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ORIGINAL ARTICLE

QoS in Vehicular Ad Hoc Networks – A Survey

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ABSTRACT

Vehicular ad hoc networks (VANETs) are different from mobile ad hoc networks (MANETs) in terms of their requirements, characteristics, and limitations. Protocols have been categorized according to various approaches taken by authors to provide quality of service (QoS). The roadside unit approach offers more reliable guaranteed service; however, on the downside, it is more costly. Assigning a mobile agent status to one particular vehicle is another approach to provide software reusability and flexibility. However, due to its decentralized methodology, its implementation is non-existent. In an enhanced approach, MANET's reactive and proactive protocols have been modified and implemented in VANET domain to provide QoS. In another approach, innovative techniques combine with RSU approach to enable smooth multimedia streaming. However, this extended approach also requires huge capital. Providing guaranteed services such as reliability, maximum delay, and throughput in VANETS has always been a challenging task. Fast changing topologies and high speed mobility are real challenges to cope with. However, a few protocols have been proposed that provide guaranteed services in VANETS under highway and city environments. These protocols have been characterized and their advantages and disadvantages have been commented upon. The applicability of each protocol in different scenarios is given, and the usage of establishing both vehicle-to-vehicle and vehicle-to-infrastructure communication in the real world has been highlighted. Open research issues have also been presented.

Keywords: Vehicular Ad Hoc Networks, VANET, QoS, Inter-Vehicle Communication

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INTRODUCTION

MANETS are energy-sensitive and self-configuring networks with dynamically changing topology and limited memory nodes. VANETS, on the other hand, have rapidly changing topologies and nodes which move swiftly in comparison to normal MANETS. Among the many applications offered by VANETS are accident alerts, news dissemination, conferences, audio/video downloads, safety messages, and Internet-on-the-move etc. The importance of safety messages cannot be understated as they ensure a driver's safety, but the speedy deployment of VANETs in near future are going to be commercial applications. The central objective of this paper is to present an overview of the protocols proposed for VANETs that guarantee certain QoS parameters. Comparison between these protocols has been drawn and discussed.

Different applications have different requirements. For instance, time-sensitive data such as safety and emergency messages should have guaranteed minimum delay while bandwidth-hungry applications have throughput requirements. Furthermore, different protocols are appropriate for different environments which makes the choice of the right protocol along with the knowledge of its characteristics in the context of QoS, important. Real-time applications demand high throughput, whereas safety messages require high reliability. In VANETS, maintaining a certain threshold of QoS is easier said than done. For instance, connectivity QoS requirement is focused in [1], which is an important parameter in VANETs due to the frequent inherent disconnections between communication links of the vehicles. This happens due to highly dynamic topology and speed of the vehicles. The trade-off comes between coverage and interference. By increasing the coverage area (or vehicles using full available transmission power) increases the interference and vice versa. Thus, determining the minimum transmission range of vehicles is critical. Therefore, transmission range, number of neighbors required and clear channel assessment are used jointly to enhance QoS in VANET [2]. Vehicle communication takes place in the range of 5.9GHz. IEEE 802.11n offer a higher throughput when compared with IEEE 802.11p for multimedia applications including high-definition television, telemedicine, and remote surgery were simulated for the said standards [3]. Moreover, for extreme traffic load generating applications IEEE 802.11n outperforms IEEE 802.11p. Also, the bit error rate of 802.11n is better when compared with IEEE 802.11p. Delivering the required data to the nodes with high rates of mobility is considered a major challenge. The contention free access method defined in 802.11e is termed as hybrid coordinated function – controlled access channel (HCCA) [4]. The transmission opportunity (TXOP) duration [TD], the time-frame during which a node can transmit a burst of data, is the main feature of HCCA. QoS studies on VANETs [5] demonstrate that the mechanism for providing QoS in vehicular environments is the IEEE 802.11e enhanced distributed channel access mechanism (EDCA) which prioritizes traffic as per the intended application (real-time, video or background). Highly prioritized data with delay constraints selects a short contention window (CW) and vice versa. When a vehicle is unsuccessful in its transmission, it selects a back-off value from the CW. The vehicle will be changing its position and decrement its back-off counter value when the channel is free. Thus, a vehicle can have a multidimensional state of various parameters such as its current position, back-off counter value, number of remaining arbitrary frame spacing and queue length [6].

The remainder of the paper is organized as follows: Section 2 provides the categorization of different protocols in light of QoS. In Section 3 different services offered by different VANET protocols have been commented upon. Section 4 gives a comparison between the different protocols. Section 5 presents the open research issues and section 6 concludes the paper.

MAINTAINING QOS

Various approaches employed for QoS are discussed below. The protocol of choice by researchers for VANETs are geographic protocols because reactive and proactive protocols are not suitable. Although different services are offered by different routing protocols, a few approaches which consider the QoS requirements have been selected by researchers for certain VANET applications.

- **Roadside Unit (RSU) Approaches**

This is the most commonly adopted approach [7], [8], [9], [10], [11]. In this approach, the provision of the internet is made possible in addition to vehicle-to-vehicle communication. Moreover, the vehicle-to-infrastructure communication also takes place. Real-time applications such as streaming of audio and video demand infrastructure such as RSU that serves the vehicles as depicted in figure 1. The coverage area is divided into clusters or cells with a central unit. The main tasks of the RSU include allocating timeslots or channels, choosing the optimal path for the nodes, keeping the information about the nodes and keeping backup routes for the nodes. When multiple gateways offer services to connect with the internet it is common for the source to select the one with the shortest hop distance. However, the deployment of multiple RSUs for coverage is costly. Thus, in [12], a meta-heuristic method is proposed to find the minimum number of RSUs required for maximum coverage. Specifically, a minimum number of vehicles must be connected to the RSU for some minimum percentage of time of the trip. Individual scores are assigned for the RSU being connected to a particular vehicle. Thus, if an RSU is connected to the vehicle for its complete travel time, it will be assigned 1.0 value, corresponding to 100%. In this manner, each cell is rated that is covered by each RSU. The RSU have also been used for virtualized vehicular networks.

RSU cloud and its resource management

In [13], traditional RSUs are equipped with microdata centers and virtual machines using software defined centers. One of the objectives of the research is to provide QoS for various applications. In addition, the overhead and delay are minimized to maintain the QoS requirements. The non-safety commercial application's appeal to the user will create a cloud-based subscription demand which offers QoS for different applications. The micro-datacenters provide services to users. Sharing of resources by virtual machines is created by the low-level middleware called hypervisor. Service hosting and migration are enabled with the help of OpenFlow and cloud controller. Both the components are managed by the cloud resource manager (CRM). However, installing RSUs along long highways can be costly.

Machine-to-machine Communication and Hypervisor for Virtualization

In [14], the machine-type communication device (MTCD) is installed on every vehicle. The vehicles can access the eNodeB at their designated time slots. In return, the eNodeB offers resource blocks (RB). Thus RB can either be busy or idle represented by the set {0, 1} following a Poisson distribution. The transmission rate of MTCD is shown as a function of signal-to-interference ratio and bandwidth by Shannon's theorem. The hypervisor is set up for the virtualization of the network. It also enables the scheduling of the resources. The vehicles with similar functions are included in the virtual network. Vehicles cannot observe the state of the RBs directly. Thus to deal with this problem partially observable Markov Chain tool is observed. The MTCD can observe RB, take action or make a decision from the history of the observation system. For correct RB selection, the maximum transmission rate is offered by the RB as a reward. The proposed tool for solving the problem offers a higher transmission rate as compared to present schemes and random selection method.

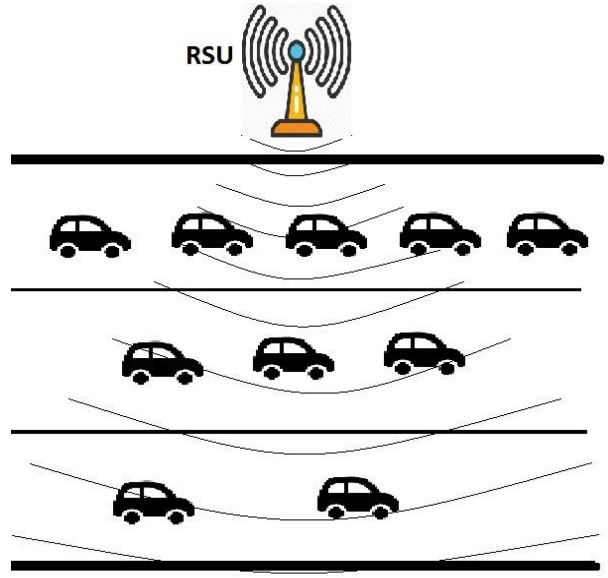

Figure 1. RSU providing coverage to the vehicles along the road

- **Mobile Agent Approaches**

By using controlling nodes and using resources efficiently, mobile agents (MA) ensure QoS [15], [16]. The inclusion of MAs for QoS is advantageous in form of software reusability (MA's software can be preserved for usage by multiple applications) and flexibility (the agent can predict connectivity and delay by learning the environment). MAs are capable of adapting to changes particularly in scenarios pertaining to highways.

- **Enhanced Approaches**

Some approaches combine certain unique characteristics and the RSU approaches to create innovative VANET protocols for providing QoS. In [17], out of QoS considerations, instead of the 802.11 DCF, 802.11p EDCA is used as it supports prioritizing the traffic. It also presents a prediction-based routing protocol using vehicles on highways whose behavior changes less drastically, and the soft handover concept is used by considering the lifetime of routes. Additionally, a proxy vehicle closer to the RSU is elected for the efficient provision of internet connectivity to distant nodes. In [18], wired connections are used for connecting RSUs to the internet. They are managed by an access router (AR) which dynamically hands over the vehicles to a new set of

RSUs while traveling. Preference is given to path with minimum distortion. In [19], the authors propose an allocation of variable intervals for safety and control channels for the provision of varying data rates to various applications. To achieve this, a Markov chain model is used to derive and adjust the minimum contention window. The coordination channels are synchronized using RSUs as per coordinated universal time (UTC).

- **Extended Approaches**

Some researchers have proposed using extensions of the reactive approaches traditionally used for MANETs. In [20] the analogy of bee colonies is given in order to describe the approach of establishing and maintaining VANETs. The conventional protocol (reactive), involving features like sequence number, route reply, and route request has been adopted in addition to time-to-live and timestamp features. [21] explains and discusses ad-hoc on-demand distance vector with multipath (AODVM). Its difference from AODV is the addition of a new field termed last hop identification (LHID). LHID helps in choosing the best route reply based on differentiating RREP coming from various neighbors and subsequently deleting other paths. In AODVM, by piggybacking a route request confirmation message (RRCM) in addition to the actual message, the response is confirmed by the source. The route is kept alive by sending special HELLO or TTL messages.

- **Various Unique Approaches**

Below are some unique approaches proposed by researchers who attempted to provide the QoS parameters in their suggested system models. We term them unique because they are entirely different from those discussed earlier.

GVGrid

In [22], the geographic area is divided into square cells termed as grids, each grid consists of a finite number of vehicles, thus, the protocol is termed as GVGrid. Based on its movement, geographic position and traffic pattern (traffic signals etc), the route with the longest lifetime is chosen. Route request (RREQ) is forwarded based on each node's selected minimum rectangular region. Preference is given to a node with a greater lifetime in an adjacent grid or the same grid as the forwarder node. Even while sending RREPs, nodes are recorded. Replacing a node in the same grid on behalf of a node that has left due to mobility helps to maintain grid sequence. Leaving nodes send LEAVE messages to their previously connected nodes which enables them to send the route send route repair (RRPR) messages to them. This RRPR enables the new node entering the network to find the previous links in the route for instantaneous connectivity. The simulation results show that GVGrid offers a substantial increase in link lifetime when compared with other benchmarks.

PBR

Internet connectivity is provided by mobile gateways in prediction based routing (PBR) [23]. The less erratic movement on highways forms the basis of PBR in order to predict the duration of a route. While trying to find a gateway the usual RREQ and RREP procedure is followed if the route to the mobile gateway is not present. The route with the maximum lifetime is selected in case many routes to the same gateway are available and the gateway, with the minimum number of hops is selected if more gateways are available. Cost of internet usage determines the willingness of a node to share its internet connection. PBR offers the least number of packets dropped when compared with reactive and proactive routing procedures in an event of link failure. PBR generates more total requests sent when compared with reactive and proactive routing procedures, while less when compared with proactive routing protocol.

DeReQ

Vehicle's velocity, traffic density, link duration, and traffic flow are integrated by delay and reliability constrained QoS (DeReQ) algorithm [24]. It selects the route with the desired maximum bound delay and maximum reliability. In terms of support for real-time data services, this algorithm is the preferred choice. Numerical analysis shows that the DeReQ algorithm has a lower delay and best link reliability when coupled with the AODV protocol. However, the performances of these parameters suffer when the mobility of the nodes increases. Still, the performance of the DeReQ algorithm is better when compared with benchmark protocols such as AODV.

Multi-source Video Streaming

Multiple sources are used in [25] for real-time data like video or voice data so that in case one source fails, other sources can be utilized. Another advantage of using multiple sources is that streams can be split up over the network. It is usual to use light-weighted codecs for VANETS. Delays due to packet losses are to some extent overcome by fragmentation. The research work also highlights the kind of channel, mobility, and the number of vehicles that best suits video streaming in a network. Intensive process is involved for error detection and correction, which may drain batteries of the nodes in MANETs, but have no effect on vehicular nodes, as they have no battery constraint.

Link Reliability approach

Different applications like emergency brakes, safety messages and onboard video conferencing require different levels of reliability [26]. The number of links of each node is summed up to calculate the number of nodes in each level of reliability. The longer the transmission range, the more the number of links of a node. Depending on their requirements, different levels are assigned to different applications. The greater the time duration of the link between the nodes, more reliable will be the link. Figure 2 below visually depicts this where the link between the two cars in the horizontal lane is more reliable than the link between those in the vertical lane because one of those cars is going to take a left turn and consequently the link between them will be severed.

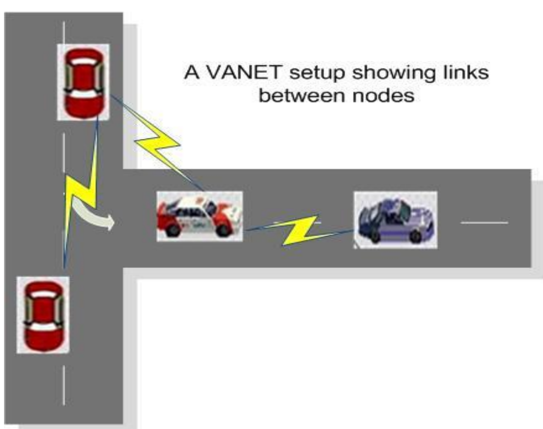

Figure 2. A scenario where the link between the identical red cars is for short amount of time

DeReHQ

All three constraints i.e. delay, reliability and hop counts (DeReHQ) are considered in [5]. The most reliable link with the least hop count and delay is chosen. Probability density function is used to calculate delay assuming that arrivals follow a Poisson distribution. The DeReHQ algorithm is combined with IEEE 802.11e protocol that allows different contention window for background, best-effort, voice, and video data types i.e., voice and video are given short contention window due to their time-sensitive nature and vice versa for background traffic. The simulation results show that as we increase the number of nodes, there is a less increase in end-to-end delay for audio and video when compared with background traffic. Also, when we vary the speed, there is very less delay for video traffic when compared with audio and background traffic-Enhancing VANET Performance by Joint Adaptation of Transmission Power and Contention Window Size

In [27] the transmission range, transmission power and size of the contention window are changed dynamically according to network density. More contention is caused in a denser network due to a higher transmission power. Additionally, the 802.11e EDCA mechanism is used in order to strike a balance which would preclude high priority data consuming all the resources or to wait for a long time. Other vehicle's messages are listened to in order to calculate network density. The dynamic changing topology is also considered to adjust the transmission power and contention window. The transmission power is mapped to transmission range. The proposed protocol offers superior throughput performance when compared with the default scheme. Also, the delay is much less when compared with the default scheme.

AQVA

Priority is given to safety messages and high throughput for non-safety messages by employing destination-initiated discovery in adaptive QoS for VANETs (AQVA) [28]. Delays caused by handoff are reduced by route reservation for which multicast route request and reply is utilized. The clustering-based approach is adopted by the authors where RSU is termed as a node; capable of providing QoS (capable node). Reactive routing protocol for route discovery is adopted in addition to clustering approach. A number of vehicles are varied and performance of the throughput parameter is numerically evaluated. It is found that AQVA performs better in comparison with contemporary approaches in terms of end-to-end delay and packet delivery ratio.

Guaranteed Services Offered by Different Routing Protocols for VANETs

Although some protocols are not particularly designed keeping in mind QoS considerations, they do provide enhanced performance in terms of reliability, high throughput, and reduced delay when compared to other protocols. Some of these protocols are briefly described here.

- **GPSR**

One such protocol is greedy perimeter stateless routing (GPSR), which operates in two modes; perimeter mode and greedy forwarding mode [29]. The node that is closest to the destination is chosen in greedy forwarding mode. When the greedy mode is not feasible, perimeter mode is used where the first node that comes in the counterclockwise direction of the forwarding node is chosen. Delays are kept at a minimum; subject to availability of sufficient nodes. The drawback of the GPSR is highlighted in [30] in terms of channel access through a practical scenario. The scenario explains that the shortest path towards the destination is not always the best and the vehicles involved in the shortest path might be having too many interferers. The link expiration time is evaluated using distance formula for the cases of vehicles going in the same and opposite directions. The next hop selection is based on the back-off time and link expiration time. The proposed protocol offers better delay and high reliability in terms of least broken links as compared to GPSR. Another improvement over GPSR is proposed in [31], where the position is estimated using the Kalman filter algorithm. The Kalman filter basically uses a set of equations to find the state of a linear system and minimize the error. As a result, the frequency of position updates is reduced and the accuracy of the position is increased.

- **CBRP**

Network partitioning and moving destination problems are addressed in contention based routing protocol (CBRP) [32]. These are solved considerably by managing data forwarding in junction and street mode, junction selection, and moving nodes. This way the CBRP ensures low packet loss ratio and high connectivity. The proposed protocol is compared with the position based routing (geographic position decides next hop) and GPSR using network simulator 2; simulation tool. A geographic street area of 2000 m x 2000 m is taken and vehicles are varied from 10 m/s to 20 m/s. As there will be more links in a highly dense network, simulation results show that CBRP can offer a packet delivery of around 100%, whereas PBRP and GPSR offer around 96% and 36% packet delivery ratio respectively for 360 nodes. The simulation results also depict that delay decreases with increasing number of vehicles. Moreover, CBPR offers the least delay when compared with the aforementioned protocols.

- **Density Aware Routing**

In sparse networks, it is possible that no node is available in the transmission range to which a packet can be forwarded (local maximum problem). This problem is resolved by maintaining two alternate routes towards the destination. The protocol has four important phases. First, road discovery is initiated using a road hierarchy (where the shortest distance is calculated using street roads or secondary roads). Second, the greedy forwarding approach is used to forward the packets. Third, a minimum number of links is required to maintain a route towards the destination. Thus, routing is based on the density of the link. In the last phase, periodic updates are generated to maintain the routes. Due to multiple routes, density-aware routing (DAR) for VANETS offers short delays and high connectivity [33].

- **MOPR**

Link states are evaluated periodically and refreshed in movement prediction based routing (MOPR) [34]. In this protocol position, velocity and direction are taken into account. It offers low delay and little overhead in comparison with GPSR and movement-based routing algorithm (where only geographic position and mobility is considered while selecting the next hop)

- **Cache Based Routing**

Hierarchical location service (HLS) [35] creates a lot of overhead in flooding and keeping track of vehicles. This burden is reduced significantly by caching. By adopting the latest cached route for routing overhead, cost is reduced. In case two or more vehicles receive the request of the route for the same destination, the vehicle with the latest route in its cache forwards the route information. Moreover, the unacceptable delay that occurs to discover the route will also be avoided. The simulation results depict that cache based routing offers less query cost when compared with HLS and flooding.

- **DTN Routing**

The store and forward approach for transmitting packets are adopted in a local maximum situation [36]. Specific streets are selected and delay is avoided by selecting streets in which traffic is going towards the destination. This is made possible with the combination of the global positioning system GPS navigation system installed on each vehicle and geographical database. As streets and streets-crossings have different IDs, a combination of street IDs, the source node and destination nodes IDs is employed for routing. Although delay tolerant network (DTN) routing ensures minimal delay, it is only appropriate for sparse vehicular networks. The proposed protocol is numerically analyzed with the aforementioned GVGrid protocol. It is found that DTN routing outperforms GVGrid when it comes to reachability and transmission delay.

- **PBRP**

Multiple channels and random back-offs are availed in position based routing protocol (PBRP) to combat the occurrence of collisions [37]. Although nodes that adopt greedy forwarding most of the time drop packets, the packet delivery ratio is still remarkable. In order to combat packet loss, packets are forwarded to multiple nodes in case of a greedy node scenario, so that if one is a greedy node, the other receiving node can forward the packet. The proposed protocol gives less delay and packet dropping probability when compared with other benchmarks.

- **EBGR**

Neighbors are first determined through the exchange of beacons in the edge node based greedy routing (EBGR), [38]. Scores are given for the value of speed towards a node, which are based on a larger cosine value between the position vector of the node to the destination and the velocity vector of the node. A higher value of cosine is interpreted as the node moving in the direction of the destination and resultantly the node which is closest to it is chosen. Nodes on the edges are responsible for saving and sending packets whenever new neighbors are accessible. A node with shorter hop and the node having the highest score is considered in shorter range if a node is not available at a longer hop. For the unlikely case that no node is available in the shortest hop, the carry and forward approach are utilized. The numerical analysis shows that EBGR offers delay of around 0.2 s to 0.4 s, whereas the GPSR suffers incremental delay (up to 2.2 s) when the number of nodes is increased.

- **MADCCA**

Vehicles have been grouped into clusters to stabilize the rapid changing topology in the mobility adaptive density connected clustering approach (MADCCA) [39]. Two hop connections are considered for creating clusters. This also reduces overhead for route maintenance due to frequent disconnections and high mobility. The cluster head (CH) is chosen on the basis of the standard deviation of the mean relative velocity and neighborhood density matrix. The CHs are chosen in such a way that adjacent CHs is out of transmission range of each other. The position and direction of the vehicles are also taken into consideration. The proposed protocol offers stable CHs duration and reduced overhead when compared with the benchmarks.

- **Overhead-Controlled Contention-based Routing**

The contention-based routing protocols are made scalable by lowering the overhead [40]. Each neighboring node that is moving in the direction of the destination sets a timer to receive back the message that he forwarded. The hop count is also set to 1. The node continues to forward the message until it receives the message back. Transmission of acknowledgment (ACK) and no acknowledgment (NACK) controls further forwarding that causes overhead. This approach prevents the duplicate forwarding phenomenon that occurs commonly in the wireless vehicular network. By doing so the efficiency of the network also increases. The proposed technique offers lower overhead while keeping the delay and packet delivery ratio to acceptable levels.

QoS offered by various Protocols, Targeted Networks, Applications and Pros & Cons of various Approaches:

In Table 1 the QoS parameters and the application scenarios for the protocols discussed thus far have been summarized.

Table 1. Proposed Protocols Offering various QoS for the target Network/ Environment

Proposed protocol	Offered QoS	Target network	Suitable application
EBGR	Minimum latency	Urban network	Voice and video streaming, instant messaging, safety and critical messages
GPSR	Minimum latency	Medium traffic network	
DTN Routing	Minimum latency	Low traffic network	
MOPR	Minimum latency and minimum beacons	Low traffic network	
Density Aware Routing	Minimum latency and Ubiquitous connection	Low traffic network	
CBRP	Ubiquitous connection	Low traffic network	Online transactions
Cache Based Routing	Minimum cost	Urban network	Background traffic
PBRP	Minimum packet drops	Urban network	Safety and critical messages
MADCCA	Reduced overhead and stable CH duration	Highway network	Best-effort traffic
Overhead-controlled contention-based routing	Reduced overhead	Urban network	

The table 1, show that each protocol is designed to provide a specific guaranteed service. Some protocols are suited to offer minimum latency [29], [33], [36], [38]. Thus, they can be used for applications such as live video and audio streaming and instant messaging. While some protocols offer lower overhead. Thus, if efficiency is the requirement, then such protocols can be implemented over the network. Other protocols such as PBRP [23] offers minimum packet drops, thus, if reliability is a critical issue then this protocol is better-suited for implementation. Moreover, the protocol performs optimally in a specified environment and terrain. The network density effect the performance and certain protocols might not be scalable.

Table 2 presents the different approaches proposed by various authors for bringing QoS in the VANETS realm together with their corresponding advantages and disadvantages.

Table 2. Pros and Cons of various approaches in VANETs

Approach	Pros	Cons
RSU	Best suited for internet connectivity and online vehicle tracking. Subsequently, this approach offers swift and precise route information. This, in turn, causes less delay and less packet loss	Huge capital needed for the deployment of the RSUs along the roads.
Assigning mobile agents	No online communication needed and mobile can remove the alternate routes easily.	Real world implementation missing as it is a decentralized approach.
Extended Approach	Multipath routes to the destination offer minimum latency and number of successfully transmitted packets is also high.	There is a pre-transmission latency due to route setup and the hybrid approach implementation needs to be tested in the real world
Enhanced Approach	Offers smooth multimedia streaming, thanks to the robust access mechanism and prediction techniques.	Due to the involvement of the RSU, this method demands incurs a high cost.

OPEN RESEARCH ISSUE

In the context of VANETS, it should be clear that a one-size-fits-all protocol is not possible. Below we point out and discuss the open issues which still need addressing by future researchers.

- **Application-Specific Handling of Data**

The IEEE 802.11e standard has come a long way in providing the prioritization of video, background and best-effort data, however, a routing protocol for VANETs that fully exploits its potential is still far from reality.

- **Coinciding Scenarios Problem**

The design of protocols mostly focuses on addressing one particular scenario. Designing a flexible protocol that works in both dense urban environments as well as sparse (highway) environments with an acceptable level of QoS presents a huge challenge. The lack of a QoS supporting protocols for such scenarios makes the challenge even harder.

- **Practical Implementation**

The actual performance of protocols designed for VANETs may vary as most of these protocols are tested in a simulated environment and are not implanted commercially. The cost-factor of deploying RSUs on highways is a major impediment in implementing vehicle-to-infrastructure communication in conjunction with vehicle-to-vehicle communication.

- **Localization in VANETs**

The GPS faces problems such as unavailability in urban environment and tunnels and inaccuracy [41]. Thus various alternatives can provide ubiquitous connection and minimum delay. These alternatives include differential GPS, map matching and dead reckoning. In differential GPS, GPS receivers moving in the same directions can correlate the errors. In map matching, the local position is aligned with the digital map to remove the error. In dead reckoning, the vehicle's next position is estimated using its velocity, direction, and last known position.

- **Game theory in VANETs**

Vehicles are always contending with each other to access the channel and resources. Thus some of the vehicles may behave selfishly to access the resources and thus, their objectives are in conflict [42]. Thus, the repeated game theory can be used to tackle such situations. This will ensure an acceptable level of a number of successful transmissions and packet delivery ratio.

- **Road and Driver Safety**

Minimum deployment cost can be ensured by optimizing the location of the RSUs. This will also ensure minimum delay to the delay-bound data such as safety messages [43]. Timely action by the vehicles by foreseeing the accident can lead to saving many lives. Thus heuristic algorithms can be adapted to solve these non-deterministic polynomial-time problems [44].

- **Artificial Neural Networks in VANETs**

Artificial neural networks can be used to detect the drowsiness of the person driving the vehicle, this approach can decrease the accidents substantially [45]. Neural networks can also be used to predict the movement of the vehicle to be used as an alternative to GPS [46].

- **Machine learning in VANETs**

Unsupervised algorithms can be used for uncategorized data that do not require any training. This technique can be used for clustering the data at an intersection in an urban environment by an RSU, where data from various vehicles is expected to cause congestion [47]. For large data, this technique is highly efficient in terms of fast processing of the data. Thus these various machine learning techniques can provide bounded delays and packet drops.

CONCLUSION

We presented the importance of QoS in VANETs for different applications and scenarios. We discussed the various approaches adopted by different authors to ensure guaranteed services in VANETs. We also discussed present VANET protocols in the light of QoS and defined their applications. The paper also reviews the different approaches and protocols. The open research issues that need to be addressed for improving the performance of routing protocols for VANETs are discussed. At present, a routing protocol that services and handles error sensitive and delay sensitive data according to their specific QoS parameters needs to be developed and existing protocols need to be made more flexible and adaptive to differentiate between requests based on their application related requirement constraints.

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