merely any resources available. As GPS data and RSU's, RC's are not available in tunnels, we focus on providing the resources to the needy vehicle by means of data transfer through multi hop in clustered vehicular cloud networks. The basic terminology comprises of a vehicle stuck in a deep tunnel without any resources to ask for help or send any warning message to any other network. Now, another vehicle enters the tunnel and a b VC cluster is formed. A VC cluster is already moving outside the tunnel and is connected with the RC. The VC outside the tunnel provides resources to the VC inside the tunnel and then the resources are forwarded to the needy vehicle. The illustration of the above mentioned scenario is as shown in the figure below (Fig. 1).
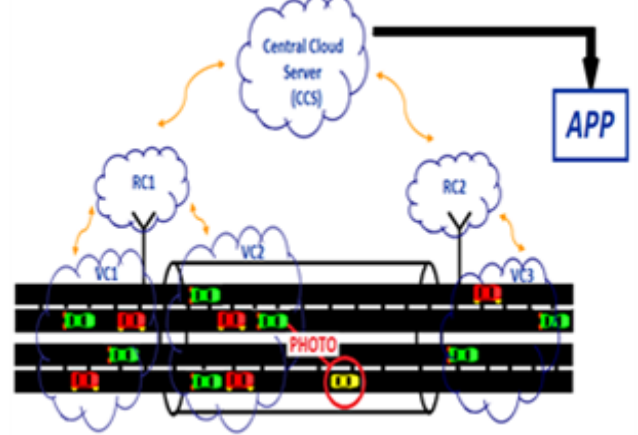

Fig. 1 Scenario

In the figure, the red and green colored cars are the normal cars moving on the road. The yellow colored car is the faulty/needy vehicle stuck in the tunnel waiting for resources and help. The VC1 is the cluster of vehicles inside the tunnel and the VC2 is the second cluster of vehicles outside the tunnel. RC1 and RC2 are the two roadside clouds that are outside the tunnel and the CCS is the central cloud server. The VC2 passes the resources required to VC1 and then the VC1 forwards it to the needy/faulty vehicle by the multi hop technique. This paper is organized as follows: Firstly we have taken a look at the abstract followed by a brief introduction. Now in section II, we have taken look at the concept of modelling connectivity in VANET, Cloud computing, clustering based on integrated architecture of Cloud computing and VANET, their dependencies and the related work done in this field. In section III, we have discussed about the

system design and the problem formulation. In section IV, we have discussed about our idea. , we also defined the protocol and the possible solution to the problem statement. In section V, we have shown the performance evaluation and taken a look at the hardware implementation, the simulation results of the proposed system in NS-2. Section VI, concludes the paper and gives a glance to the future work that can be done in this model.

II. RELATED WORK

In [1], the paper discusses about the VANET architecture, its application and the need of its requirement in today's world with respect to the increasing on-road traffic. The paper also gives an explanation on the collision avoidance system.

In [2], the authors have discussed about the architecture of cloud enabled VANET to support data storage, processing, communication and using in–vehicular resources.

In [3], the paper discusses about the secure navigation and authentic data exchange between the RSU's and the vehicles for safety and security reasons. The authors have also discussed about various techniques for encrypting the data at the transmitters' end and decrypting it at the receivers' end for securing the data and preventing any malicious attacks on it. Simulations done in NS2 support the method and theory proposed in the paper.

In [4], the authors have proposed a novel technique for localization in VANET as an alternative to the current existing GPS in cases where the GPS technology fails to give data (tunnels). The technique uses the clustering of vehicles approach and then transmits the data through multi hop networks.

In [5], the paper gives us the algorithm and theory for the direction estimation of a target point from a reference point with the help of the cardinal points.

In [6], the authors have explained about the challenges related to localization in VANETS. The paper discusses various techniques for localization in VANETS such as ad hoc localization, GPS, image video processing, cellular localization etc. the paper gives a comparative analysis for the above techniques thus helping us to choose the best among them. In [7, 8], the author proposes the high-speed vehicle detection with the help of the vehicle-to-vehicle and vehicle-to-infrastructure communication modes in vehicular ad hoc networks. In [9], the authors have proposed the Vehicle-to-Vehicle relay scheme to extend the range of roadside access points and allow drive thru vehicles to maintain high throughput and increase the network utilization for better vehicular communication in VANETs. In [10], the authors have proposed the RFID based localization in VANETS. Both GPS and RFID based systems have been used in to check for accuracy of the data. In [11], the authors have done a comparative analysis of the localization techniques for vehicles in vehicular networks. The paper discusses various possible techniques for localization in VANET that will help in developing new techniques for accurate results by integrating the currently available techniques.

In [12], the authors have proposed the tunnel based on road vehicle localization in vehicular ad hoc networks. The authors have proposed the smart tunnel concept for providing remote access to applications in vehicular networks. Connectivity in mobile ad hoc networks and one-dimensional networks has a mature body of research and many works investigated it through simulation and/or analytical evaluation [13, 14].

In [15] the authors propose a novel Grid-based On-road localization system (GOT) in which the vehicles with and without accurate GPS signals organize themselves into a Vehicular Ad-Hoc Network (VANET), exchange distance and location and help assist other to calculate the accurate position for all the vehicles inside the network. Most of these works study the problem in static networks and are thus more suitable for sensor networks. However, some of them also tried to tackle the problem of connectivity in presence of mobility but the attempts are mostly restricted to low-mobility networks and/or well-known mobility models. So our work is different from this body of research in that we consider vehicular movements which is a special type of mobility with many distinctive characteristics.

III. SYSTEM MODELLING OF CONNECTIVITY IN VANETs

For this paper, we would be considering a unidirectional uninterrupted highway model.

The vehicles enter the highway in a line, following Poisson Point Process [PPP] with intensity λ, i.e. number of vehicles entering the highway per second. After the arrival of each vehicle i, it is assigned an independent uniformly distributed speed V_i, whose probability distribution function is given as:

$$f(V_i)(x) = \begin{cases} \dfrac{1}{Vmax - Vmin}, & Vmin < x < Vmax \\ 0, & otherwise \end{cases} \quad \dots(1)$$

Let T_i represent the time interval between the entry of vehicle and i and each subsequent vehicle j. The entry time interval is independent identically distributed (i.i.d) whose probability distribution function is shown as:

$$f(T_i)(y) = \begin{cases} \lambda e^{-\lambda y}, & y \geq 0 \\ 0, & y < 0 \end{cases} \quad \dots(2)$$

The model is shown in the figure2 to study the connectivity of the vehicles.

The vehicles start sending the data as soon as they arrive on the highway. Their speeds remain constant on the highway. Let us assume that vehicle i enters the highway at t=0 with speed V_i. Another vehicle j enters the highway at t=T_i. Hence, inter-vehicular distance, d$_{ij}$ =$V_i T_i$. i starts transmitting data to j at t=T_i.

Let duration of data transmission be t=Tt. Hence, the data sent by i is received by j at time t such that

$$t = Ti + Tt \quad \dots (3)$$

For Channel Model, we are adopting Unit Disk model for this paper. According Unit Disk model, two vehicles can communicate with each other directly if and only if their Euclidean distance is less than their transmitting range.

Also, it is assumed that the movements of all the vehicles are independent of each other. Therefore, the vehicles can pass each other, given that no. of overtakes don't surpass the total number of lanes at any given point of time.
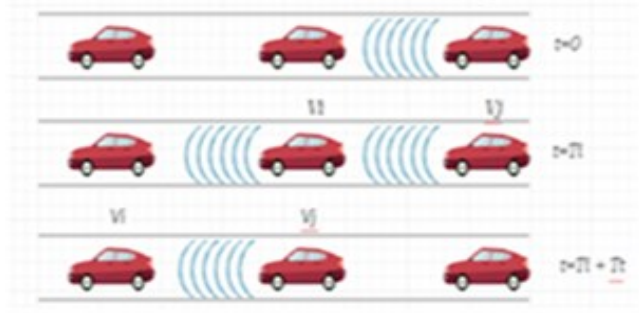

Fig. 2 Connectivity Scenario

IV. SYSTEM DESIGN AND PROBLEM FORMULATION

Vehicle and accident detection in tunnels is an important factor to be considered for the safety of other people and building up intelligent transport systems. In long tunnels, as there is no light, it is hard to see anything or detect a sign of blockage at an earlier point. As GPS data and RSU's are not available inside the tunnels, it is important to identify and develop new techniques to address this problem.

So, what can be the solution for detecting the accidents and vehicles in long and deep tunnels, places where there is no connectivity with the GPS, Internet etc.

How can we store the data of the vehicles without much delay and access it on real time basis without actually using the traditional methods of central servers, server farms?

How can we send faster emergency warning message to the neighboring vehicles regarding the situation.

V. PROPOSED SOLUTION AND ALGORITHM

In this section, we propose the localization based on link prediction and clustering technique in tunnels and places where the GPS data is unavailable. We propose to use the vehicles moving on the road in clustered networks as service providers to the needy vehicles.

As the GPS data is not available in the tunnel, we propose to use the Time of Arrival (TOA) and Time Difference of Arrival (TDOA) techniques. Estimation of the exact location of any particular vehicle that is stuck in the tunnel by the help of clustering in vehicular cloud to send data obtained to roadside cloud for the proper monitoring of the stranded vehicles.

The algorithm was developed to implement the concept of vehicle detection with the help of Link prediction and clustered networks in the vehicular cloud.

LINK PREDICTION: The link prediction technique is used
By the help of following properties.

A. Degree centrality

No of connections or ties with other nodes

$$k_i = C_d(i) = \sum_j^N x_{ij} \quad \dots (4)$$

B. Closeness centrality

Inverse sum of the shortest distance to all other nodes from focal node

$$CC_i = \frac{1}{d_i} = \frac{N}{\sum_{j=1}^N d_{ij}} \quad \dots (5)$$

d_i *is average distance from node i to all other nodes*

C. Betweenness centrality

The more the nodes depend on a node to make connection with other nodes, the more power or significance that node has.

Represents ability of capture of flow of information

$$BC_i = \sum_{i \neq s \neq t} \frac{n_{st}^i}{g_{st}} \quad \dots (6)$$

g_{st} is the shortest paths from node s to t
n_{st}^i is the no. of shortest paths between s and t, that are passing through node i.
The shortest path is calculated by Dijkstra algorithm.

D. STRAIGHTNESS Centrality

Straightness centrality or "being central as being straight to the others". This centrality index originates from the idea of the efficiency in the communication between two nodes. The efficiency in a system increases when there is less deviation of their shortest path from the virtual straight line (straight Euclidean path) connecting them.

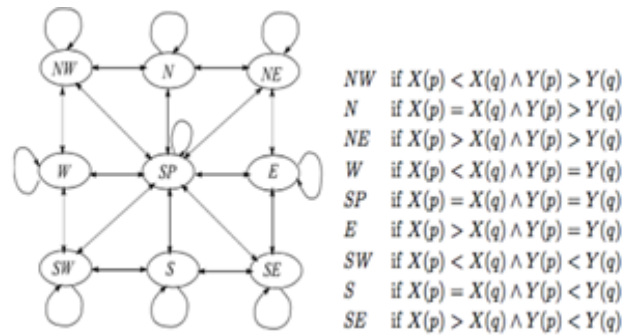|	
NW	if $X(p) < X(q) \wedge Y(p) > Y(q)$
N	if $X(p) = X(q) \wedge Y(p) > Y(q)$
NE	if $X(p) > X(q) \wedge Y(p) > Y(q)$
W	if $X(p) < X(q) \wedge Y(p) = Y(q)$
SP	if $X(p) = X(q) \wedge Y(p) = Y(q)$
E	if $X(p) > X(q) \wedge Y(p) = Y(q)$
SW	if $X(p) < X(q) \wedge Y(p) < Y(q)$
S	if $X(p) = X(q) \wedge Y(p) < Y(q)$
SE	if $X(p) > X(q) \wedge Y(p) < Y(q)$

Fig. 3 State flow and algorithm for direction estimation

Now the vehicular cloud which uses the clustering technique to find the cluster head which are in range of the needy vehicle and check for the link prediction by the parameters (Degree Centrality, Closeness Centrality and Betweenness Centrality, Straightness Centrality)which help to found the shortest Link.

But if the vehicle is in the region of No GPS and we assume that there is a vehicle stuck in a long tunnel. The GPS receiver of the vehicle is unable to identify the location and therefore this vehicle is unable to send any warning message or to request for help. Let this vehicle be denoted as A. The exact location of A is given as A (X, Y). Now that the transceiver of the OBU of vehicle A is active, vehicle *A* can broadcast a notification of its presence to all the other vehicles that are in the communication range using DSRC spectrum. Now a vehicle B heading towards the tunnel wants to estimate the position and reconfirm the presence of this vehicle A. The vehicle B has its GPS in proper functioning condition and with the help of this on board GPS sensor, it immediately records its own position say B (X, Y) at the TOA of the broadcast notification of vehicle A. The vehicle B repeats this for N signaling periods. Finally, the vehicle B applies the multilateral method to find the exact location of vehicle A

Let the current location of vehicle A be **(X, Y)**
Receive the first message from vehicle A
Record the current location of vehicle B as**(x_0, y_0)**
Record the TOA as **τ_0**
     While (A is sending the message)
     {
          if (Time elapsed || Entered the Tunnel)
stop
          else
          {
          Record the location of vehicle B as **(x_i, y_i)**
          Record the TOA as **τ_i**
          for (i=0; i<n; i++)
               {
               Calculate TDOA (**τ_{ij}**)
$\tau_{i,j} = \tau_i - \tau_j - (i - j) * \delta t$
               }
          }
Take four pairs of points of vehicle B's instantaneous positions as:
(x_i, y_i) = [(x_0, y_0), (x_1, y_1), (x_2, y_2), (x_3, y_3)]
Ensure- **($x_0 \neq x_1 \neq x_2 \neq x_3$) and ($y_0 \neq y_1 \neq y_2 \neq y_3$);**
After recording all these values, use the formula for getting the approximate value of the location of vehicle A.

$$A_1 = \frac{2}{c} * \left(\frac{x_2 - x_0}{\tau_{0,2}} - \frac{x_1 - x_0}{\tau_{0,1}} \right) \quad \dots (7)$$

$$B_1 = \frac{2}{c} * \left(\frac{y_2 - y_0}{\tau_{0,2}} - \frac{y_1 - y_0}{\tau_{0,1}} \right) \quad \dots (8)$$

$$C_1 = c * (\tau_{0,2} - \tau_{0,1}) - \frac{1}{c} * \left(\frac{x_2^2 + y_2^2 - x_0^2 - y_0^2}{\tau_{0,2}} - \frac{x_1^2 + y_1^2 - x_0^2 - y_0^2}{\tau_{0,1}} \right) \quad \dots (9)$$

$$A_2 = \frac{2}{c} * \left(\frac{x_3 - x_0}{\tau_{0,3}} - \frac{x_1 - x_0}{\tau_{0,1}} \right) \quad \dots (10)$$

$$B_2 = \frac{2}{c} * \left(\frac{y_3 - y_0}{\tau_{0,3}} - \frac{y_1 - y_0}{\tau_{0,1}} \right) \quad \dots (11)$$

$$C_2 = c * (\tau_{0,3} - \tau_{0,1}) - \frac{1}{c} * \left(\frac{x_3^2 + y_3^2 - x_0^2 - y_0^2}{\tau_{0,3}} - \frac{x_1^2 + y_1^2 - x_0^2 - y_0^2}{\tau_{0,1}} \right) \quad \dots (12)$$

$$X_k = \frac{C_1 * A_2 - C_2 * A_1}{B_1 * A_2 - B_2 * A_1}. \quad \dots (13)$$

$$Y_k = \frac{C_1 * B_2 - C_2 * B_1}{A_1 * B_2 - A_2 * B_1}. \quad \dots (14)$$

Location based monitoring algorithm (app on device):
1: Authenticate the user of the app (police official)
2: Auto detect the location with the help of inbuilt GPS
3: Send the location information to the central cloud

VI. PERFORMANCE EVALUATION

In this section, we have discussed about the GPS and Camera based hardware implemented in the vehicle, traffic generated with the help of a SUMO (Simulation of Urban Mobility) NS-2 (Network Simulator 2) simulation and sample template of the mobile app that is to be designed.

A. On Board Navigation Unit.

The on board navigation unit is an embedded system comprising of microcontroller interfaced with a GPS module, Camera, Radio Module (433MHz), Speaker alarm and LCD display. The OBU continuously monitors the location, position and the speed of the vehicle with the help of the GPS receiver and the microcontroller. The Fig.4 below shows the partially developed hardware of the On Board Unit.

B. Simulations in NS-2 and SUMO-MOVE

Fig. 4: Partially developed On Board Unit

To evaluate and test our algorithm, we have created a test scenario. The traffic model for the test scenario was developed using SUMO-MOVE. The Fig.5 below illustrates the test scenario. The green car is the one that is stuck in the tunnel. The red and the blue cars are arriving for helping the green car. Now the direction estimation using cardinal points is used to check the direction and the algorithm discussed above is used to calculate the coordinates of the green car. The distance between the cars is then calculated and the car closes to the victim car will move forward to help it and the other car will return back.
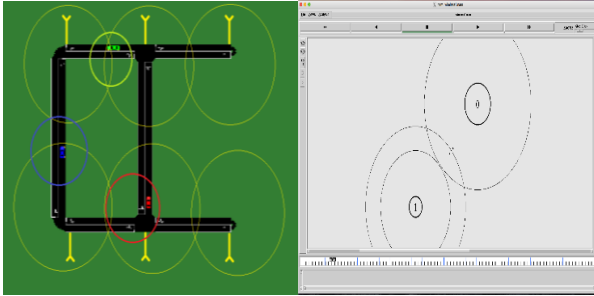

Fig. 5 Test case traffic simulation.

This traffic simulation was then imported into NS2 with the help of MOVE. The Figure illustrates the NS2 simulation for the test case. The node 0 is the fixed node i.e., the vehicle stuck in the tunnel. The node 1 is the dynamic node and is moving towards the node 0 to find its exact location. As the node 1 moves towards the node 0, it receives the beacon broadcasted message of node 0 and the time of arrival and the location at that particular instance is recorded moving towards the node 0 to find its exact location.

The algorithm was then implemented with the help of a PERL script. The Fig.6 below illustrates the computation of the values obtained from the NS2 simulation in the formula discussed in the algorithm.
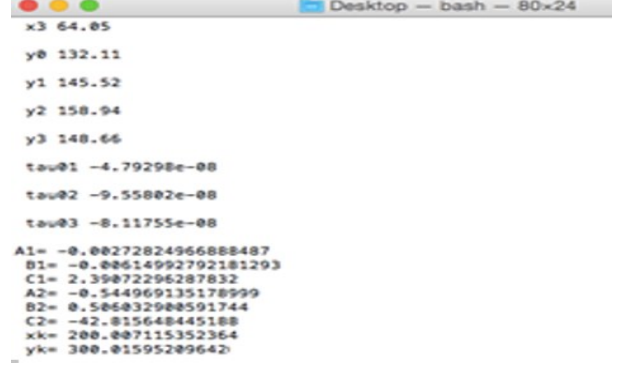

Fig.6 Computation of recorded values in the algorithm

In the scenario shown below in figure 7, nodes n0 to n7 are vehicles moving on the road in the given direction. This time nodes n3, n4, and n5 are in the tunnel, and can't access the GPS, hence being as the negative link, unable to transfer information. Because they are quite apart from each other, all the vehicles form two separate clusters. Both the clusters will have separate cluster heads, elected based on closeness centrality as mentioned earlier. Nodes n6 and n1 are appointed, based on the closeness to other nodes in the cluster. Now suppose n5 wants to communicate with n3, both of which are a negative link. So, first n5 will send the information to be sent, to n6, the cluster head via RSU. Because n6 has GPS access, nor does n1, the information can directly be forwarded to n1, by n6. Then it can easily be passed on to n3, the destination node. The link lifetime will constantly be updated, to update the system if links are about to break. Immediately the new cluster will be made, cluster head will be appointed, and the information will reach n3 eventually. In this way, communication will be easily possible between different vehicles, even in the absence of GPS in any location.
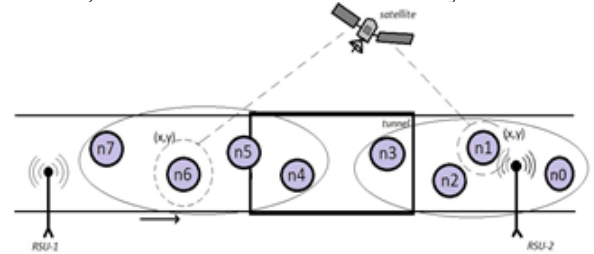

Fig. 7: Test case Traffic scenario

C. Sample Template of Mobile Application.

The cloud services being used here are the Software as a Service (SaaS) and Platform as a Service (PaaS). The SaaS platform helps us in building up the network between the mobile app and the central cloud with the help of the Internet. The PaaS platform provides us the data storage service, where we are continuously updating the data obtained from the vehicular and the roadside cloud.

The police official, who is the in charge of the area will have to login by entering the correct credentials into the mobile app. The Mobile App will automatically detect his location and then send request to the central cloud server. The central cloud server will in return send the data of that area bounding to a 10Km radius to the app. The mobile app will give information about the total number of vehicles moving in that area, if there is any emergency vehicle that is stuck, if any other vehicle has met with an accident and so on. The mobile app will also display the date, time, indicator for incoming data and the data rate also. The police official will also have a provision for calling help from the nearest hospital just by the click of a button. All the tasks listed above will be running continuously with a very negligible time lag and therefore making the system efficient, smart and reliable. The sample template of the app is as shown in the Fig. 8.
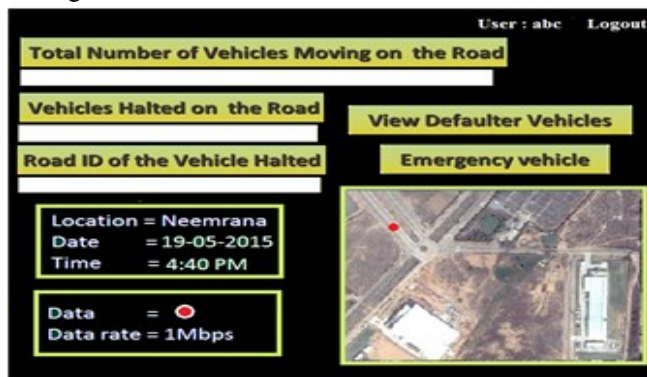

Fig. 8: Sample template of the app.

VII. CONCLUSION AND FUTURE WORK

Intelligent Transport System (ITS), smart traffic monitoring and fast forwarding of the emergency and warning messages in VANET's is the next level technology and has a very role to play in the future technology of the safe traffic maintenance environment. In this paper, we have explained the idea the Localization technique using clustering and link prediction used in the traffic management system. Further, we intend to extend the system and include more features into it, integrate the mobile app and the hardware system with the Central Cloud Server and implement the security algorithms (Cryptography) into it and thus make the system more efficient, wide and reliable. In future we want to integrate video monitoring also in the Tunnel or NO GPS zone.

REFERENCES

[1] R. Thenmozhi, Yusuf H., Vignesh J., Dinesh K., "Survey on Collision Avoidance System in VANET", International Journal of Innovative Research and Development, Vol. 3, Issue. 4, April 2014.

[2] Ashutosh Shukla, Nikhil Shukla, "Future of the Vehicular Ad Hoc Network and the Cloud", ISSN No. 2347- 9337, IJARES Vol. 1 Issue 1, January 2014.

[3] T. S Vamsi Krishna, R. Hariharan, "VANET- based Vehicle Tracking on Message Authentication and Secure Navigation Route", International Journal of Computer Applications, Volume 113 - No. 7, March 2015.

[4] Nasreddine Lagraa, Mohamed. Bachir. Yagoubi, Sarah. Benkouider, "Localization Technique in VANets Using Clustering (LVC)", International Journal of Computer Science Issues, Vol. 7, Issue 4, No. 9, July 2010.

[5] Tao Chen, Hechen Liu, Markus Schneider, "Evaluation of Cardinal Direction Developments between Moving Points", ACM GIS'10, November 2010.

[6] Kashif Naseer Qureshi, Abdul Hanan Abdullah, "Localization- Based System Challenges in Vehicular Ad Hoc Networks: Survey", Smart Computing Review, Vol. 4, No. 6, December 2014.

[7] Shabbir Ahmed, Salil S. Kanhere, "Message Dissemination in Vehicular Networks", Delay Tolerant Networks: Protocols and Applications, August 2011.

[8] Rajendra Prasad Nayak, "High Speed Vehicle Detection in Vehicular Ad-hoc Network", Thesis- National Institute of Technology Rourkela, May 2013.

[9] Jing Zhao, Todd Arnold, Yang Zhang, Guohong Cao, "Extending Drive-Thru Data Access by Vehicle-to-Vehicle Relay", VANET'08, September 2008.

[10] Eun-Kyu Lee, Soon Y. Oh, Mario Gerla, "RFID Assisted Vehicle Positioning in VANETS", Pervasive and Mobile Computing, May 2011.

[11] Sunita S. Shinde, Ravi M. Yadahalli, Arifa S. Tamboli, "Vehicular Ad-Hoc Network Localization Techniques: A Review", International Journal of Electronics and Communication Technology, ISSN: 2230-9543, Vol. 3, Issue. 2, June 2012.

[12] V. Ravikmar, K. Nilofar Banu, "On-Road Localization System for Smart Tunnel Support for the High Performance Remote Communication in VANET", International Research Journal of Infinite Innovations in Engineering and Technology, ISSN: 2349-2279, Vol. 1, Issue. 4, December 2014.

[13] P.Santi and D.M.Blough 'The certificate Transmitting range for connectivity in sparse wireless adhoc networks " IEEE Trans. On Mob. Comp., Vol. 2, no.1, pp.25-39, Jan-Mar 2003.

[14] D.Miorandi, E.Altman , " connectivity in one dimensional adhoc networks : A queuing theoretical approach ,"Wireless networks, vol.1,n.6, pp.573-587,2006.approach,"

[15] Yan, Tan, Wensheng Zhang, and Guiling Wang. "A grid-based on-road localization system in vanet with linear error propagation." Wireless Communications, IEEE Transactions on 13.2 (2014): 861-875.