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Performance Analysis of Various Data Collection Schemes used in VANET

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Abstract

Objectives: The main objective of this paper is to find the best method for collecting the data for VANET in terms of communication overhead, average latency and packet delivery ratio. **Methods/Analysis:** OMNet++ is used to compare the existing techniques for data collection in VANET at single RSU. Performance Index is calculated by finding the Communication Overhead (CO), average latency and Packet Delivery Ratio (PDR) for each scheme of data collection. The scheme with higher value of performance index will outperform others. Simulation parameters like dimension of space, minimum velocity and maximum velocity of vehicles are kept constant. **Findings:** Comparison of different Data Collection Schemes is done on the basis of performance index. Performance Index shows the effectiveness of data collection schemes. PI is based on various parameters like CO, Latency, and PDR. PI of a data collection scheme decreases when CO increases and vice-versa. So, if number of messages will increase CO will increase and hence will decrease the PI. PI of a data collection scheme decreases when latency increases and vice-versa. So, if time delay is more latency will increase and hence will decrease the PI. PI of a Data Collection Schemes increases when PDR increases and vice-versa. So, if number of packets received by a destination will be more PDR will increase and hence will increase the PI. Analysis of results show that PI of VIB-CP is the best among all DCSs, as it has less CO, low latency, and high PDR. **Novelty/Improvement:** Comparison of heterogeneous Data Collection Schemes is made on same parameters and their performance index is measured. Out of all existing schemes it is analyzed that VIB-CP outperforms.

Keywords: Communication Overhead (CO), Data Collection Schemes (DCS), Data Mining (DM), Packet Delivery Ratio (PDR), Performance Index (PI)

1. Introduction

VANET is an emerging technology, and is a specific type of Mobile Ad-Hoc Networks (MANET). Zeadally et al.[1] explored that VANET consists of two types of wireless nodes mobile units and the Road Side Units (RSU). Mobile units in VANET are the highly dynamic vehicles equipped with a sensing device commonly a Global Positioning System (GPS), and antennas acting as transceivers for transmitting and receiving data or information, collectively known as On Board Unit (OBU) that are used for communication among other vehicles on road or with the fixed units in network. Road side units in VANET are the fixed wireless nodes on the road sides that will provide internet connections to the vehicles through Internet Service Providers (ISP).

As discussed by Boukerche[2], there are two types of communication possible in VANETs Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). V2V is an infrastructure less approach where communication is among the vehicles moving in the network that can locate each other position and then transmit messages using their On Board Units (OBU). V2I is an infrastructure based approach as it provides communication among vehicles and the fixed units such as Road Side Units or traffic lights.

Balasubramanian et al.[3] found that in VANET dynamic changes in network topology occurs frequently and is also

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prone to environmental obstacles like tress, buildings, and other vehicles on road. Above all these challenges, the major application areas where VANET plays significant role as given by Eriksson et al.[4]; Lee et al.[5] explained Safety and Traffic Applications: avoiding road accidents, maintaining road conditions, generating warning alerts, vehicles position tracking and checking traffic violations, vehicle path map; Providing Information: internet access, news, music, videos, parking availability, video conferencing discussed by Yang et al[6]. Kabir[7] discussed that VANETs are featured by high vehicle mobility on the road. Samara[8] argued that due to this high mobility, VANET topology keep on changing very fast leading to high communication overhead in exchanging new available topology information.

Due to this, the most recent and challenging application of VANET is to find the vehicle best path map. A best path map includes all the road segments a particular vehicle must choose to reach its destination within time, without any collision or traffic problems. So the basic necessity to find a best path map for a particular vehicle is data collection from all the ongoing vehicles that are following different paths or different segments to reach the same destination under bad road conditions or any accidents. So, first issue is the selection of DCS that can be used to get the best path map for a vehicle. Once it is done next issue is to apply DM to the collected data, so that a useful and best path map can be selected for vehicles for a particular destination. DCSs are used to maintain data at RSUs (Road Side Units) by collecting information from the ongoing vehicles which are in the vicinity of a particular RSU (Figure 1).

Complete methodology can be represented through the flow chart (Figure 2).

The paper is organized in the following way: Section I gives some introductory background. Section II discusses the existing DCSs in VANET. Section III covers the DM

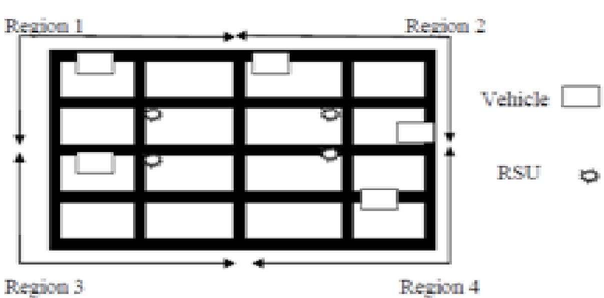

Figure 1. Area consisting of RSUs and moving vehicles.

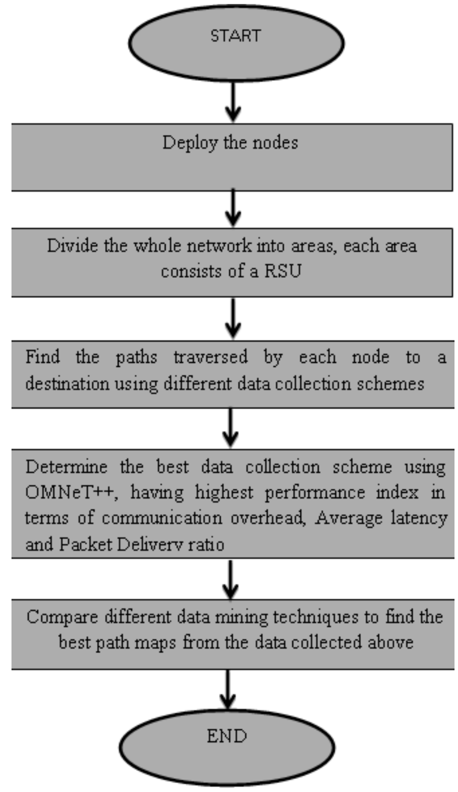

Figure 2. Flow chart showing methodology.

techniques in VANET. Section IV compares the different DM techniques discussed in section III. Section V elaborates the implementation of different DCSs in OMNeT++ and shows the results that are used to find the best DCS. Section VI concludes the work done.

2. Data Collection Schemes (DCS) in VANET

Various DCSs has been proposed by various authors for collecting the path information for vehicles. The schemes can be categorized into two groups Static and Dynamic. In static schemes path information remain static if due to some reason vehicles change the path that information cannot be provided by the static schemes but dynamic schemes are capable of providing such kind of path information.

Kaplan[9] explained Global Positioning System (GPS), which was evolved in 1973 by U.S. Department of defense. It consists of twenty four satellites which operate in orbit moving around the earth. Every one out of 24 satellites rotates around the earth twice a day at the height of about 20,200 km. The orbits are placed in a manner such that each region of earth can be monitored by minimum 4 satellites. A GPS receiver constantly receives information from these 4 satellites. Boukerche et al.[10] monitored the different events that are occurring by sensing different activities like temperature, humidity, fire, etc. using GPS. GPS is used to locate the moving nodes of the network so that they can be tracked easily. Time of Arrival (TOA) is used to locate the position of the moving vehicle by using trilateration technique. But it may not be the accurate location information due to various line of sight problems such as obstacles in path like buildings, trees etc.

Boukerche et al.[11] introduced that not each vehicle in the VANET should be equipped with GPS, as it is not available all the times and is not even robust enough so it leads to many problems in VANET. Lagraa et al.[12] proposed a protocol that was used to find the location of a vehicle without the use of GPS due to its above said disadvantages. It makes use of the clustering approach, where cluster heads are appointed and they communicate with the other nodes in the network using a single coordinate system. Jagadeesh et al.[13] reviewed that map matching is not a position tracking technique but it can be used with one such technique like GPS. Map matching technique can find the location tracked by GPS on a preloaded map and pinpoint the location of those vehicles on map. Yang and Kang[14] discussed various techniques for map matching to match the GPS points that consider only short polling time intervals. So a new algorithm was proposed that works for long interval polling.

King et al.[15] proposed a method for dead reckoning that is used to find location of neighbor nodes. Based on the previous known position of a vehicle and by finding its movement information through speed, distance and time, the latest position of that vehicle can be obtained. The previous known position of a vehicle can be found using GPS or any reference point like river, any crossing, etc. Dead reckoning is used in the situations where GPS fails like under a tunnel a vehicle losses its GPS connection.

Hac[16] proposed cellular architecture. Here area is divided into cells and location of a vehicle is traversed through the signals received from them. During handoff vehicles pass their information to the towers which help in detecting the congestion levels or any cellular activity.

Rajaratnam[17] presented hand off traffic model using mean and variance, as poisson method is not valid for longer times. The focus was on to identify the traffic pattern during the hand off process. This will help to identify the traffic pattern in VANET as the nodes are highly mobile. Atikom and Peachavanish[18] used a metric, CDT (Cell Dwell Time) that was used to find traffic congestion on the road. CDT is the time till a vehicle is connected to a base station before its hand off to other base station. So more is the value of CDT, more is the traffic congestion on road as it will be connected tone base station for more time. Civilis et al.[19] presented different update techniques to find the position of moving vehicles. In this vehicles are treated as clients and central database as a server. The above discussed are static DCS but are able to get the general information about vehicles.

Sakthipriya and Sathyanarayanan[20] presented a cluster based communication scheme for VANET. Here the communication is made under the observation of nominated cluster head. The communication based on cluster head is more reliable as failure of ne cluster will not affect other one.

Gamess and Chachati[21] compared the performance of existing routing protocols in VNET by changing the various performance metrics like traffic pattern, speed of vehicles and number of vehicles on the road. It also focused on the amount of memory required for each routing protocol.

Dynamic schemes are more efficient in terms of CO, Latency and PDR with respect to the above schemes. Farouk and Samara[22] categorized DCS into two groups depending upon their data collection method as RSU initiated or Vehicle initiated. The various DCSs are as follows:

2.1 RSU Initiated (RI)

In this scheme, RSU will initiate a beacon message after M seconds to vehicles in its vicinity. Each vehicle in response will generate a packet containing the partial path information to the RSU. Yang et al.[23] proposed a new scheme, road side probing where Road Side Units (RSU) commence the probing procedure and enquire each vehicle that is going on the road to collect environmental, traffic, accidents information.

2.2 Vehicle Initiated-Broadcast Mode (VIB)

In this scheme, vehicle will initiate the packet transmission in broadcast mode to all the RSUs in its range. Xu et al.[24] proposed two methods to collect data using broadcast mode, confined two-hop broadcast mechanism and probabilistic confined two-hop broadcast. Their basic need is to detect traffic congestion and improve the detection range of RSU to maximum extent. VIB scheme is further divided into two schemes.

2.1.1 VIB-New Segment (VIB-NS)

Vehicle will transmit the packet whenever a new segment is received by it in its path.

2.1.2 VIB-Complete Path (VIB-CP)

Vehicle will transmit the packet only when they have collected the complete path information, that is, when it has traversed all the road segments in its path and now it has reached its final destination and stopped moving.

2.3 Vehicle Initiated-RSU Find Mode (VIR)

Vehicle will initiate the packet transmission as a unicast message for that it will broadcast an RSU find message and the RSU which is present in its range and is close to it will reply first with a message containing its address. VIR scheme is further divided into two.

2.3.1 VIB- New Segment (VIB-NS)

Vehicle will transmit the packet to a particular RSU whenever a new segment is received by it.

2.3.2 VIB-Complete Path (VIB-CP)

Vehicle will transmit the packet only when they have collected the complete path information.

3. Data Mining (DM) Techniques in VANET

Han and Kamber[25] explained DM as a technique that is used to obtain unambiguous information from the data collected. Here various DM techniques used in VANETs and the applications they have served when implemented are discussed.

3.1 Clustering

Clustering is basically an unsupervised learning technique. In this classes are formed and each class is known as a cluster such that intra-cluster association is more than inter-cluster association and each cluster is observed by a Cluster Head (CH). Clustering technique provides more real time information related to traffic jams or accidents on the road. Various clustering techniques for mining data for VANET have been proposed in literature. Some of these techniques are mentioned below.

Santos et al.[26] proposed a technique where nodes exchange their states using HELLO messages and if it does not receive any message for a time limit it announces itself as the Cluster Head (CH), otherwise it registers itself as the member node to the existing CH. Here nodes know their destination, so they are forwarded to that directly. Gunter et al.[27] adopted the similar mechanism that is used in the above scheme for forming the cluster. Nodes can act as members for multiple clusters. So they can be referred as Gateways and are will therefore route the packets to their destination.

Su and Zhang[28] proposed a distributed scheme known as cluster based multi-channel scheme for improving the QoS in VANET. The aim is to provide QoS for delivery of the real-time data and thus improving the throughput for the traffic that is non-real-time. Wang et al.[29] proposed a clustering technique for cluster-head selection which is similar to finding the Minimum Dominating Sets (MDS). This approach is well known as Position based Prioritized Clustering (PPC). Kayis and Acarman[30] proposed a new clustering scheme that categorizes vehicles into groups on the basis of their range of speed. Vehicles which follow same speed are placed in one group or same cluster.

3.2 Association Rule based Mining

Vijayarani et al.[31] described association as the discovery of togetherness or connection of objects. An association rule shows relationship among objects such that existence of one object in a set reveals existence of another object related to it. Yen et al.[32] discovered that by collecting the past interest behavior of a customer, decision made for an organization can be improved. The association rules are generated according on the user request.

Rezgui and Cherkaoui[33] proposed a latest scheme called VANET Association Rules Mining (VARM) where each vehicle collects data for each neighbor in its range, and extracts various rules for temporal correlation so as to detect malicious or faulty vehicles The association rule is used to identify the behavior of neighboring vehicles and then have a check for malicious or faulty vehicles. Bae and Olariu[34] have also taken advantage of association rules mining in an application for VANETs. In their work, association rules mining was used to extract control rules for the linguistic information system in their proposed context-aware driving assistance system that helps prevent the occurrence of traffic accidents.

Kotsiantis, and Kanellopoulos[35] has suggested four ways to improve the efficiency of association rules the computational cost; reduce the number of elapses over the database, sampling the database, add more constraints on the organization of patterns, and use parallelization.

3.3 Classification

Pandey and Pal[36] presented a model which describes a set of predetermined classes from a set of tuples known as the training set. This technique is supervised, which means that it requires an input from the user, in this case the training set, to build the model and train it accordingly. Sujatha et al.[37] described so many classification techniques used for different applications in VANET, such as Bayesian networks, decision tree induction, case-based reasoning, k-nearest neighbor classifier, fuzzy logic techniques and genetic algorithm.

Kargl et al.[38] aimed at providing a security engineering approach for VANETs towards the assessment of the security needed for certain applications. In order to do so, the authors proposed the use of classification DM in order to analyze the large set of VANETs applications, classify them according to their security requirements and provide security solution for each class of application.

3.4 Sequential Mining

Anthony et al.[39] described sequential mining as a technique that is used to discover sequences of events that commonly occur together and frequently. It can be on the basis of time or order of events. An item is called frequent if it occurs more than a predefined threshold value.

Kang and Yong[40] proposed a new algorithm is designed to find the frequent mining pattern by giving the formal definition of movement patterns.

Tsoukatos and Gunopulos[41] suggests a new protocol DFS_MINE for fast mining of patterns by using depth first like approach to find the longest sequential pattern.

4. Comparison of DM Techniques in VANET

A comparison is made among three DM techniques based upon their objectives, applications, the dataset used and benefits (Table 1).

Table 1. Comparison of data mining techniques

Forming Clustering	Association Based Rules	Classification
Data is maintained in clusters from communicating vehicles only.	Easy to log data by humans as well as communicating vehicles.	Requires a training set for mining based on different classes.
Collecting real time congestion information, no previous data is maintained.	Helps in detecting events based on previous data	Distinguish malicious message from legitimate message
More communication overhead	Less communication overhead	More than Clustering
Average Packet delivery ratio, faces end to end delay	Maximize Packet delivery ratio and minimize end to end delay	Less packet delivery ratio, and more delay as compared with other techniques.

5. Results and Discussion

The implementation of various DCS is done in OMNet++ at single RSU (Figure 3). There are certain fixed parameters used for the simulation (Table 2).

Results of CO, Latency and PDR are found by taking readings form OMNeT++ environment (Figure 4).

CO depends on number of messages transmitted and the number of vehicles communicating through these messages. The formula used for computing CO is shown in equation 1.

$$CO = \frac{\Sigma \text{Total messages}}{\Sigma \text{Number of vehicles}} \quad (1)$$

Comparison of different DCSs on the basis of CO is done (Figure 5).

Latency is the time data packet takes to reach the destination. It is also known as end-to-end delay. The formula used for computing latency is shown in equation 2.

$$\text{Latency} = \frac{\Sigma(\text{arrive time} - \text{send time})}{\Sigma \text{Number of links}} \quad (2)$$

Comparison of different DCSs on basis of Latency is done (Figure 6).

Packet Delivery Ratio (PDR) is the ratio of data packets received by the destination to those generated

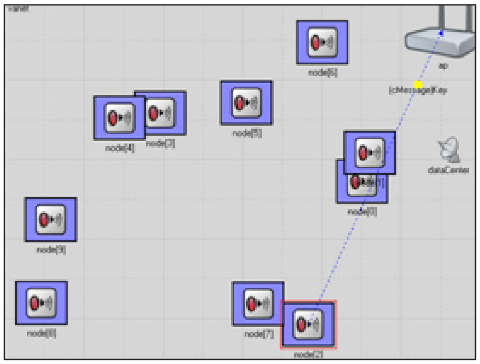

Figure 3. OMNeT++ scenario.

Table 2. Parameters for simulation

Parameters	Value
Dimension of Space	1000m × 1000m
Minimum Velocity	0 m/s
Maximum Velocity	120 m/s
Radio Range	200 m
Data Payload size	512 bytes/packet
Physical Link Bandwidth	2 Mbps
Traffic Type	Constant Bit Rate
Scenario	Random mobility

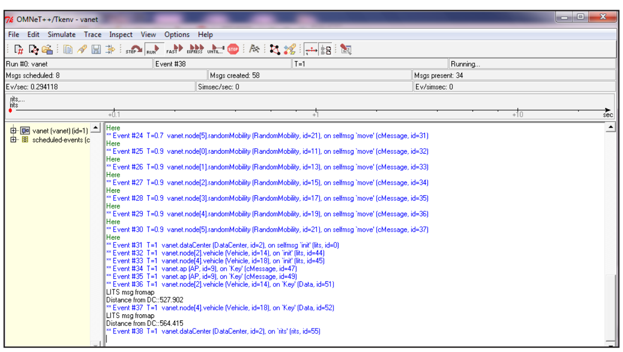

Figure 4. OMNeT++ simulation environment.

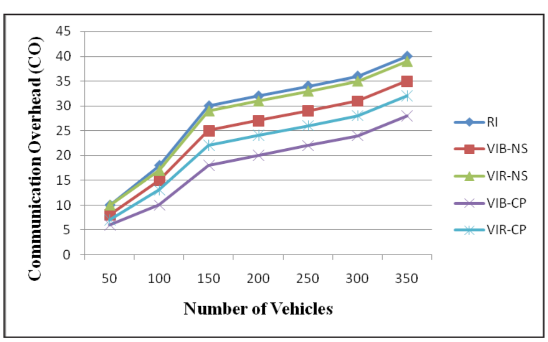

Figure 5. Communication overhead with number of vehicles for different DCSs.

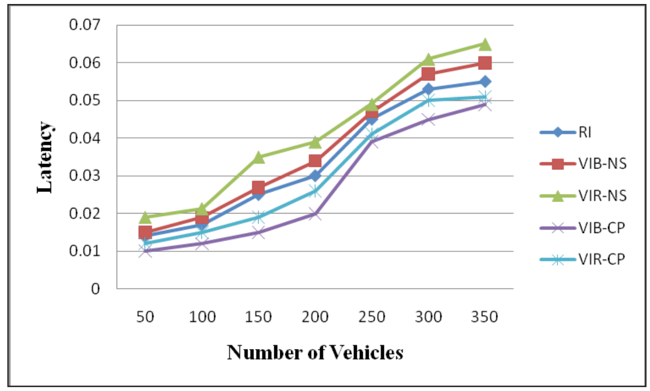

Figure 6. Latency with number of vehicles for different DCSs.

by the source. The formula used for computing PDR is shown in equation 3.

$$PDR = \frac{\Sigma \text{ Number of packet receive}}{\Sigma \text{ Number of packet send}} \tag{3}$$

Comparison of different DCSs on the basis of PDR is done (Figure 7).

Performance Index (PI) shows the effectiveness of DCS. PI is based on various parameters like CO, Latency, and PDR. PI of a DCS decreases when CO increases and vice-versa. So, if number of messages will increase CO will increase and hence will decrease the PI. PI of a DCS decreases when latency increases and vice-versa. So, if time delay is more latency will increase and hence will decrease the PI. PI of a DCS increases when PDR increases and vice-versa. So, if number of packets received by a destination will be more PDR will increase and hence will increase the PI. The formula used for computing PI is shown in equation 4.

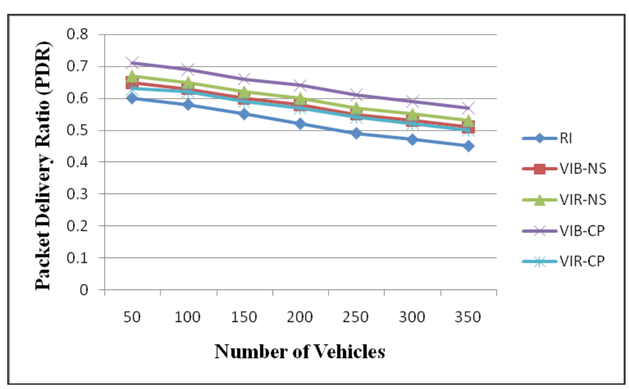

Figure 7. Packet Delivery Ratio with number of vehicles for different DCSs.

$$PI = \frac{k^{*}PDR}{\left(CO^{*}L\right)} \quad (4)$$

Where k is a constant that depends on the number of segments vehicles have to traverse.

Comparison of different DCSs on the basis of PI is done (Figure 8).

So above results show that VIB-CP has less CO, less latency, and high PDR. Hence it has highest PI among all DCSs.

Comparisons of different DCSs based on implementation are made (Table 3).

6. Conclusion

Most of the existing path generation schemes are static, like GPS as the most common example. In GPS the path to be followed from a source to destination is always fixed, that do not consider any accident, traffic congestions or any unpredictable behavior on that path. So, dynamic DCS are required to generate path map from source to destination under unusual situations.

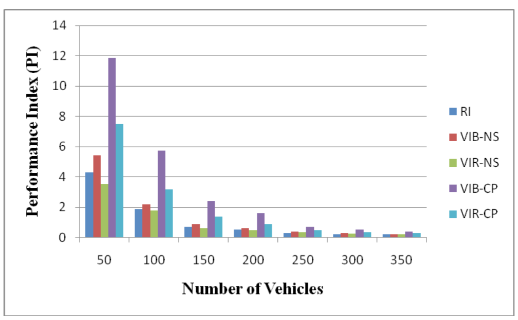

Figure 8. Performance Index with number of vehicles for different DCSs.

Table 3. Comparison of modern DCSs in VANET

	Performance Parameters			Performance Index (PI)
DCS	Communication Overhead (CO)	Latency	Packet Delivery Ratio (PDR)	$PI = \frac{PDR}{CO^{*}L}$
RI	HIGH	MODERATE	LOW	LOW
VIB-NS	MODERATE	MODERATE	MODERATE	AVERAGE
VIR-NS	HIGH	HIGH	MODERATE	LOW
VIB-CP	LOWEST	LOWEST	HIGH	BEST
VIR-CP	LOW	LOW	MODERATE	BETTER

The static schemes are hardware based whereas dynamic are algorithm based. In this work the various dynamic schemes are compared based on their CO, Latency and PDR. Finally PI is calculated using equation (4) for each DCS. From the result it can be concluded that PI **of** VIB-CP is the best among all DCSs, as it has less CO, low latency, and high PDR.

This review helps the novice to choose appropriate DCS and DM technique in VANET.

7. References

1. Zeadally S, Hunt R, Shyan Y, Angela Irwin C, Hassan A. Vehicular ad hoc networks (VANETS): Status, results, and challenges, Telecommunation System. EURASIP Journal on Wireless Communications and Networking. 2012.
2. Boukerche A. Vehicular Ad Hoc Networks: A new challenge for localization-based system. Computer Communication. 2008.
3. Balasubramanian R, Mahajan A, Venkataramani BN, Levine BN, Zahorjan J. Interactive WiFi connectivity for moving vehicles. SIGCOMM Computer Communication. 2010.
4. Eriksson J, Balakrishnan H, Madden S. Cabernet: vehicular content delivery using WiFi. Proceedings of the 14th ACM International Conference on Mobile Computing and Networking (MobiCom'08); San Francisco, California, USA. 2008. p. 199–10.
5. Lee S, Lee U, Lee K, Gerla M. Content distribution in VANETs using network coding: the effect of disk I/O and processing O/H. Proceedings of the 5th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON'08); San Francisco, California, USA. 2008. p. 117–25.
6. Yang Q, Lim A, Li S, Fang J, Agrawal P. ACAR: Adaptive Connectivity Aware Routing for vehicular ad hoc networks in city scenarios. Mobile Network Application. 2010.
7. Kabir H. Research issues on Vehicular Ad hoc Network. International Journal of Engineering Trends and Technology). 2013 Dec; 6(4).
8. Samara G, Wafaa AH, Sures R. Security analysis of Vehicular Ad Hoc Networks. Second International Conference on Network Applications, Protocols and Services; 2010.
9. Kaplan D, Christopher J. Understanding GPS: Principles and applications. Artech House; 1996.
10. Boukerche A, Oliveira H, Nakamura EF, Loureiro AA. Localization systems for wireless sensor networks. IEEE Wireless Communications-Special Issue on Wireless Sensor Networks. 2007; 14:6–12.
11. Boukerche A, Oliveira ABF, Nakamura EF, Loureiro AAF. Vehicular Ad Hoc Networks: a new challenge for localization-based systems. Computer Communications. 2008.

12. Lagraa N, Bachir M, Yagoubi, Benkouider S. Localization technique in VANets using Clustering (LVC). International Journal of Computer Science. 2010 July; 7(4):9.
13. Jagadeesh G, Srikanthan T, Zhang X. A map matching method for GPS based real-time vehicle location. Journal of Navigation. 2005; 57:429–40.
14. Yang J, Kang S. The map matching algorithm of GPS data with relatively long polling time intervals. Journal of the Eastern Asia Society for Transportation Studies. 2005; 6:2561–73.
15. King T, Fubbler H, Transier M, Effelsberg W. On the application of dead-reckoning to position-based routing for vehicular highway scenarios. Proceedings of ACM Conference on Emerging Network Experiment and Technology. 2005.
16. Hac A. Cellular network model with hand off delays. IEEE Communications Magazine. 1995.
17. Rajaratnam M, Takawira F. Hand-off traffic modeling in cellular networks. IEEE Communications Magazine. 1997.
18. Pattara-Atikom W, Peachavanish R. Estimating road traffic congestion from cell dwell time using neural network. Communications Magazine. 2007.
19. Civilis A, Jensen C, Nenortaite J, Pakalnis S. Efficient tracking of moving objects with precision guarantees. Proceedings of the First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services; IEEE; 2004.
20. Sakthipriya N, Sathyanarayanan P. A reliable communication scheme for VANET communication environments. Indian Journal of Science and Technology. 2014 June; 7(S5):31–6.
21. Gamess E, Chachati M. Analyzing routing protocol performance with NCTUns for vehicular networks. Indian Journal of Science and Technology. 2014 Sept; 7(9):1391–402.
22. Farouk A, Samara S. A sequential patterns data mining approach towards vehicular route prediction in VANETs. Mobile Networks and Applications. 2013 Dec; 18(6):788–02.
23. Yang L, Xu J, Wu G, Guo J. Road probing: RSU assisted data collection in vehicular networks. IEEE Communications. 2009.
24. Xu Y, Wu Y, Wu G, Xu J, Liu B, Sun L. Data collection for the detection of urban traffic congestion by VANETs. IEEE Asia-Pacific Services Computing Conference; 2010.
25. Han J, Kamber. Data mining: Concepts and techniques. 2nd ed. Morgan Kaufmann Publisher; 2006.
26. Santos R, Edwards R, Seed N. Inter vehicular data exchange between fast moving road traffic using ad-hoc cluster based location algorithm and 802.11b direct sequence spread spectrum radio. Post-Graduate Networking Conference; 2003.
27. Gunter Y, Wiegel B, Gromann H. Medium access concept for VANETs based on clustering. Proceedings of the 66th IEEE Vehicular Technology Conference (VTC); Baltimore. 2007; 30:2189–93.
28. Su H, Zhang X. Clustering-based multichannel MAC protocols for QoS provisioning over vehicular ad hoc networks. IEEE Transactions on Vehicular Technology. 2007 Nov; 56(6).
29. Wang Z, Liu L, Zhou M, Ansari N. A position-based clustering technique for ad hoc intervehicle communication. IEEE Transactions on Systems, Man and Cybernetics. 2008 Mar; 38(2).
30. Kayis O, Acarman T. Clustering formation for inter-vehicle communication. Proceedings of the 10th IEEE, Intelligent Transportation Systems Conference (ITSC'07); 2007.
31. Vijayarani S, Tamilarasi A, SeethaLakshmi R. Privacy preserving data mining based on association rule- A survey. Proceedings of the International Conference on Communication and Computational Intelligence; 2010 Dec 27–29. p. 99–3.
32. Yen S, Chen A. An efficient data mining technique for discovering interesting association rules. IEEE Transactions. 1997.
33. Rezgui J, Cherkaoui S. Detecting faulty and malicious vehicles using rule-based communications data mining. 5th IEEE Workshop on User Mobility and Vehicular Networks; 2011.
34. Bae I, Olariu S. A tolerant context-aware driver assistance system for VANETs-based smart cars. IEEE Global Telecommunications Conference (GLOBE-COM 2010); 2010 Dec 6–10. p. 1-5.
35. Kotsiantis S, Kanellopoulos D. Association rules mining: a recent overview. GESTS International Transactions on Computer Science and Engineering. 2006; 32(1):71–82.
36. Pandey U, Pal S. Data mining: A prediction of performer or underperformer using classification. International Journal of Computer Science and Information Technologies. 2011; 2(2).
37. Sujatha M, Prabhakar S, Devi G. A Survey of classification techniques in data mining. International Journal of Innovations in Engineering and Technology (IJIET). 2013 Aug; 2(4).
38. Kargl F, Ma Z, Schoch E. Security engineering for VANETs. 4th Workshop on Embedded Security in Car; 2006 Nov.
39. Lee J, Chen Y, Chong W. Mining frequent trajectory patterns in spatial-temporal databases. Information Sciences. 2009; 2218–31.
40. Kang J, Yong H. Mining spatio-temporal patterns in trajectory data. Journal of Information Processing Systems. 2010 Dec; 6(4).
41. Tsoukatos I, Gunopulos D. Efficient Mining of Spatiotemporal Patterns. In: Jensen CS, et al., editors. 2001; 425–42.