# Unicast Routing Protocols in Vehicular Adhoc Networks: A Comparative Analysis

Muhammad Uzair, Muazzam A. Khan, Nazar A. Saqib, and Jawad Ahmad

***Abstract*—Vehicular Adhoc networks are the networks built by means of the principles of Mobile ad hoc networks (MANETs). This allows effortless and effectual communication between vehicles without the need to create a permanent infrastructure. The applications of VANET are increasing as we are moving towards the era of fully autonomous self-driving vehicles. Various routing protocols have been proposed in vehicular Adhoc networks. In this paper we have done comparative analysis of frequently used unicast routing protocols in vehicular adhoc networks. This comparative analysis is based on qualitative comparison of commonly used unicast routing protocols. This will give us the clear view of the strengths and weaknesses of the available unicast routing protocols of VANETs. Primary focus of the comparative analysis is autonomous self-driving vehicles and based on the results of comparison it is suggested to use WLANWiMAX Double-Technology Routing (WWDTR) for wireless communication in autonomous vehicles.**

***Index Terms*—Component, internet of vehicles, unicast routing, vehicular Adhoc networks, routing.**

## I. Introduction

VANET is the type of wireless network that is created between vehicles when required. Wireless equipment, capable of sending and receiving wireless signals must be installed on the Vehicles, in order for the vehicles to act as nodes in the network. The range of wireless transceiver is limited therefore a vehicle that is equipped with a wireless transceiver is limited to a few hundred meters. In order to communicate with other vehicles, it is required that the vehicles must act as nodes in the network and are able to pass communicate with other nodes in the network. [1] VANET's provides robust vehicular communication to ensure road safety while providing additional services [2]. V2V communication is possible because of VANET's and apart from its uses in commercial vehicles, this technology is now being used extensively in military vehicles also [3].

In an environment of fully autonomous self-driving cars there is no chance of mistake. So every node (vehicle) must be aware of all the other nodes present on that specific path. Therefore there is no room for error in this scenario. This can be achieved only by selecting appropriate routing protocol for VANET wireless network [4] and by using intelligent transport system (ITS) [5]. Our discussion includes major unicast routing protocols and after the discussion, a comparison is done to see which of the routing protocols are suitable for this type of situation [6].

Unicast routing protocols are used in one-to-one communication between nodes of a network. The advantage of using unicast routing protocols is that we can address specific nodes in the network and nodes can communicate effectively with their neighboring nodes [7].

Vehicular Ad Hoc networks have various applications. The main concern in VANET's nowadays is the safety of vehicles. [7] With the help of VANET's the vehicles can be made secure from accidents [8]. Another aspect is making the cars fully autonomous so that the human error factor can be minimized.

To achieve this kind of reliability we need a protocol that can handle the wireless communication of the motor vehicles efficiently and without the risk of any errors and delays. In wireless sensor networks there is always a chance of packet loss that can have a serious impact in case of autonomous vehicles. This issue also has to be addressed [9]. However this study is beyond the scope of this paper and can be addressed as future work.

The advancement in automobile sector lead to the development of super speed vehicles. To make these fast moving vehicles autonomous with the help of wireless communication, lot of work has to be done on the communication protocols and the processing of the gathered data. But here our main focus is on comparing the existing protocols and then choosing the best suited protocol for autonomous vehicles.

As the focus of this paper is on the protocol best suited for autonomous vehicles therefore we will not go in depth of how the autonomous vehicles work on hardware level. For simplicity we consider that the vehicles are controlled by AI algorithms that takes data from both the environment of vehicle and by communication with other vehicles. It can than analyze this data and can make smart decisions.

## II. Literature Review

With the passage of time our communication has shifted from wired network to wireless networks. Wireless

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networks are advancing rapidly and every year new wireless standards are being introduced with more security and reliability. Still a lot of work has to be done in order to make the wireless networks more efficient, stable, and secure. Wireless networks consist of many nodes. These nodes can be of different types and capabilities. They communicate over short distance to exchange data. Every node has its limitations and due to these limitations the wireless network capabilities are limited.

Routing protocols acts as a backbone to make the wireless sensor network communication more efficient. Different variants of routing protocols have been proposed so far for communication between wireless sensor nodes. These are divided into following types: Unicast, Multicast, Geocast and Broadcast routing protocols. All of these protocols are important but we will focus our study on latest available Unicast routing protocols. Following are the latest known unicast routing protocols: IGRP, IEGRP, GeoSVR, RBVT, STAR, VADD, Ant colony based, GeoSpray, DAR, TDR, 3GDD and WWDTR.

The Intersection-based Geographical Routing Protocol (IGRP) is a unicast routing technique that works through the selection of road intersection which is necessary for the packet to pass in order to reach the gateway to the internet. The selection process is done in a way that ensures high probability, network connectivity and fulfills the constraints of quality of service (QoS), delay tolerance, error rate, and bandwidth usage [10].

In hybrid vehicular routing protocol unicast routing technique is used and the routes are changed dynamically with the help of Road Side Units (RSUs) which maximizes the packet delivery. An evaluation approach based on the Infrastructure Enhanced Geographic Routing Protocol (IEGRP) is provided which is used as a function of vehicular densities, infrastructure availability, and varied distance of source to destination and Qos characteristics of the application [11]. It reveals much superior delivery rates with the partial and full infrastructure in comparison to other related protocols [12].

In Intersection-Based routing protocol for urban vehicular communications with traffic light considerations, another protocol is proposed which is called as Shortest-Path-Based Traffic-Light-Aware Routing (STAR) which takes a shot at the traffic light thought. In this protocol the traffic lights exhibit on the crossing point and the traffic example are consolidated to decide how the bundles are forwarded. Simulations are done on ns-2 to assess the performance of STAR. The recreation comes about demonstrates that STAR accomplishes shorter normal deferral and the conveyance proportion is additionally high in it when contrasted with existing protocols for VANET [13].

Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks (VADD) proposes a thought of convey and forward, as the vehicular systems are exceptionally versatile furthermore separates all the more every now and again. By using this system a moving vehicle conveys a packet until another vehicle lands into its neighborhood and afterward advances that packet to the new vehicle. Unsurprising vehicle versatility is restricted to format of the street and example of the traffic [8]. In existing traffic design the vehicle can find the following street and forward the packet so that the deferral can be diminished. This approach utilizes a few vehicle-helped information conveyance (VADD) conventions to determine the best street that has the most minimal information conveyance delay [14].

In simple geographical protocols the dynamic change in the nature of the vehicular network that includes the obstacles present between the nodes, frequently changing topology and the density of vehicles could create network partition that ultimately result in poor network communication. To address this issue GeoSVR protocol is proposed. GeoSVR is a geographic stateless routing protocol that also has the information of node location and the digital map of the network. GeoSVR works better than its predecessor protocols and it provides higher packet delivery in unreliable and frequently changing network conditions [15].

GeoSpray protocol is based on vehicular delay-tolerant networks. Geospray makes the decision of routing by taking into account the graphical location data and after that it combines a hybrid approach between the multiple and single copy schemes. It initiates with the multiple copy scheme first and transmits limited number of packets in order to discover alternative paths, it than switches itself to the forwarding scheme that makes use the additional contact opportunities. It also clears the packets delivered across the nodes of the network to improve the resource utilization [16].

Road-Based using Vehicular Traffic information routing (RBVT) protocol controls the real time information of vehicular traffic, it than uses this information to create a road based path that consists of the succession of intersections of road with high probability and network connectivity. It uses the geographical forwarding technique to send and receive the packets between the intersections which reduces the dependence on individual node movement. In case of dense networks the optimization of the forwarding is done by making use of a distributed receiver based choice of next hops in the network that is based on multiple factors [17].

A delay sensitive vehicular routing protocol, which utilizes the intersections as stays to make superlative delay routing ways containing a rundown of intersections. One of the primary normal for this protocol is the occasional estimation delay in street fragment that is communicated as the blend of delay difference and normal delay utilizing multi-hop vehicle handing-off. ACO (Ant colony optimization) hypothesis is utilized to discover end-to-end best delay ways from the source to the objective intersection that is closest to the goal. The

procedure of course setup is proficient by receptive forward ants and in reverse ants, which are really responsible for the system investigation and the separately dissemination of pheromone. At every intersection, routing determination is executed to pick the best next intersection artfully in light of the table of pheromone routing. Source starts a proactive course support to grow, overhaul and enhance the data of routing amid the time of information transmission utilizing the occasional proactive ants examining. Basic convey or potentially greedy forwarding method is likewise used to transfer the bundles between the connecting intersections. The outcomes from the recreation demonstrates that this protocol indicates enhanced correspondence execution as contrasted and the min-delay routing protocol (CAR) and basic geographical routing protocol (GPSR), in regards to the normal end-to-end delay, overhead and conveyance proportion [18].

The principle challenge confronted by the Delay-Tolerant Network (DTN) routing protocol is the impediment of the transmission in the network while additionally accomplishing high network scope [19]. A great part of the work is done on the probabilistic sending by utilizing gossip-based approach keeping in mind the end goal to decrease the transmissions of network in MANETs. Gossip-based approach is utilized as a part of DTNs to demonstrate that it exhibits a property of stage move for the conveyance proportion: for a portion of the estimations of gossip probabilities and the lifetimes of the packet conveyance proportion is low and just a couple of hubs scarcely get it and the rest of the gossip probabilities and the lifetimes of the packets the conveyance proportion is at its pinnacle and expansive rate of hubs get the packet. Stage move limits coordinate up to the base transmissions in the network despite the fact that giving the most astounding conceivable proportion of conveyance. Disturbed Adaptive Routing (DAR) is introduced which is a gossip-based DTN routing protocol and it abuses the property of the stage move and assembles a versatile calculation to compute the gossip probabilities based on the stage move limits in arbitrary networks. Notwithstanding this DAR is expanded with a procedure that exchanges off a little packet of metadata containing the outline vector trade of epidemic protocol, in this manner it additionally diminishes the network transmissions. Test comes about demonstrates that the DAR protocol is better from the customary epidemic routing protocol by 76\% as far as the networks transmissions furthermore gives 27\% more conveyance proportion and brings down the normal packet delay by 18% [20].

In realistic cases due to the presence of three-dimensional (3-D) scenarios the vehicle distribution is nonplanar. The existing routing protocol takes the ideal situations and doesn't consider the nonplanar scenarios. The research is based on the issues that are faced in 3D scenarios and through analysis, it is demonstrated that there are severe problems in plane-based routing protocols. Three-dimensional scenario oriented Routing (TDR) protocol is proposed to resolve these issues. It makes use of the three dimensional information and establishes a hop by hop route to transmit packets as far as it can through the optimal direct neighbor node that is present of the same plane as the node which is currently forwarding [21].

In 3G-assisted data delivery (3GDD) a utility function to explore the trade-off between the delay of delivery and the ration of delivery is constructed that provides a integrated framework which reflects the two factors. 3G-assisted data delivery is formulated which avoids the complexities of this optimization problem and further the problem of original optimization problem is taken as integer linear programming. By solving the ILP problem we can derive the allocation of 3G in different stages of time. Taking in account of the 3G budget at each stage of time the packets are unlikely to deliver through VANET are delivered through 3G [22].

WLAN-WiMAX Double-Technology Routing (WWDTR) makes use of the position based routing technique on those parts of the route in which the packets are sent using WLAN radios, so that frequent changes of the topology can be handled efficiently in shorter transmission ranges of the WLAN vehicles. Furthermore, different parts of the route are employed with the topology based routing in which the packets are being sent through WiMAX radios. WiMAX enabled vehicles have more stable routes and thus it becomes a hybrid routing scheme. The logic of route selection takes into account both subscriber's and operator's preferences that may include QoS and the utilization of network. A network architecture is also proposed to help forwarding the packets to the given operator's access network through the routes that partially makes use of the other operators links [23].

## III. Types Routing in Wireless Sensor Networks

Routing in the wireless sensor network differs from the conventional routing of fixed networks. It is because of the reason that the nodes are in constant motion in WSN's and WSN network is not infrastructure based, whereas fixed networks is infrastructure based network. As the nodes are mobile therefore there are different limitations on these nodes such as limited energy, wireless links are unreliable and there is also a chance of node failure due to many different reasons [24].

Unicast routing protocols uses different kinds of routing techniques and to perform these techniques they use different types of information. We can divide them into following categories:

A. Position Based
B. Map Based
C. Path Based

D. Topology Based

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### *A. Position Based*

Position based routing algorithms uses the geographic positioning information to select the next hop. Packet is forwarded to the node that is closest to the destination without any map knowledge. Position based routing is effective since it does not have to save the information of the global route from source to destination node. This is beneficial in case of the wireless sensor nodes since no overhead information needs to be saved in the sensor node's memory and therefore it can work perfectly with the nodes having low resources [25].

### *B. Map Based*

Unlike the Position based routing protocols, Map based routing protocols do not work on the geographic information. In this type of routing, the information of the paths present in the network is stored and is used whenever there is need of communication between two nodes. This technique can be beneficial to keep the communication delay to minimum but on the other hand it also creates overhead on the nodes because they have to save the information in their memory. In case of Wireless sensor nodes where the nodes are moving too fast. The path information gets outdated very frequently so this type of routing is avoided in WSN having limited energy and memory sources. But on the other hand if the nodes have faster processing capabilities, energy backup and large memory than this technique might work better than position based routing.

### *C. Path Based*

In path based routing the source node chooses one of the path to the intended destination node that is already stored in the node's cache. The node will choose the path that has maximum number of nodes present in it. It then sends a query message along that path. Whenever a node receives this query message it first checks that if it has the path present in its local cache. If this intermediate node does have the path to the intended destination node than a route from the source to destination is obtained by combining the path through which the query message for path finding has traveled plus the path that is stored on the intermediate node.

### *D. Topology Based*

Topology based routing is the routing in which the routing the protocols can be reactive, proactive and hybrid. In case if the topology is reactive, the path will be discovered at the time when communication is needed between source and destination node. In proactive approach however the path is maintained all the time while hybrid is basically a mixture of proactive and reactive routing.

## IV. Communication Needs of Autonomous Vehicles

The automobile industry is progressing rapidly. In past, automobile companies main focus was on the vehicle's luxury, design and speed but now as the artificial intelligence became more efficient and reliable. The focus of the automobile industry has shifted on making these vehicles smart and environment aware. To achieve this goal they have installed several sensors on the vehicles and with the help of the artificial intelligence, these vehicles can make some decisions. However, some of the key players of automobile industry and taken this this one-step ahead and are working very hard on making these vehicles fully autonomous and driverless. Achievements have made in creating making autonomous vehicles [26].

Although much of the work is done in, making the artificial intelligence more efficient in these vehicles but very less work is done in proposing and selecting suitable wireless communication protocols. Communication needs of autonomous vehicles that works through the wireless communication has to be understood in autonomous vehicles so that they can map their surrounding environment and can make decisions by combining their own sensor's data plus the data they fetched from other vehicles sensors. The sensor data include the pedestrian's location, distance and time to intersection and also the distance to the leading vehicle [27].

## V. Characteristics of Autonomous Vehicles

1. Must know their surrounding environment by using their own sensors information
2. Must be able to communicate with other autonomous vehicles to fetch their sensors information
3. Build a traffic pattern with the help of obtained information
4. Adjust speed and lane based on traffic pattern
5. Must be able to fetch the data in real time from other autonomous vehicles
6. Communication is done with minimum possible delay

## VI. Comparative Analysis

Comparison is done between different Unicast Routing protocols in VANET's. Table I contains the important parameters on the basis of which the comparison is done.

First we have communication environment. There are two types of protocols. One of the type works only with less dense networks called rural communication protocols and its performance decreases if the network gets congested and the other type of protocols works with both less dense and congested networks and are called as urban communication protocols.

Delay tolerance is not acceptable in case of wireless communication in autonomous vehicles. Because it can have fatal consequences i.e accidents. Therefore there is

no room for delay in the protocols that have to be used in the autonomous vehicle's communication.

We do have different types of scenarios in case of autonomous vehicles. One scenario is that we use the same type of wireless sensor nodes in all the vehicles and make a Homogeneous network. Off-course by making the network homogeneous we can avoid complexities in the network. At the moment the concept of autonomous vehicles is still in its early stages so we can make the network homogeneous to make it more efficient but heterogeneous network is essential to be deployed in the near future because different types of vehicles can have different types of wireless sensor nodes.

The protocols that use greedy forwarding techniques are intelligent and every node decide smartly about how it will forward the data and by using what path. It does this with the help of information from its neighboring nodes. If there is a more efficient path to transfer the data than it sends the data through that path instead of following a predefined path. So greedy forwarding techniques improves the efficiency of routing in network

Routing information is very important in vehicular AdHoc network, as on the basis of this information the protocol choose the most efficient path. In case of autonomous vehicles position based routing is most preferable as the routing is performed on the basis of GPS positioning and through the position based routing the algorithm used in autonomous vehicles can decide the vehicle's preferable speed and can also predict other vehicle's route based on the data obtained from its GPS.

TABLE I: COMPARISON OF UNICAST ROUTING PROTOCOLS

| Routing Protocol | Communication Environment | Delay tolerant | Network Type | Greedy Forwarding | Type of Routing Protocol |
|---|---|---|---|---|---|
| IGRP | Urban | ✓ | Homogeneous | ✓ | Position based |
| IEGRP | Urban | ✓ | Homogeneous | ✓ | Position based |
| GeoSVR | Urban | ✓ | Homogeneous | ✓ | Map based |
| RBVT | Rural | ✓ | Homogeneous | ✓ | Map based |
| STAR | Rural | ✓ | Homogeneous | ✓ | Map based |
| VADD | Urban | ✓ | Homogeneous | ✓ | Path Based |
| GeoSpray | Urban | ✓ | Homogeneous | ✓ | Position Based |
| WWDTR | Urban | × | Heterogeneous | ✓ | Position/Topology Based |
| 3GDD | Urban | × | Heterogeneous | × | N/A |
| TDR | Urban | × | Homogeneous | ✓ | Position Based |
| DAR | Urban | ✓ | Homogeneous | × | N/A |
| Ant Colony Based | Urban | × | Homogeneous | ✓ | Map Based |

## VII. CONCLUSION

A comprehensive review of most recent and frequently used unicast routing algorithms in AdHoc networks is done. This review was based on some major characteristics.

Main focus of this paper is on the wireless routing protocols in autonomous vehicles. The characteristics of autonomous vehicles have been studied and based on these characteristics. The comparative analysis of different unicast routing protocols is done. From the comparison it is concluded that the best protocol that will have the most efficient performance in the wireless communication of autonomous vehicles is WLAN-WiMAX Double-Technology Routing (WWDTR) because it can make use of the location information and it is not a delay tolerant protocol. Also it supports heterogeneous network type that is a plus point and it can make use of both topology and position based information for finding a path to a node.

## VIII. FUTURE WORK

In this paper we have performed very brief comparison of the routing protocols and have reviewed some of the major properties of routing protocols and then selected the best routing protocol based on the characteristics that seems to be more suitable for wireless communication of autonomous vehicles. As the future work of this research the scope of this paper's comparison can be extended if we include some other variables such as; QOS (Quality of Service), Internet Connectivity, route repair capability, traffic data and predictability etc. They can be considered as secondary characteristics that will add to the weight of

current characteristics.

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