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Traffic Congestion Detection and Management Using Vehicular Ad-Hoc Networks (VANETs) In India

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Abstract

India is a nation which has the one of the largest Non-Lane based road network in the world. Many developed nations today use Intelligent Transportation system (ITS) to solve traffic related problems and provide smooth and safe ride on roads. The road traffic congestions are recurring problem in India. One of the major reasons that lead to traffic congestion is the poor infrastructure and attitude of road users in India.

VANETs are widely emerging in many developed countries as a less expensive, distributive and collaborative traffic congestion system. It basically requires some inexpensive devices to be incorporated in vehicles itself and communicate with geostationary satellite to accumulate the data and fetch into the system. It will basically reduce the cost of project as it doesn't require implementation of expensive loop sensors and high range video processing devices. Data to be disseminated are buffered at the roadside parked vehicle, which continuously provides data dissemination services for the passing by vehicles and Vehicular Ad-Hoc Networks provides a smart solution for traffic density detection and better parking management of traffic over Non-lane based roads of India.
Motivated by the fact that there are large amounts of roadside parked vehicles in urban areas, this paper highlights the findings of a parking-based opinion survey conducted at Delhi city in India and proposes a smart solution for parking management and traffic detection through a data dissemination scheme for VANETs in India. Through this review paper, it has been tried to provide an innovative approach as VANETs in solving traffic problems in India that has significantly large amount of public and private vehicles on roads.

Keywords: VANETs, Ad-Hoc Networks

Introduction

India is among the fast developing nations in the world which have the highest density of public and private vehicles. It has always been a cumbersome task to manage traffic in India. High traffic density is result of variable predictable and unpredictable factors. Predictable factors include road construction sites or peak hours of travel (i.e. office hours) about which drivers are aware, whereas unpredictable factors include weather conditions, accidents and human behavior. Such congestion problems can be avoided if drivers are pre-aware of these traffic bottlenecks.

The growing population of India has created many problems one of the challenging ones being car parking. Besides the problem of space for cars moving on the road, greater is the problem of space for a parked vehicle considering that private vehicles remain parked for most of their time. While residential projects still escape with designated parking, the real problem lie with commercial spaces many a time which is overcome by taking extra open spaces to park.

1.1. Problem of Congestion and Parking in Indian Cities

India's vehicle population underwent the second-largest growth rate, up by 8.9% to 20.8 million units, compared with 19.1 million in 2009. The vehicle population in China has been increasing at more than 30% and at around 10% in India. However, this has recently dropped to negative growth in the first quarter of 2013(Sausanis, 2011).
The average journey speed in Indian cities is low, particularly in cities which have high car volumes (Ghate and Sundar, 2013). In 2007, a study commissioned for the Ministry of Urban Development, Government of India, found that the average journey speed in Delhi was around 16 km/h and only slightly higher in Mumbai. The study found the average journey speed to be below 20 km/h in Hyderabad, Chennai and Bangalore, as well as low in cities with slow moving vehicles such as Varanasi and Bhubaneswar (Wilbur Smith Associates, 2008).

In New Delhi, Delhi's Master Plan 2021 aims to attract 80% of road travel to public transport by 2020. An estimate indicates that by the year 2021, travel demand in Delhi will increase to 27.9 million passenger trips as compared to 13.9 million passenger trips in 2001. This increase in travel demand is more than double. It implies that in future, public transport will cater to 22.3 million passenger trips. However, according to the statistics of the Ministry of Road Transport and highways, the number of registered buses in New Delhi has seen little growth, while private vehicles, particularly two-wheelers, are

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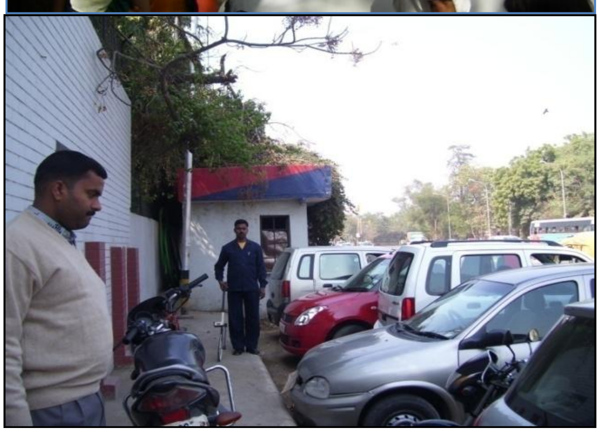
increasing at their highest rate over the last few years. Similarly in Mumbai, though the sub-urban rail link meets most suburban travel demand, road congestion is not reduced. During peak hour, traffic in Mumbai traffic flows at a speed of 5 km/h speed (Kumar, 2013). Similarly in Bangalore and Hyderabad cities in India, total vehicles are around 6.8 million, of which around 70% are two-wheelers. On the other hand, cars and other passenger vehicles such as jeeps, taxis, and auto-rickshaws, account for around 25%, while buses account for only 0.7% of the total motorized vehicles registered in the cities of Hyderabad and Bangalore.

Similarly, a survey conducted by CSIR-CRRI to see the commuting problems near mainstream school premises has found that the adjacent walls of these school premises are blocked with parked cars hence the school children, teachers; other pedestrians using the pathways are compelled to come on the road to face heavy traffic ,which in turn forces the bus commuters to wait on the road instead of waiting on the bus stop due to inconveniences and traffic chaos.



Pictures 1&2: Survey area showing Traffic Chaos and Unauthorized Parking adjoining school premises (in Delhi)

However, traffic congestion does not occur only due to increasing level of motorized vehicles. Some Indian cities with low levels of motor vehicles e.g. Indian city like Varanasi has only 7% of total motorized vehicles as compared to Delhi , traffic flow is slow and causes heavy congestion. It suggests that congestion also occurs due to mismanagement between demand for and supply of transport services. These factors may include direct and indirect elements such as increasing levels of vehicles and a constant level of road infrastructure, low cost private transport services and lack of policy interventions.

Working Group on Urban Transport for 12th Plan period (2012-17) has highlighted a number of causes leading to urban congestion, including inefficient urban planning and poor implementation of regulations, lack of adequate urban infrastructure. Thus, it becomes imperative to understand the sources of congestion and provide a smart solution for addressing these issues in a comprehensive manner, including policies such as congestion pricing, parking policies, land use planning .

1.2. Vehicular Ad-Hoc Networks (VANETs) as a Smart Solution

The Vehicular Ad-Hoc Network is an emerging technology to achieve intelligent inter-vehicle communications, seamless internet connectivity resulting in improved road safety, essential alerts and accessing comforts and entertainments. The technology integrates WLAN/cellular and Ad Hoc networks to achieve the continuous connectivity. VANET turns every participating car into a wireless router or node, allowing cars approximately 100 to 300 meters of each other to connect and, in turn, create a network with a wide range. As cars fall out of the signal range and drop out of the network, other cars can join in, connecting vehicles to one another so that a mobile Internet is created.

This paper discusses how VANETs have been used in detecting traffic density and parking management solutions in India. The aim of VANET is to provide a safety for drivers and other road users, savings space upwards of 70 percent, reduces total parking cost, environmental friendly and provides higher throughput with faster operations. VANET is a vast subject of study which is used to implement many components of ITS. VANETs are blend of both Inter-Vehicular Communication (IVC) and Road-Vehicular Communication (RVC) .Communication in VANET can be facilitated in two ways: (i) Vehicle-to-Vehicle (V2V) (ii) Vehicle-to-Infrastructure (V2I). Every moving car is assumed to be a node which in turn communicates either with nearby node or other nearby fixed equipment.

Safety applications will monitor the surface of the road and approaching vehicles and feed information that could

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put the vehicle at risk back to the driver. The technology would allow drivers to warn other vehicles of potential dangers, while an emergency braking system will be installed to prevent accidents. The VANET provides following information in order to accompany user with traffic congestion update ahead which helps in reducing the average traffic halt time during predictable and unpredictable obstacles:

(i) To integrate the data related to position, density & distance between the node and the location of the jam

(ii) To relay this clustered information to the source node i.e. driver's information panel

With this pre-fetched information, drivers can detour from the congested route. It only reduces the accumulation of vehicles on that route, whereas save the time also. But the major drawback is that they all process data and relay it to common traffic data centre. Another major problem with this set up is that it is mapped statically, whereas the traffic remains dynamic.

Researchers in India are working on VANET which when fully operational would allow communication among vehicles and also between vehicles and roadside equipment. Researchers say that VANET technology could alleviate road congestion and prevent accidents. Researchers at the Indian Institute of Technology (IIT) in Kharagpur plan to equip vehicles with sensors, which will be controlled by a telematics box inside the car .This box would be able to communicate with the driver and pass on the vital traffic informations such as post-crash notification technology would allow a vehicle involved in an accident to broadcast messages to vehicle in the area, as well as to the emergency services and road hazard control notification which enables cars to notify other vehicles in the area of road slides, or unpredictable terrain ahead, while the cooperative collision warning alerts drivers that they are about to collide. VANET will also provide drivers with the latest congested road notification feature which will detect and notify the drivers of road congestion ahead, allowing motorists to alter their course. Likewise the TOLL notification feature will enable the drivers to pass through a tolling area without stopping, while the parking availability setting helps motorists find parking spaces.

1.3. VANETs Characteristics

The uniqueness related to routing of VANETs as compared with MANETs is as following:

- **Unlimited transmission power**: Mobile device power issues are not a significant constraint in vehicular Networks. Since the vehicle itself can provide continuous power to computing and communication devices.
- **High computational capability**: Operating vehicles can afford significant computing, communication and sensing capabilities.
- **Highly dynamic topology**: Vehicular network scenarios are very different from classic ad hoc networks. In VANETs, vehicles can move fast. It can join and leave the network much more frequently than MANETs. Since the radio range is small compared with the high speed of vehicles (typically, the radio range is only 250 meters while the speed for vehicles in freeway will be 30m/s). This indicates the topology in VANETs changes much more frequently.
- **Predicable Mobility**: Unlike classic mobile ad hoc networks, where it is hard to predict the nodes' mobility, vehicles tend to have very predictable movements that are (usually) limited to roadways. The movement of nodes in VANETs is constrained by the layout of roads. Roadway information is often available from positioning systems and map based technologies such as GPS. Each pair of nodes can communicate directly when they are within the radio range.
- **Potentially large scale**: Unlike most ad hoc networks studied in the literature that usually assume a limited network size, vehicular networks can in principle extend over the entire road network and so include many participants.
- **Partitioned network**: Vehicular networks will be frequently partitioned. The dynamic nature of traffic may result in large inter vehicle gaps in sparsely populated scenarios and hence in several isolated clusters of nodes.
- **Network connectivity**: The degree to which the network is connected is highly dependent on two factors: the range of wireless links and the fraction of participant vehicles, where only a fraction of vehicles on the road could be equipped with wireless interfaces.

1.4. Architecture of VANETs

VANETs are an emerging wireless communication technology under intelligent transportation system (ITS). These are the distributed self-organized system which includes a wireless communication system equipped in vehicles to communicate with each other and relay the information from one node to another. These types of networks are devised to bring significant improvement the transportation system. Nodes are expected to communicate by means of Dedicated Short Range Communication (DSRC) standard that employs the IEEE

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802.11p standard for wireless communication. To allow communication with participants out of radio range, messages have to be forwarded by other nodes (multi-hop communication). Vehicles are not subject to the strict energy, space and computing capabilities restrictions normally adopted for MANETs. More challenging is the potentially very high speed of the nodes (up to 250 km/h) and the large dimensions of the VANET. The primary VANET's goal is to increase road safety. To achieve this, the vehicles act as sensors and exchange warnings or more generally telematics information (like current speed, location) that enables the drivers to react early to abnormal and potentially dangerous situations like accidents, traffic jams or glaze. The information provided by other vehicles and stationary infrastructure might also be used for driver assistant systems like adaptive cruise control (ACC) [9] or breaking assistants. In addition, authorized entities like police or firefighters should be able to send alarm signals and instructions e.g. to clear their way or stop other road users. Besides that, the VANET should increase comfort by means of value-added services like location based services or Internet on the road.

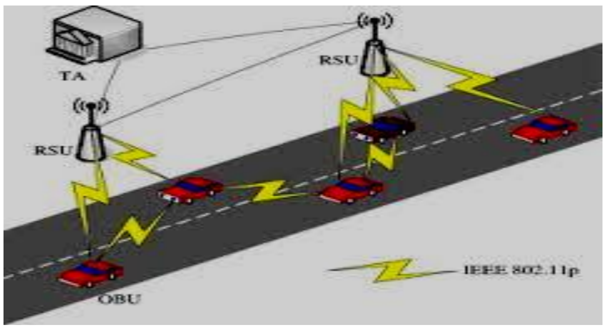

Fig 1: Architecture of VANET equipped with RSU.

Vehicular networks are composed of mobile nodes, vehicles equipped with On Board Units (OBU), and stationary nodes called Road Side Units (RSU) attached to infrastructure that will be deployed along the roads. Both OBU and RSU devices have wireless/wired communications capabilities. OBUs communicate with each other and with the RSUs in ad hoc manner. There are mainly two types of communications scenarios in vehicular networks [11]: Vehicle-to-Vehicle (V2V) and Vehicle-to-RSU (V2R). The RSUs can also communicate with each other and with other networks like the internet as shown in Figure 1.Vehicular Networks are expected to employ variety of advanced wireless technologies such as Dedicated

Short Range Communications (DSRC), which is an enhanced version of the WiFi technology suitable for VANET environments. The DSRC is developed to support the data transfer in rapidly changing communication environments, like VANET, where time critical responses and high data rates are required.

1.5. VANET as a Solution for Indian Non-Lane Based Roads

A case study of Delhi traffic volume

- From the data above it is evident that the number of motorized and non-motorized vehicles on road in India increases significantly.
- India has non-lane based roads. With low breadth of roads and high volume of traffic, traffic congestion becomes inevitable.
- Intelligent Transportation system will be implemented till 2020 in four metro cities of India i.e. Delhi, Mumbai, Kolkata and Chennai.
- Wireless communication between two vehicles will lead one of them to find out if there's any jam or not. It would also minimize the number of accidents on road as India has a notorious figure in road accidents.
- The road culture of Delhi is characterized by complexity and a high degree of heterogeneity .
- High numbers of motorized forms of transport include auto rickshaws, two-wheel vehicles and buses, and non-motorized forms including pedestrians, cyclists and cycle rickshaws.
- Following is the survey done by CSIR-Central Road Research Institute based in Delhi (table-1),it depicts the increasing number of light and heavy vehicles volume in last 10 years.

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Table 1. Year Wise Vehicles Growth in Delhi (DSH, 2010)

Vehicle Type	Vehicular Population of Delhi 2000 - 2010										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
LCV	82891	84543	67845	70956	73734	74264	78435	84060	91656	101046	109606
HCV	74991	75976	60970	63765	66262	66738	70487	75541	82638	90806	100303
Buses	41483	47578	47102	48813	54419	55747	46581	52763	55148	58047	61471
3W	86985	86985	49538	52905	53656	73644	74189	75297	83948	86482	88181
2W	2230534	2265955	2517788	2665750	2844004	3062536	3299838	3578199	3797943	4055229	4342403
PC	939085	989522	1224629	1326167	1445149	1487334	1614830	1760399	1899442	2058920	2231281

1.6. Challenges for implementing VANET on Non-lane based lanes

1.6.1. Technical challenges in India

- Congestion and collision Control: - Uneven traffic load in Indian rural and urban areas divides network in many partitions.
- Environmental Impact: - VANET works on electromagnetic particles' transmission. Due to improper infrastructure, it becomes difficult to process hurdle free transmission.
- Security:- As VANET provides the road safety applications which are life critical therefore security of these messages must be satisfied.
- Infrastructure: India along with other developing economies still lack the required infrastructure for development of Intelligent Transportation Network.

1.6.2. Social challenges in India

- Social challenges generally indicate the economical factor in implementation of VANET. Many developing nations lack proper infrastructure and resources to implement VANET on effective basis.

1.7. Routing techniques in VANETs

1.7.1. ***Ad-Hoc Routing***: Some of the well known ad hoc routing protocols such as AODV (Ad Hoc on demand distance vector) and DSR (Dynamic source routing) are therefore can be applied to VANET as well. However, the simulation of these algorithms in VANET brought out frequent communication break which is mainly attributed to high dynamic nature of its nodes. To meet the VANET challenges, these existing algorithms are suitably modified.

Namboodiri et al. (2004) considered the following application in their model:

- A highly partitioned highway scenario is used where most path segments are relatively small.
- The initial simulation with AODV algorithm resulted in frequent link break as expected, owing to dynamic nature of node's mobility.
- Two predictions are added to AODV to upgrade the algorithm.
- In one, node position and their speed information are fed in AODV to predict link life time.
- The simulation on both showed improved packet driving ratio.
- However, the success of this algorithm largely depends on the authenticity of node position and mobility.

1.7.2. **Position Based Routing**: The technique employs the awareness of vehicle about the position of other vehicle to develop routing strategy. This algorithm has some advantages and constraints e.g. **Advantages**: It works best in open space scenario (Highways) with evenly distributed nodes. The absence of fewer obstacles in highway scenario is attributed to its good performance. The comparison of simulation result of GPSR from that of DSR in highway scenario is generally considered to be better. **Constraints**: In city conditions (pic. 2) , GPSR suffers from many problems: e.g. Greedy forwarding

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are restricted owing to obstacles, node mobility can induce routing loops for face routing, routing performance degrades because of longer path resulting higher delays. Packet can at times be forwarded in wrong direction resulting higher delays.

Pic 2: Traffic Congestion at Delhi and Hyderabad cities in India

The above routing algorithms i.e. Adhoc routing and position-based routing uses Greedy Forwarding technique and face routing algorithms are described as below: In attempt to send the packet close to Destination (D), the source (S) forwarded it under various algorithms shown in figure below. This each node starting from source forwarded the message to the neighboring node. The most suitable neighbor (location E in figure) may be one that has minimum distance (known as Greedy) from the destination and lies within the range (circle) of forwarding data from 'S'. Apart from this method, the scheme can also consider MFR, NFP, and 'Compass Routing'.

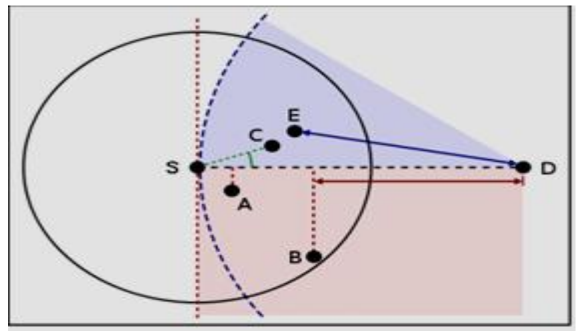

Fig-2: Greedy forwarding variants: The source node(S) has different choices to find a relay node for further forwarding a message to destination (D).A=Nearest with Forwarding Progress (NFP),B=Most Forwarding progress with Radius (MFR),C=Compass Routing, E=Greedy

Greedy forwarding at times leads to a dead end. In such cases, it cannot find any nearby neighbor to forward the packet. Face routing technique recover it from that situation and find a path to another node, where greedy forwarding can be resumed.

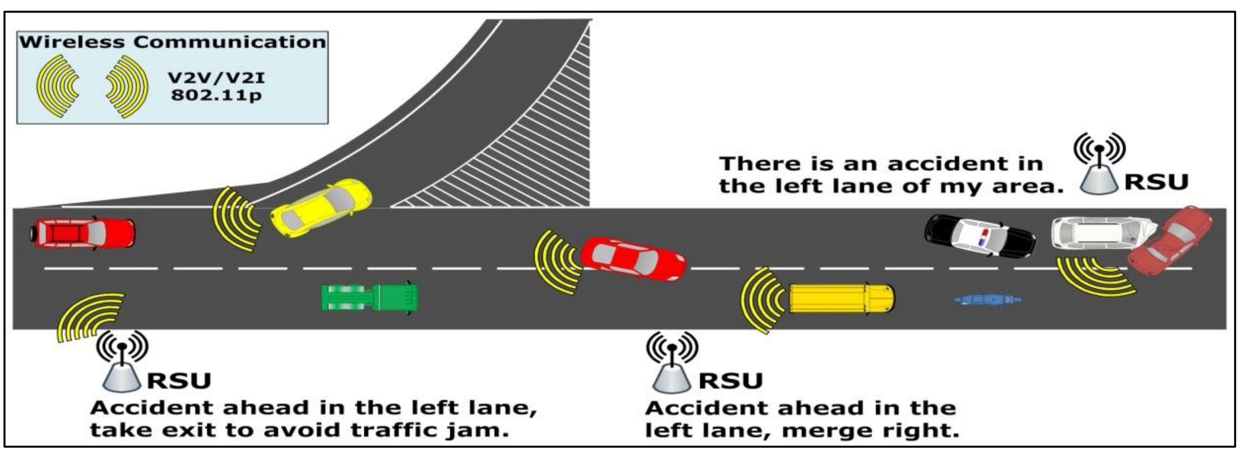

Fig 3: Architecture of VANET equipped with RSU

2. The Proposed Parking-Based Scheme for India

To facilitate data dissemination, the roadside parked vehicles are to be organized into clusters. Generally, this proposed parking-based data dissemination scheme is divided into two phases: a) data forwarding from the data source to appropriate parking clusters within the target area and b) data dissemination from the parking cluster to passing by vehicles.

2.1. Parking Cluster

Due to the high stability and utilization of roadside parking, clustering parked vehicles is feasible in urban areas of India. A realistic survey carried out by A. Adiv et al (1987) provides a quantitative understanding of roadside parking in cities, in which the on-street parking meters in the Ann Arbor city (US) are continuously monitored during six midweek days. It showed that the parking time is 41.40 minutes in average, with a standard deviation of 27.17. The occupancy ratio, defined as occupied space-hour/available space-hour, averages 93.0% throughout one day. Even the occupancy ratio during off-peak time reaches almost 80%.

In the proposed parking-based scheme, the vehicles have been grouped which are parked along the same road segment and are mutually reachable into a cluster and take it as data buffering unit at street level. Considering the fact that vehicle mobility is strictly constrained by traffic rules and street layout, buffering each data at some clusters in the target area is enough. Therefore, how to elect data buffering units from the existing clusters and then give the cluster management scheme has been shown as following:

In some road segments, the parked vehicles form one cluster while on the other road segments, the parked vehicles are isolated from each other and form different partially distributed groups. To determine whether it should act as data buffering unit, let each cluster be periodically report its distribution to other clusters along the same road (with the help of vehicles travelling across the road). After obtaining the distribution of other clusters along the same road, a cluster decides whether it would work as buffering unit according to following rule: if there is only one cluster along the road, this cluster is undoubtedly elected as data buffering unit; if there are two or more than two clusters along the road, the two clusters located at the two ends of the road are elected as data buffering units. After elected as data buffering unit, a cluster needs to be responsible for the cluster management, including head election and membership management.

In the proposed scheme, the following head selection mechanism is specified. In a scenario in the two vehicles located at the two ends of the cluster are elected as cluster head. In a two-way road, the two cluster heads, respectively, provide services for the vehicles coming from the nearest intersection. In another scenario, the vehicle which locates at the end of the road segment is elected as cluster head in each cluster; this is also to ensure that a vehicle moving into the road could encounter the cluster head in a short time. After the cluster head is determined, the cluster members periodically report their position to the cluster head. Thus, the cluster head is able to manage all parked vehicles, act as local service access points, and perform the data dissemination operation. Considering the fact that the vehicle works as cluster head might leave at any time, then the following rule is specified: while the cluster head is leaving (the engine is started), a new round of head selection is triggered, and the data to be disseminated as well as the cluster state are transferred from the old cluster head to the new one.

2.2. Data Forwarding from Data Source to Roadside Parking

In the proposed parking-based scheme, the parking clusters help to buffer the data messages in their target area and provide data dissemination service for the vehicles passing by. To realize this one-hop data dissemination, the data source should first distribute each data to the selected parking clusters within the target area. According to the strategy used, this process could be further divided into two phases: phase-I: routing from data source to one parking cluster and phase-II: routing from one parking cluster to other parking clusters.

This paper highlighted different uses of inter-vehicle communication (IVC) for controlling traffic congestion and the importance of the VANET to interexchange position data among the vehicles such that, the density of the vehicles and their relative

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speed is known to other vehicles in the area or approaching the area.

3. Conclusion

Overall in India the parking-based scheme is needed to apply urgently uniformly all over the country especially in highly congested areas which will involve a data source system such as computer with a wireless interface and access point with a data forwarder which will help to forward the received data to the target parking clusters (a group of vehicles parked on same road and belong to same cluster) and end users (vehicle users who will receive the message and work accordingly).

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