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Performance Challenges and Solutions for Vehicular Ad Hoc Networks: Survey

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ABSTRACT
Intelligent Transportation Systems (ITS) support vehicle to vehicle communication using transport based infrastructure which can be referred as Vehicular Ad Hoc Networks which are self-organized, self-healing networks that provide wireless communication among vehicles and roadside equipment. VANET is formed between vehicles on an as-needed basis. To form a VANET, wireless transceivers and computerized control modules are attached with vehicles that allow them to act as network nodes. Each vehicle's wireless network range may be limited to a few hundred meters, so providing end-to-end communication across a larger distance requires messages to hop through several nodes. VANET based network faces various challenges related to performance, quality of services, security, limited ranges of wireless links, velocity, different mobility patterns, environment conditions etc. In this paper, we will explore the issues and their solutions offered by the different authors to enhance the performance of VANET.
Keywords: VANET, wireless, Qos, Security, Mobility, ITS, MAC

I. INTRODUCTION

VANET support various applications related to consumers, businesses, governments, law enforcement agencies and emergency services. These applications focus on the idea of improving the safety of motor vehicles. Accident avoidance warnings could quickly notify drivers of numerous conditions that could cause a collision. When vehicles ahead brake quickly, an audio warning could alert the driver or an onboard computer might automatically apply the brakes. If vehicles on the road ahead swerve to avoid a road obstruction, the driver may be advised to change lanes. In a scenario in which a driver fails to observe a traffic signal, putting it on a collision course with a cross street vehicle, both drivers may be alerted or corrective action may be taken by the vehicles' onboard computers. In case of any accident, trajectory and velocity information exchanged between vehicles prior to collision may allow the accident to be reconstructed more easily. Rescue vehicles could instantly receive exact coordinates of the location of an accident, which can help them to reach the scene of the emergency faster[38].

VANET Architectures and Characteristics

VANET are based on the concept of mobile ad hoc networks and can communicate using pure cellular/WLANpure, ad hoc/hybrid networks. Figure: 1.1 below shows the architecture of VANET.

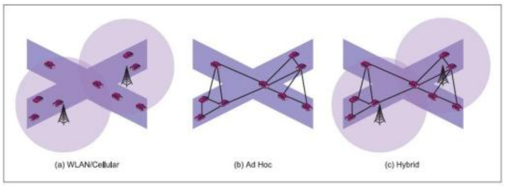

Figure: 1.1 VANET Architectures and Characteristics

a. VANET based on cellular gateways and WLAN use access points at traffic intersections to connect to the Internet and collect traffic information for routing purposes. The network architecture under this scenario is a pure cellular or WLAN structure [39].

b. Stationary or fixed gateways around the sides of roads could provide connectivity to vehicles but are eventually unfeasible considering the infrastructure costs involved. In such a scenario, all vehicles and roadside wireless devices can form a mobile ad hoc network to enable vehicle-to-vehicle communications [39].

c. A hybrid architecture can be formed by combining the cellular, WLAN and ad hoc networks together for VANET. Hybrid architecture which uses some vehicles with both WLAN and cellular capabilities as the gateways and mobile network routers so that vehicles with only WLAN capability can communicate through multi-hop links [39].

Issues related to VANET

To design VANET, there are various factors need to be considered such as communication support between vehicle-to-vehicle and vehicle communication with roadside units or gateways. Following are the major issues related to the communication over VANET [38]:

- Dynamic Topology and Mobility
- Routing Protocols and MAC protocols
- Location & object tracking
- IP Address Auto-Configuration
- Resource Management
- Flow and Congestion Control in VANET
- Cross-Layer Communication
- Location Identification and Vehicle Tracking
- Secure & Reliable Communication
- Quality of Services

Dynamic Topology and Mobility

In V2V communication environments, vehicles use wireless links for communication. Because of the characteristics, V2V is affected by dynamic network topology and density of neighbor vehicles. It is important to analyze the vehicle mobility pattern for efficient V2V routing protocols[1,2].

Secure Communication

Security provisioning is a challenging issue in VANET because vehicles can join and leave the network dynamically and there is need to define a proper security architecture that will protect them from different types of security attacks. There is need to explore the different security aspects of vehicular networks such as Threat model, Authentication and secure positioning etc[11,12].

Routing Protocols and MAC protocols

In case of VANET, vehicles can join and leave the network any time, so there is need to rebuild the routing information in routing tables. So it is very difficult to design a robust protocol for VANET. Vehicles can move to any remote location so it is also necessary to maintain the routing information on the basis of geographical data[33,34].

When vehicles join the network, they can start the data transmission simultaneously which can cause the collision at MAC layer. Data transmission at large scale can also cause the congestion at network. SO there is need to design a routing protocol which can deal with the local and global geographical information and it should be able to manage the MAC layer protocols simultaneously [22,23].

Quality of Services

VANET supports various applications which require communication with minimum delay. Provision of Quality-of-Service focuses on the different parameters such as Faded Signal-to-Noise Ratio, Residual Channel Capacity, Connection Life Time, handover delays, End-to-End delays, Jitter, packet loss ratios, Packet Delivery Ratio etc. But it is difficult to manage Qos due to dynamic topology and unique characteristics of VANET [35,36].

II. LITERATURE REVIEW

Now we will discuss the various methods those have been developed by different researchers to resolve the performance issues related to VANET.

Mobility Constrain and solutions

Si-Ho Cha et al. [1] implemented the vehicle mobility model to invent optimal routing protocols for V2V. They also discussed routing protocol considerations for V2V communication through the analysis of vehicle mobility pattern using VanetMobiSim.

An architecture for intra- and inter-system management for virtual environments is proposed by Rodolfo I. Meneguette[2] in vehicular networks, supporting user-driven applications. More specifically, they considered applications that depend on virtual environments which must be constantly updated, such as online gaming. To efficiently support these applications, the proposed architecture includes an extension of the 802.21 protocol to cope with the virtual environment updates. NS3 simulations were performed to evaluate the proposal over the proxy MIPv6 considering VANET and LTE networks as base stations. They observed that the proposed mechanism that extends the 802.21 protocol had a shorter handover time and lower packet loss when acting with the presented architecture.

Gongjun Yan et al. [3] presented an overview of popular simulators used in vehicular networking research along with an experimental comparison of two popular vehicular mobility simulators. They showed that the mobility model and topology used can greatly affect the network performance.

In another scenario, a mobility handover scheme MHVA proposed by Xiaonan Wang [4] for IPv6-based vehicular ad hoc networks. In MHVA, a vehicle is uniquely identified by its home IPv6 address, and it can keep the communication with other nodes without a care-of address during the mobility process. In addition, MHVA adopts an advanced mobility handover mechanism where the mobility handover operation in the network layer is completed before the one in the link layer is performed. As a result, during the advanced mobility handover process, a vehicle can keep the connection with its current associated AP in the link layer, so it can receive the data forwarded by the AP. Therefore, the packet loss rate is reduced, the mobility handover cost is decreased, and the mobility handover delay is shortened. From both the theoretical perspective and simulative perspective, the performance parameters of MHVA are evaluated, and the data results show that the mobility handover cost of MHVA is lower and the mobility handover delay is shorter.

An analytical model to characterize information flow in VANET incorporating macroscopic traffic characteristics, such as traffic density, relative speed between adjacent lanes, and driver composition was presented by LiliDu[5]. The information flow in VANET is characterized using an information flow network (IFN). The analytical expressions for the expected degree of the individual nodes as well as the reachability of an IFN are provided. Moreover, a state of the art simulation model is developed to validate the analytical results. The proposed analytical results not only provide us significant insights to evaluate the performance of information propagation in VANET, but also provide theoretical basis for the design of algorithms for the efficient routing of information based on average end-to-end performance.

SuparnaDasGupta et al. [6] proposed a new routing protocol, a Speedy Routing Protocol for Vehicular Ad hoc Network. In this routing protocol they tried to reduce overhead of maintaining routing data and traverse preferred distance through shortest path. They explored Vehicular Ad hoc network which is a special case of Mobile Ad hoc networks, with high nodes mobility specification and a large energy resource which could extend coverage and system lifetime.

Sanaa Taha et al. [7] proposed a extension of MIPv6, NEMO protocol that works appropriately for a scenario where a Wi-Fi hotspot is deployed in public transportation (such as buses, trains, shuttles) and called a NEMO-based VANET [1–4]. In such networks, the OBU inside a vehicle also works as a Mobile Router (MR) to support a group of Mobile Network Nodes (MNNs), such as cell phones and PDAs, located inside the vehicle with required communications.

D. S. Gaikwad et al. [8] did a survey of VANET Routing Protocols and Mobility Models. They explored Routing protocols which are need to design, addressed the challenges of VANET such as, high mobility of nodes, random topology, and heterogeneous networks. They reviewed the Mobility models which reflect the movement pattern of nodes on the road.

A novel approach based proposed by G. Xue [9] on the observation that in high-speed VANET environment, the target objects are strictly constrained by the road network. Their mobilities are well patterned and many patterns can clearly be identified. These patterns can smartly be leveraged so that a large amount of control overhead can be saved. Towards this end, in this article we adopt Variable-order Markov model to abstract Vehicular Mobility Pattern (VMP) from the real trace data in Shanghai. They leverage VMP for predicting the possible trajectories of moving vehicles which help to keep the timely effectiveness of the evolutional location information. To reveal the benefits of VMP, we propose a Prediction-based Soft Routing Protocol (PSR), taking VMP as an advantage. The experimental results show that PSR significantly outperforms existing solutions in terms of control packet overhead, packet delivery ratio, packet delivery delay. In certain scenarios, the control packet overhead can be saved by up to 90% compared with DSR, and 75% compared with WSR.

R. S. Shukla et al. [10] presented a simulation study of Realistic Vehicular Mobility Model on the performance study of VANET that uses Ad-hoc On-Demand Distance Vector (AODV), Dynamic MANET On demand (DYMO) and Optimized Link State Routing (OLSR). It gives an overview of the developments of the mobility model and routing protocols for VANET.

Security issues and solutions

A system architecture that contains multiple base stations in the coverage area of a certifying authority was proposed by A. Mondal [11]. The base station verifies the identification of the vehicle and the certifying authority verifies the authentication of the vehicle using its vehicle identification number. The certifying authority also generates a digital signature for each authentic vehicle and assigns it to the corresponding vehicle through base station. The base station allocates a channel to each authentic vehicle. The channel remains busy as long as the vehicle is within the coverage area of this base station. So the base station is able to track an authentic vehicle by sensing the allocated channel within its coverage area.

D. Chuan [12] proposed a security mechanism called TGPSR to provide a holistic protection for geographic information routing protocol (GPSR) which has great applied potential in VANET. TGPSR is expected to effectively prevent malicious behaviors especially for tampering with routing protocol or neighbor location table (NLT). Extensive simulations confirm that TGPSR is superior to GPSR in defending against malicious behaviors and without compromising performance through comparing many metrics such as throughput, packet loss rate, packet delivery rate, jitter, average delay, routing efficiency, and simulation time.

In another scenario, C. S. Voruguntiet al. [13] proposed a protocol based on hierarchical model for node authentication in group communication in VANET and claimed that their protocol is robust against conventional security attacks. They presented a improved scheme and showed that a previous scheme could not withstand to various conventional security attacks and fails to provide authentication.

Tian Fuet al. [14] presented a certificate less authentication VANET protocol based on non-bilinear pairings. The author analyzes the protocol plan and its security and function, which show that the protocol not only effectively protects the vehicle unit identification information and location privacy but also obtains high operation efficiency.

To provide safety message authentication in VANET S. Biswas [15] introduced a new scheme for safety. For a practical implementation of VANET, we anticipate that road side units (RSUs) are not physically protected and are prone to several different attacks including node compromise attacks. Thus, an RSU should not be automatically trusted by on road vehicles. In our proposed scheme, a road side controller (RSC) is responsible for controlling all the RSUs, and delivering messages through RSUs to vehicles in a given area, where each RSU uses a proxy signature mechanism based on Elliptic Curve Cryptography (ECC), which is a variation of known ECDS-based proxy signature schemes and modified according to the VANET's criteria and security requirements. The underlying network constraints and properties from VANET standards have been taken into consideration along with the security, reliability and other related issues. They also discuss the potential forgery and attack scenarios on our proposed scheme. The security analysis and simulation results prove the strength and adaptability of their proposed scheme in future VANET.

Proposed an, An ECPP named as efficient conditional privacy preservation was protocol proposed by C. D. Jung[16], based on group signature scheme for secure vehicular communications. However, ECPP does not provide unlink ability and traceability when multiple RSUs are compromised. They made up for the limitations and propose a robust conditional privacy-preserving authentication protocol without loss of efficiency as compared with ECPP. Furthermore, in our protocol, RSUs can issue multiple anonymous certificates to an OBU to alleviate system overheads for validity check of RSUs. In order to achieve these goals, they considered a universal re-encryption scheme as our building block.

J. Grover [17] described various trust establishment approaches for VANET. If all the nodes establish trust with other nodes in VANET, probability of occurrence of attacks can be drastically reduced. They explained that establishment of trust is amongst the most critical aspects of any system's security. For any network, trust refers to a set of relationships amongst the entities participating in the network operations. Trust establishment plays a key role in prevention of attacks in VANET. The nodes involved in defense of the network against such attacks must establish mutual trust for the network to operate smoothly.

In another work, to ensure that messages will not be revealed or stolen, Chin-Ling [18] proposed a secure ambulance communication protocol for VANET. The proposed scheme combines symmetric encryption, message authentication codes and digital signature mechanisms, and thereby achieves non-repudiation, availability, integrity, confidentiality, mutual authentication, session key security, known-key security and the ability to prevent known attacks. Finally, with NS2 simulation results that are based on realistic vehicle density statistics and the Taipei city road map, we argue that our secure ambulance communication protocol is effective in real VANET scenarios.

A. Ali et al. [19] proposed a security framework for efficient periodic and event-driven messages. Proposed framework uses TPM hardware to reduce processing time for secure messaging. Framework is based upon two major components i.e. smart utilization of symmetric and asymmetric security methods and a trusted grouping scheme. Furthermore, simulations were carried out to highlight the potential bottlenecks created by processing delays while using trial security standard for VANET.

An algorithm based on private key encryption is used to make secure communication using QualNet simulator was developed by M. Kaur [20]. They also did the performance analysis on the basis of confidentiality, integrity, availability and authenticity to improve road safety and optimize road traffic.

Bo Qin et al. [21] proposed a identity-based group signatures (IBGS) to divide a large-scale VANET into easy-to-manage groups and establish liability in vehicular communications while preserving privacy. Each party's human-recognizable identity is used as its public key and no additional certificate is required. This efficiently avoids the complicated certificate management of existing protocols. They further investigated selfish verification approach to accelerate message processing in VANET. With this approach, a vehicle selects only the messages affecting its driving decisions and validates the selected messages as if they were a single one.

Shared Channel utilization and performance issues

In another work,J. Luo et al. [22] proposed a Hybrid Mac protocol(H-MAC) that combines reservation and competition mechanisms to solve the sudden burst data flow at link layer of the VANET(Vehicle Ad hoc Network). Based on the entire network time synchronization, H-MAC protocol divides a frame cycle into two parts. The first part is reservation period in which each node has its own slot. Node could send stable data flow such as beacon packets in the slot. The second part is competition period in which burst data could be sent. Therefore, beacon frames and burst data are divided. H-MAC improves the utilization of channels and reduces delays that caused by collision of the burst data. Simulation results show that the proposed H-MAC protocol provides high reliability of broadcast data at MAC layer.

A novel MAC protocol where nodes dynamically organize themselves into clusters was proposed by K. Abdel[23]. Cluster heads are elected based on their stability on the road with minimal overhead since all clustering information is embedded in control channel's safety messages. The proposed MAC protocol is adaptable to drivers' behavior on the road and has learning mechanism for predicting the future speed and position of all cluster members using the fuzzy logic inference system. By using OFDMA, each cluster will use a set of subcarriers that are different from the neighboring clusters to eliminate the hidden terminal problem. Increasing the system reliability, reducing the time delay for vehicular safety applications and efficiently clustering vehicles in highly dynamic and dense networks in a distributed manner are the main contributions of our proposed MAC protocol.

J. Liuet al. [24]proposed Adaptive-ADHOC (A-ADHOC) MAC protocol, which implements a robust mechanism supporting the adaptive frame length. Evaluation result shows that A-ADHOC can maintain a high contending success probability and obtain about 50% reduction of response time over original ADHOC protocol, while providing important enhancement on network scalability and robustness.

The latest standards and protocols which can allow the use of already available WLAN infrastructure in the vehicular context was discussed by S. Faraz [25] . The use of roadside WLAN APs would provide the same services as those envisaged by the intelligent transportation systems using the dedicated roadside base stations. Authors presented an overview of the recent developments, limitations, standards and protocols that can facilitate 802.11-based R2V communication.

Wei-Yen et al. [26] investigated the performance difference between 802.11a and 802.11p for Vehicle-to-Infrastructure communication through real-world experiments. They measured contact duration and losses of 802.11p and 802.11a in both LOS and NLOS environments. In addition, they investigated their throughput with different modulations over various distances between OBU and RSU to evaluate the feasibility of using rate adaptation for non-safety V-to-I applications.

The unfairness problem that exists among vehicles of different velocities in V2I networks was addressed by Harigovindan[27]. Analytical expressions are derived for optimal minimum CW (CW_{min}) required to ensure fairness, in the sense of equal chance of communicating with RSU, among competing vehicles of different mean velocities in the network. Analytical results are validated using extensive simulations.

D. J. Deng et al. [28] proposed a simple, but yet well performing collision alleviation scheme to alleviate intensive collisions between highest priority access categories which usually used to schedule emergency message since safety is the most critical and promising issue in VANET. In addition to theoretical analysis, simulations are conducted to evaluate its performance. The simulation results show that the proposed scheme can not only increase the achievable channel throughput of the legacy protocol at most 15%, but also reduce the average packet access delay of the legacy protocol at least 5% and the packet collision probability at most 60% in congested VANET environments.

In continuation to this ,D. N. M. Dang et al. [29] proposed an analytical model to evaluate the performance of the IEEE 802.11p based MAC for VANET under non-saturation condition through the packet delivery ratio, the average delay of emergency message and the throughput of service message. The 2-D Markov model is used to model two access categories in the IEEE 802.11p. The analytical model is validated by the extensive simulation, and it shows the impact of different parameters on the performance of network.

A new contention window control scheme, called DBM-ACW, was proposed by A. Balador[30] for VANET environments. Analysis and simulation results using OMNeT++ in urban scenarios show that DBM-ACW provides better overall performance compared with previous proposals, even with high network densities.

KhanhQuanget al. [31] proposed a dynamic Sub-channel Assignment Algorithm (DSA) based on orthogonal frequency division multiple access (OFDMA) technology operating in the time division duplexing (TDD). The proposed of dynamic Sub-channel Assignment Algorithm solves several drawbacks of existing radio resource allocation techniques in OFDM system used in ad-hoc and multi-hop networks, such as the hidden and exposed node problem, mobility, co-channels interference in frequency (CCI). An interference avoidance mechanism allows the system to reduce CCI and to operate with full frequency re-use. The proposed routing protocol is jointed with the MAC protocol based the algorithm to ensure the mobility and multi-hop, thus the quality of service in ad-hoc and multi-hop networks is significantly improved.

A simple theoretical model to compute the maximum spatial reuse feasible in a VANET was proposed by Anh Tuan et al. **[**32**]**. They focused on the ad hoc mode of the IEEE 802.11p standard. This model offers simple and closed formulae on the maximum number of simultaneous transmitters, and on the distribution of the distance between them. It leads to an accurate upper bound on the maximum capacity. In order to validate approach, results from the analytical models are compared to simulations performed with the network simulator NS-3. They considered different traffic distributions (traffic of vehicles) and we study the impact of this traffic on capacity.

III. PROBLEM FORMULATION

Vehicle network is a special type of wireless network in which data is transferred between high speed cars. Each car is treated as node and each node can move anywhere in the network and this type of network has dynamic topology affected by mobility pattern. There are different issues related to these networks and researches are trying to solve all these issues such as dynamic topology, behavior of network according to mobility/traffic pattern, stability of wireless links, reliable data transfer between high speed vehicles, design a robust protocol to control the behavior of vehicle network, object tracking & location awareness etc. We can have unicast and multicast communication over vehicle networks but this is again a challenge to develop such kind of protocols.

In case of vehicle networks, any node can leave or join the network at any time and it is affected by the mobility and traffic in urban areas. So VANET should allow only the authentic vehicles to participate in the network for efficient resources utilization. It is also open to the several security threats such as Sybil attack, malicious vehicular nodes, spoofing, misbehavior of nodes etc. So there is need to resolve all these issues.

Collision-free transmission is essential for reliable and real time communication over VANET. It is a major issue that how we can provide the Collision free transmission using Collision aware MAC protocol.

VANET operate in a distributed environment so it is essential to support some services over VANET such as service discovery, application discovery, location aware service etc. This is another issue that how we can ensure the efficiency of all these services over VANET.

In case of hybrid VANET, we can also use the real time applications such as audio/video streaming, Google Maps etc. So these types of applications require transmission with minimum delay but in VANET, we have high speed mobile nodes. So it is very difficult to satisfy the Quality of service constraint in VANET.

Our future research work will focus on the effect of mobility, security and collision awareness in MAC protocol in VANETs based Intelligent Transport System. According to discussion mentioned above, the research work will try to achieve following objectives:-

1. To provide a performance analysis of VANET in highly mobile environment.
2. To develop/enhance a mobility aware algorithm/ model/ system/framework/protocol for VANET to enhance the network performance in highly mobile environment.
3. To develop an algorithm/ model/ system/ framework/protocol for secure communication over VANET.
4. To enhance the existing MAC protocol to provide the collision aware and reliable communication over VANET.

IV. CONCLUSION

In this article, we explored the various issues related to mobile environment, shared channel utilization and collision free communication, security etc. Now we will summarize the efforts done by the researchers. In [1] author implemented a vehicle mobility model to invent optimal routing protocols for V2V based communication. In [2] author proposed an architecture that includes an extension of the 802.21 protocol to resolve the virtual environment updates and it has shorter handover time and lower packet loss when acting with the presented architecture. In [4] author offered a scheme called MHVA adopts an advanced mobility handover mechanism having shorter mobility handover delay. In [5] author studied the various traffic characteristics, such as traffic density, relative speed between adjacent lanes, and driver composition and proposed analytical results related to information propagation in VANET. In [6-10] authors offered solutions which can adopt the highly mobile environment and can adopt the different mobility patterns and models and ensures the network performance.

In [11-21] authors offered various solution related to the security threats i.e. security framework, road side units based on Elliptic Curve Cryptography, digital signature for vehicle authentication, identity-based group signatures, selfish verification approach etc. Simulation results show the effectiveness of the proposed methods.

In [22-32] authors studied the shared channel utilization methods and offered various solutions i.e. Hybrid Mac protocol(H-MAC), MAC protocol which can observe and adaptable drivers' behavior on road side, Adaptive-ADHOC (A-ADHOC) MAC protocol which offers network scalability and robustness, 802.11a and 802.11p and 802.11-based R2V communication, collision alleviation scheme to alleviate intensive collisions between highest priority access categories, dynamic Sub-channel Assignment Algorithm (DSA) based on orthogonal frequency division multiple access (OFDMA) technology operating in the time division duplexing (TDD) etc. Simulation results show the effectiveness on the channel utilization and performance enhancement with collision free communication.

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