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A SURVEY ON THE LINK CONNECTIVITY OF VANETS

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***Abstract*— Vehicular ad hoc network (VANET) is highly popular among the other ad hoc networks. These networks form mobile wireless links which utilize moving vehicles as nodes. Due to the fast growth in the automobile industry there is a desire to adapt a technique which provides a solution for driving assistance and traffic monitoring. Researchers have attained a great progress on VANET study but there are some major challenges require to be overcome. It is very difficult to design a routing protocol which efficiently route the data among the vehicles, for vehicles communication (V2V), among vehicle and roadside unit, for vehicle to roadside communication (V2I) and between roadside units, for roadside to roadside communication (R2R). Selecting the best node that constitutes the route from source to destination is particularly challenging. Also, mobility of the vehicle is another factor that degrades the overall performance of the network as the vehicles move at relatively higher speeds. To sustain the connection between the vehicles for a longer duration of time and to find the optimal path for data transmission, this paper provides a review study on several routing protocols and presents a comparison on the basis of packet to packet delivery rate, delay rate and packet collision rate.**

Keywords— VANETs, V2V, R2R, V2I

I. INTRODUCTION

Vehicular ad hoc network are forming wireless networks with vehicles as nodes that can move freely in the environment. The main use of VANETs is for safety and comfort applications. During the communication, the vehicles communicate and transfer many useful information. To avoid multiple vehicle collisions, a vehicular network can broadcast warning messages to drivers about the traffic accidents or bad road conditions. These networks can also reach the internet services using the roadside units. VANETs are having high transmission power and high computational capability which makes them different from other wireless networks. In a wireless network, maintaining link connectivity for a longer period of time is particularly challenging. In VANETs, since the vehicles moves at relatively higher speeds, the network topology changes frequently and due to this frequent disconnection take place which increases the delay and packet failure. The vehicles are outfitted with onboard units that communicate with each other and with the nearby wireless units. This communication helps in maintaining the connection but the problem is not solved yet. There is a need to adapt a routing protocol which efficiently route the data and enhance the performance of the network by taking certain parameters (delay, packet to packet delivery rate and packet collision rate) into consideration so that these effects will not degrade the performance of the network.

II. ROUTING PROTOCOL

A. Geographic Routing

This routing scheme is based on the location of the destination node and source node. By knowing the position of destination node through GPS or by sending beacon messages and by knowing own position, the message can be directly routed. There is no need to know the topology of the network.

B. Topology based Routing

This routing scheme considers that how the route is selected for transferring the data from source to destination.

C. Cluster based Routing

This routing scheme is based on the selection of the node which can be considered as the cluster head and all other nodes other than the cluster head are known as cluster member. When any node fails to make connection with other clusters then that node is called as border node.

D. Hybrid Routing

This routing scheme basically takes the best of topological and positional based routing schemes.

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E. Data fusion based Routing

This routing scheme is based on sending the information which is of interest or important, it reduces data from the redundant nodes. From cooperative nodes to achieve a complete view it fuses the information from complementary nodes.

III. RELATED WORK

Fonseca, et al has done the survey on location based routing protocols in highways and urban city environment for vehicular ad-hoc networks. In this paper, the topology based routing protocols are compared with position based routing protocols. Author deeply studied the protocols like anchor based street and traffic aware routing(A-STAR), greedy perimeter stateless routing(GPSR), greedy traffic aware routing(GyATR) etc and concluded that there is no protocol that CAN used both in highways and urban environment[11].

Rahim Tafazoli, et al proposed a position vector routing protocol which predicts the node's position. The author designed the position routing vector protocol to predict the performance in an urban vehicular ad-hoc network environment. It provides navigation information which improves the efficiency of routing protocol in a vehicular network. They also used information related to link quality to further improve the efficiency of the system. This information is helpful in reducing delay and helps to maintain the connection for a longer time [15].

Valery Naumov, et al proposed a new routing, connectivity aware routing (CAR) which will route the data accurately to the destination node. In this, AODV based path discovery is used to find the routes, no previous node's information is used. Only information about the nodes that are near the crossing and close to the road curve is recorded in the path discovery packet. These are known as anchor points. The path that provides better connectivity and less delay that path is selected from the multiple discovery packets that destination receives [26].

Yang, Qing, et al proposed adaptive connectivity aware routing protocol. Due to huge network size and due to recurrent network disconnections there is a requirement to adapt this protocol. Results have shown that this protocol performs well in comparison to already existing VANET protocols in terms of packet to packet delivery ratio, throughput and delay. This protocol also works in the condition where accurate statistical data is inaccessible [20].

Chen Chen, et al proposed a connectivity-aware intersection based routing (CAIR) protocol to address high mobility, frequent link disconnection problem because it becomes difficult to form an efficient route in this situation for delivering the packets. These problems are overcome by choosing the optimal route which has high connectivity and less experienced delay. Author also proposed Geographical forward which is based on position prediction, is used to transfer packets between two intersections along the route [8].

Caixing Shao, et al presents connectivity-aware MAC protocol because in the existing MAC protocols the network connectivity is often ignored. This protocol is used for Platoon-based VANETs. Its main function is to develop road safety applications and reduce fuel expenditure. To obtain the relation between connectivity probability and network throughput, author presents the multi Markov model and calculated that with connectivity probability the throughput increases [4].

Jing Zhao, et al proposed vehicle assisted data delivery carry and forward technique in vehicular ad-hoc network to overcome the issue of frequent disconnections due to high mobility of vehicle. In this, throughout the packet forwarding process, dynamic path selection should be executed continuously. By using this protocol, packet to packet delivery rate increases and delay decreases in routing the data packet. Simulation results have also shown that this protocol is better than the epidemic routing protocols and GPSR [19].

Karp and Kung proposed Greedy Perimeter stateless routing (GPSR) [25] and [23] Fubler et al proposed contention based forwarding (CBF). In CBF, a node forwards the packet to that node which is closer to the destination geographically. Sometimes a situation arrives where the source and destination node distance is closer than the neighbors and destination node distance. This state is called as local maximum. In such situation, GPSR recovers using perimeter mode. The perimeter mode is based on right hand rule. When CBF is compared with GPSR in highway conditions, it is observed that packet delivery rate of contention based routing is higher when perimeter mode disabled. The packet delivery rate of GPSR further drops when beacon interval increases.

To overcome above problem, Kim et al proposed cross link detection protocol (CLDP). In this, each node check their neighbor nodes that whether it has been crossed by other links or not. After checking, when it returns to the original node then that node will calculate which cross link can be removed so as to protect the network from portioning. The nodes which are removed are not going to be used to forward the packet because on these nodes such cross links are not routable. It has the disadvantage that it is having high complexity and even its convergence time is very high [3].

Wenjing wang, et al studied and proposed two routing scheme, connection based restricted forwarding scheme and connectionless geographic forwarding scheme for routing in small scale VANETs. They also showed their effects on delay and packet failure. For large scale routing author proposed other protocols like two phase routing protocol which incorporates mapping information in routing. When existing routing protocols are applied on large scale the system performance gets degraded therefore there was a need to adapt a two phase routing scheme [18].

John W. Polak, et al describes that to make possible the cross-layer designs for vehicular ad-hoc networks the connection between mobility and network connectivity is most important. In this paper, author demonstrates three things. Firstly, for realistic vehicular network, it provides an analytical framework including the designing of the

mobility model and metrics for evaluation of node connection in VANETs. Secondly, on network connectivity, they show the effects of macroscopic and microscopic motion models through simulations. Thirdly, they show in vehicular network multi-hop paths performance is not as good as single-hop links. This knowledge of multi-hop transmission will be of great importance to study the routing algorithm [27].

Bu-sung le, et al proposed a new position based routing scheme, anchor based street and traffic aware routing (A-STAR). This routing scheme aims to identify path that has high connectivity to deliver the packets and also aims at providing a recovery strategy for lost packets. In this, with the help of street maps the sequence number of anchors or junctions is computed. Traffic awareness is necessary while computation. With the help of statistically related maps or dynamically related maps it is easy to calculate a path which has higher connectivity and which can achieve higher packet delivery rate. Simulation results have shown that this protocol performs well in comparison to GPSR and GSR in terms of packet to packet delivery rate [28].

Lochert, et al proposed a Geographic source routing (GSR) for vehicular ad-hoc networks in city environment. This routing scheme uses reaction location service to achieve the destination node's position. To achieve the city topology they used the street map. The source node calculates the junction by using Dijkastra's shortest path algorithm to send the packet. In position based manner the packets are forwarded between the junctions. GSR shows better results in terms of smaller total bandwidth consumption compared to AODV and DSR. Also, the average packet delivery rate is higher in this case. Geographic source routing is applicable only in city environments not in highways [24].

Jerbi Moez, et al proposed an improved greedy routing protocol(GyATR), consists of two modules; Junction selection and forwarding data between two junctions, which aims at efficient relay data by using real time traffic density information in vehicular ad-hoc networks. Vehicle speed and directions are also taken into consideration. GYATR's aim is to efficiently deliver the packets from source to destination for the reduction of delay. It also aims to reduce control message overhead and packet loss. Simulation results have shown that the packet delivery rate of GyATR is better than GSR. It is only compared to GSR [21].

Huang, et al describes that although multipath routing schemes help in reducing delay and increase the packet to packet delivery ratio but in wireless networks they also give rise to mutual interferences that result in reducing the system's efficiency. So to overcome this problem, On the behavior of node disjoint path, author explored the effect of mutual interference and showed that if node disjoint paths are properly chosen then it helps in reducing delay and packet loss and ultimately enhance the link quality. Simulation results have shown that there is an improvement in packet to packet delivery rate and end to end delay as compared to single path routing [17].

Haiqing Liu, et al presents the effects of different road traffic parameter by taking the example of AODV protocol for logical connection. Moreover Data mining technique is used to study the connection between logical connection and among the three road traffic parameters (road length, number of vehicles and speed). Author also presents the non linear regression-based logical prediction model and the machine based prediction logical connection model. Results show that both these models are highly accurate for the prediction [7].

Namboodiri et al proposed two predictions based routing protocol. These are PR- AODV and PR- AODVM. In AODV because of the high mobility among the vehicles, the connections get disconnected frequently. So to overcome this problem author used speed and position information of the vehicles. Simulations results have shown that there is a slight improvement in terms of the packet to packet delivery rate [22].

G. Mary Valantinaa, et al proposed point to point ad-hoc on demand vector routing protocol (PP-AODV) for link connectivity in vehicular ad-hoc network. With this, author used fuzzy logic to calculate whether a link is good or not by taking into account multiple metrics that include delay, bandwidth and packet collision. This protocol helps when position information is unavailable. Based on neighbor information we can fetch vehicle movement [2].

David, et al presented some of the connectivity issues of VANETs and describes some types of delay (Re-healing time delay, Mac delay). Re-healing time delay is a delay which occurs when a node re-establishes its disconnected nodes. Time period required for a packet to successfully deliver to the destination is called Mac delay. To reduce these types of delay and to maintain the connectivity so that messages are sent continuously without facing any problem author developed an analytical framework to describe the benefits of deploying large number of RSUs and his research showed that RSU deployment can significantly improve the message penetration time and reduce Re-healing delay and Mac delay time [6].

Manoj Dongre, et al presents communication pattern for traffic congestion control and showed how it solves the existing traffic congestion problem. Moreover, it solves the problem of message flooding by decreasing the number of messages broadcasted by the vehicles or nodes. Only in case of event occurrence the messages will be generated. It will not generate on regular basis. Only affected vehicles broadcast the messages continuously. This pattern also ensures vehicle to vehicle communication [5].

Bernabe Dorronsoro, et al describes that VANETs are ad hoc networks or wireless networks in which vehicles are moving at higher speeds. The primary problem faced in ad hoc networks is network partitioning. The author has proposed remote links for separate clusters to improve the network connectivity between the devices called bypass links, so that they comprise of a hybrid network. They also proposed cellular genetic algorithm to overcome these problems [16].

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Wang et al proposed passive cluster based flooding protocol for vehicular ad-hoc network (PassCAR). In this protocol there is one cluster head and other clusters are connected by gateways. When the route is discovered, the destination node replies back and send the route reply packet. Through the established path, the data is transmitted. Simulation results have shown that PassCAR is better than other protocols as this protocol provides better packet delivery rate [13].

Devjeet Choudhary, et al describes that a vehicle spends a large amount of time in the poor link connection quality area where there is no GPS information. In that case the data throughput can be decreased. To solve this problem, in this paper, author proposed a protocol of localization using VANET based on clustering and link prediction. This prediction helps the network to create a good quality of connection between vehicles [1].

Rabayah and Malaney proposed a scalable hybrid routing protocol for vehicular ad hoc network. This type of routing combines the feature of reactive routing and location based geographic routing. Author proposed Hybrid location based ad-hoc routing protocol. This protocol finds the best quality route by combining AODV and expected transmission count parameters. The route discovery process is done on the on-demand basis [12].

Zhang, et al proposed estimated distance based routing protocol for route selection from source to destination node and by restricting the range of route request packet; this protocol helps in reducing the routing overhead. The estimated distance is the amalgamation of estimated geographical distance and estimated topological distance, where estimated geographical distance is the geographical distance between the nodes and estimated topological distance is a topology based Estimated distance (an aid to EGD) [14].

Beijar et al proposed a Zone routing protocol (ZRP). This routing protocol comes under the hybrid based routing protocol. ZRP uses both the neighbor discovery protocol and medium access control layer to detect the new nodes. Also, it detects the link failures. Neighbor discovery protocol is used to update the neighbor table, it regularly exchange the beacon messages. By adjusting the transmission power of the nodes and by regulating the number of nodes in a zone the performance of the protocol can be optimized [29].

Wang J, et al describes that the performance in vehicular ad-hoc networks mainly depend on the network connectivity and the type of service it provides (good or bad) in the network. Medium access control mechanism and quality of service etc are the most important issues of VANETs. In this paper, author presents vehicular cyber-physical system. In VCPS, message is composed of data elements. The message is divided into parts. One is essential part and the other one is auxiliary part. The essential parts consist of that data element without which the message has no use. The auxiliary part consists of those elements which are useful in case when the essential part is reached to driver. The disadvantage of VCPS is that only limited number of messages can be sent which is inappropriate [10].

To solve this problem Wagh, et al studied the problems in VCPS and proposed four strategies. Knapsack problem based strategy (KPS), Flexible composition aware strategy (FCS), Fine-grained FCS strategy (FFCS) and Data element-domain strategy (DDS). Simulations have been performed on these strategies and it is found that these strategies are very efficient. Among all, FFCS Shows better results than others. FFCS deliver more messages to the receiver [9].

IV. CHALLENGES IN VANETS

A. Routing Protocols

Researchers have utilized many routing protocols to effectively route the data but the problem is not yet solved. Adaptation of certain effective routing protocols is needed.

B. Connectivity

To achieve the maximum performance out of the network, there should be a good connection between the vehicles and the infrastructure. For this, design the network effectively so that the repeated disconnection problems can be solved.

C. Mobility

Due to high mobility of vehicles, the connection breaks down and the information gets dissipated. There is a need to check the performance of the network after considering certain parameters.

D. Security and Privacy

No private information of user is passed among the vehicles is a difficult challenge that has to be worked upon. Certain algorithms are required which can work and give a solution for it.

E. Validation

Before checking the performance of VANETs in real time, the critical system properties have to be checked. To validate it earlier, field operational test is to be conducted, but conducting this test is also a challenge.

V. CHARACTERISTICS OF VANETS

A. Dynamic topology

Due to high speed of the vehicles, vehicular ad hoc network has a constantly changing topology.

B. Mobility models

Due to frequent topology variation there is need of an accurate mobility model to implement vehicular ad hoc network efficiently.

C. Infinite energy supply

As compared to another mobile ad hoc networks the nodes in vehicular ad hoc network having a longer battery life.

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D. Localization functionality

Vehicles are outfitted with GPS and GALILEO (positioning systems) incorporated by electronics maps.

VI. APPLICATIONS IN VANETS

A. Emergency electronic Brake light application

It is a safety application aimed to indicate a driver of a hard braking vehicle in the path in front.

B. Blind spot warning application

It a blind spot is suggested to make awake that it is not secure to change the lane.

C. Forward collision warning application

It is a safety application aimed at warning the driver of a near end crash with slower moving vehicle ahead.

D. Direct Pass Warning application

It is a safety application aimed to let the driver know that it is not safe to trying to pass through a moving vehicle which is slow.

E. Intersection movement assists application

It is a safety application aimed at warning the driver that it is not secure to go into the junction.

F. Left turns assist application

It is safety application aimed at warning the driver that because of approaching traffic, taking left turn is not secure to practice.

VII. DISCUSSION AND OPINION

A. Geographic routing

The geographical based routing is better than AODV in terms of packet to packet delivery rate. With the increase in traffic density it is reported that there is decrease in average delay. As there is no protocol which perform well in both urban and highway environment it is recommended to propose hybrid protocol [1].It provides navigation information which further improves the efficiency of routing protocol in terms of packet to packet delivery rate [2].Results have shown that CAR provides better efficiency than GPSR in terms of packet to packet delivery rate. It is found that with the increase in traffic density, delay decreases in highway environment [3].To maintain the connectivity in a situation when statistical data is inaccessible this protocol works [4]. Further, when two intersections occur along the route this protocol helps in predicting the position. As a result, delay decreases to maintain the connectivity [5]. Results have shown that this protocol is better than existing MAC protocol because in existing MAC protocol the network connectivity is often ignored [6]. By using epidemic protocol it is found that with the increase in data transferring ratio, the packet delivery rate decreases. But with this protocol, it helps in managing the data and show better results [7]. GPSR performs well in comparison to DSR as it route the data close to the destination node. As a result of this, GPSR (97%) achieves higher packet delivery rate than DSR (85%) [8]. When two nodes select similar MAC slot then collision occurs. The packet delivery rate of CBF is very high because at the time of collision occurrence, only on that time this protocol needs to transmit the packet again [9]. By removing fully cross links, the CLDP performs well in comparison to GPSR [10]. Proposed two phase routing scheme because existing protocols failed in large scale routing and as a result of that connection among vehicles suffer [11]. To study the routing algorithms to efficiently route the data, it provides information regarding the multi hop transmission [12]. A-STAR selects the optimum route which has high connectivity to effectively route the data by taking the traffic knowledge, it is found that the packet delivery rate further improved by approx. 40% [13]. Although position based routing is better than AODV and DSR. But it is found that there occurs a loss in connectivity during the selection of path by the algorithm which fails GSR [14]. GYATR performs well in comparison to GSR in terms of less delay as the path is discovered increasingly when it is transferred from source to destination node [15].

A. Topology based routing

It is found that when NDMR is compared with other single path routing scheme, this protocol performs well in terms of packet to packet delivery rate and delay rate but when the number of nodes increases from one to hundred, delay increases [16]. To further increase the connectivity these models play an important role as these models are highly accurate for prediction [17]. It is found that with the decrease in gateway density the gateway connectivity decreases. With the decrease in traffic density the path lifetime increases [18].

To maintain connectivity in a situation when the destination position is unavailable then this protocol works. Based on neighbor information we can fetch vehicle movement [19]. Present the idea that deploying large number of road side units will reduce the re-healing delay and MAC which ultimately improves the connectivity [20] presents communication pattern for traffic congestion control by decreasing the number of messages, broadcasted by the vehicles or nodes. This helps in reducing the collision rate as it reduces the message overhead [21].

B. Clustering based routing

In case of network portioning to further improve the network connectivity, remote links are proposed for separate clusters [22]. As compared to other protocol the packet delivery rate of PassCAR is better than other protocols by approx. 45% as this protocol uses node degree as routing metric which increases the sending request packet rate per hop [23]. Compared to other protocols, the localization protocol has higher data throughput as it is based on clustering and link prediction [24].

C. **Hybrid routing**

With the increase in network size and traffic density the routing overhead rate increases slowly in case of HLAR [25]. Further, to reduce the routing overhead the estimated distance based routing is used as it restricts the range of request packets [26]. It is found that optimal radius for ZRP does not depend upon traffic density. Also, the geographic based routing protocol outperforms ZRP [27].

D. **Data fusion based routing**

The disadvantage of this protocol is that only limited number of messages can be sent [28]. To overcome this protocol, [29] FFCS is proposed and found that FFCS gives better performance than FCS and KPS in terms less delay and less packet collision rate as FFCS has great control on auxiliary part.

Fast recovery on demand multipath routing protocol is not capable to evidently characterize the route discovery method. Therefore this protocol can be improved if certain parameters (delay, bandwidth, packet collision) are considered for the selection of the route. Position and connectivity based routing protocol gives good performance when the node compactness is less. XOR based routing protocol solves the problem of those protocols which stores the information on each node in the ad hoc network. Mobicast routing should be implemented carefully because deviations will result in protocol failure.
In a situation, where a huge amount of data has to be transmitted, in that case the probability of packet collision rate will be high. So to deal with a situation, how the important packet can be sent to the destination in minimum time that has to be studied.
After reviewing several routing protocols it is derived that there is need of several security protocols to boost up the quality of service and also required a solution to evaluate the feasibility and limitations with different traffic densities from different scenarios by utilizing vehicular traces.

VIII. CONCLUSION AND FUTURE SCOPE

For communication between the vehicles, network connectivity is very important issue as it is very difficult to transfer the data and messages to other vehicles when disconnections occur. Therefore, it is significant to design the best routing protocol. Designing of efficient routing protocol to maintain the link connectivity between the vehicles for VANETs is one of the major challenges that need to be addressed. This paper presents a review on large number of routing protocols and different techniques to route the data to maintain the link connection for a longer period of time and it is discussed on the basis of packet to packet delivery rate, delay rate and packet collision rate. After analyzing the different protocols and different techniques it can be predicted that there is a need of additional effort. Few issues like constant topological variation, high mobility issues need to be addressed seriously.

Through this work it is concluded that there can be some techniques to control the amount of data that is sent on the network on limited channel bandwidth and also there is a great need to design special mobility models which can solve the issue of mobility.

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