Novel Routing Framework for VANET Considering Challenges for Safety Application in City Logistics

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Abstract The Intelligent Transportation System (ITS) addresses issues regarding traffic management and road safety in the domain of Vehicular Ad hoc Networks (VANETs). With the evaluation of new applications, new goals regarding efficiency and security are added for logistics and general user application, which demand time bounded and reliable services. In this paper, we discuss VANET with regards to its suitability in logistics scenarios, challenges to cope with high mobile vehicles and their short contact duration to meet the goal of efficiency. Although VANET helps to provide efficient solutions for logistics and transportation, there are still number of issues to be solved to obtain an appropriate solution. In the context of increasing number of vehicles, high bandwidth requirements for applications, and highly dynamic topology, route optimization and efficient security mechanisms requires special attention. To this regards, a number of routing protocols have been proposed, yet each routing protocol focuses on traditional topological based routing protocols. The selection of the routing methods depends upon the nature of the networks. Number of researchers argued that the most of the routing protocols focus on the particular scenario and consider particular factors for evaluation such as type of network, mobility pattern, and Quality of Service (QoS) requirements for applications. Thus, the performance of the routing protocols depends upon the particular scenario. In this paper, we focus on designing a routing protocol framework, which can provide a reliable and efficient solution for the path selection by considering different factors from application scenarios like logistics and transportation using varying parameters such as speed, number of wireless nodes, traffic loads and bit error rate. Furthermore,

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we consider channel parameters for the routing protocols to render the communication to be reliable. For proof of concept, we provide and discuss basic simulation results of our proposed framework.

Keywords Routing · IEEE 802.11p · VANET · Safety application · ITS

1 Introduction

Vehicular Adhoc Networks (VANETs) [23] is the type of adhoc network, where vehicles act as a wireless nodes and have the ability to communicate with other vehicles and with the Road Side Units (RSU) wirelessly while in motion. In VANET, wireless nodes can communicate using three modes: Vehicle to vehicle (V2V), Vehicle to Infrastructure (V2I) and Infrastructure to Infrastructure (I2I). Here, infrastructure refers to road side units (RSUs), and higher order backends. It is a key technology in Intelligent Transport Systems (ITS) for achieving new goals such as road safety and efficiency [45]. It can be considered as spin-off of Mobile Ad hoc Networks (MANETs), but it differs in terms of path predictability and speed of nodes.

VANET mainly deals with driver safety applications, traffic management and non-safety applications such as commercial and infotainment applications. Safety messages are usually small in size. While developed for the latter, the next generation ITS adds the use of bandwidth hungry applications, which require less delay and high bandwidth [3]. Considering higher rate of road accidents and traffic congestion due to mismanagement of traffic, the safety applications requirement are of highest priority for many transportation companies and specially for logistics. City logistics efficiency and safety requirements are at high priority due to high demand of products and home delivery services with secure communication [41]. The requirement of these services are depicted in Fig. 1, where on time flow of goods is the key for efficiency [27]. Furthermore, requiring highly optimized routes, infotainment and lookup services are at user's top list.

Adhoc network are not only attractive because of ease, low cost and fast deployment but also because of their design. The concept of noncentralized design make it robust, self control and self organized. Though forming of network "on the fly" is attractive, the challenges to design, optimize and analyze are formidable. Moreover, with the deployment of infrastructure, mobility and flexibility, these networks have transformed into hybrid architectures, which require resource utilization and intelligence for efficiency. Never the less, the increased mobility in VANET, though it is in organized fashion, has posed challenges to the existing MAC and routing mechanisms. The involvement of highly mobile, static and mixed node deployment pattern and requirement of Quality of services (QoS) [37] have made it more complex. In addition to it, the emergence of a wide variety of new applications e.g. emergency handling services, car parking, infotainment, theft detection, safety on road, navigation, law enforcement, fleet management and health care assistance also requires efficiency and flexibility of the deployed network.

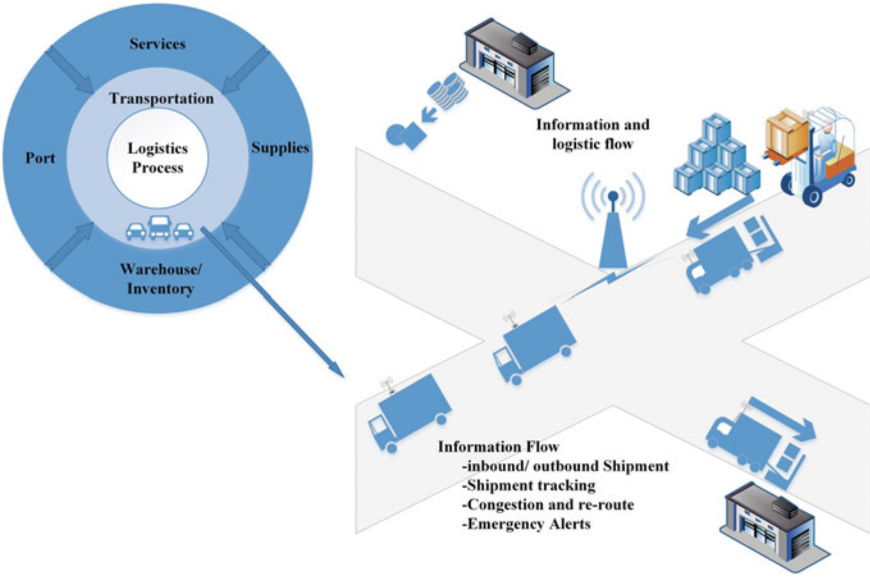

Fig. 1 Vehicular Adhoc Networks (VANET) in logistics scenario

To achieve the goal of an efficient, flexible and self organized network, the research community targets three kind of approaches. First, efficient MAC mechanisms ensure the maximal utilization of physical resources, and provide information to upper layers for QoS provisioning. Second, the efficient routing strategies find a best route between source and destination, and recover a route in case of link failure. Third, the design of efficient applications to achieve respective goals. Performance of the third depends upon the first two approaches. The MAC and routing mechanisms are not simple to define for all scenarios. In city, highway and rural area, adhoc networks face different types of challenges. In city environments, obstacles like buildings, trees, etc. and greater number of nodes cause communication loss and congestion issues. In highway scenarios, vehicles are moving with high speed, which cause link breakage and formation of new links due to change of neighboring nodes. Considering multiple scenarios reveals a broad variation in behavior of the wireless network. Therefore, routing strategies differ for respective scenarios and parameters from the physical layer can help for the best path selection. Hence, we consider properties of both layers to gather real time traffic information for path selection and optimization.

2 Literature Review

To expolite the features of MAC protocols and extract parameters for designing a new routing mechanism, the survey on MAC protocols is summarized in Table 1, which indicates the limitations of 802.11p MAC for some application scenarios, most specifically for delay sensitive and bandwidth hungry applications. The authors in

Table 1 IEEE 802.11p MAC protocols, addressed problems and limitations

Protocols	**Addressed problems**	**Limitations**
TDMA [10]	Channel access delays; Real time applications	No suitable for high mobility; Complex algorithm; Lacks a realistic mobility model; Limited throughput
W-HCF [5]	Guaranteed bandwidth and access delay for infotainment applications	Processing delays are involved for QoS management; Centralized approach; Not suitable for bandwidth hungry applications
ABS Scheme [40]	Chance of contention; Affecting throughput	Important CCH messages (emergency messages) can be missed; Not suitable for bandwidth hungry applications
Extended SCH intervals [42]	Improving channel utilization through SCH	Only suitable if vehicles avoid to listen CCH
CDS [43]	Backoff window size	Not realistic due to unknown number of high speed vehicles in a range
CBMAC [19]	Hidden node problem; High density of node	Lacks a realistic mobility model; Edge nodes of clusters cause confusions; Not suitable for bandwidth hungry applications
SDM [11]	TDMA based scheme for guaranteed channel access	Unused time slots issues
Distributed Scheme [46]	Distributed TDMA with two hop neighbors	Introduced latency when joining two groups
802.11p MAC [31]	High density scenarios for throughput degradation and increase delays	Ignored the speed of vehicles; Not suitable for bandwidth hungry applications

[25] evaluated Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) for real time applications through simulations. Their results show that under heavy traffic loads the performance deteriorates, both for individual nodes and for the whole network due to CSMA. To solve this issue, the authors proposed STDMA (Self-organizing Time Division Multiple Access) and evaluated it for VANET. The simulation showed that STDMA performs well in VANET for real time applications. Unfortunately, the authors did not discuss the causes of packet drop in CSMA/CA, which needs to be analyzed in detail. The designed algorithm is too complex and not suitable for highly mobile nodes.

In [5], the authors targeted Infotainment applications and showed through simulations that performance of bandwidth hungry applications suffers due contention based MAC scheme and delay generated due channel switching. To work on this issue, the proposed extension is called W-HCF (WAVE-based Hybrid Coordination Function) and it provides controlled channel access on top of the contention base channel access and achieved better results. The results did not mention the overheads involved in W-HCF. However, the proposed method in [5] is centralized, introduces processing delays for the handling of QoS managements and also it offers limited bandwidth only. The authors in [40] addressed the chance of contention to increase throughput, but the resulting bandwidth was not enough for multimedia applications. Due to channel switching and channel contention, the probability of loss of emergency messages is also greater. The authors in [42] focused on SCH to improve channel utilization, but scheme failed for the CCH messages. In [43], the authors focused on the evaluation of 802.11p for V2I communication and showed via simulations that backoff window sizes are not adaptive and cause throughput degradation, particularly in dense scenarios. They proposed two solutions i.e. centralized and distributed to render the back-off window sizes adaptive. Simulations showed that both approaches improve the throughput. To solve the hidden node problem, the authors in [19] proposed a mechanism but the evaluation lacks a realistic mobility model and is not suitable for interactive applications. To give opportunity of channel access for each node in VANET, TDMA based protocols SDM [11] and Distributed Scheme [46] were proposed. As there are limited time slots, these can accommodate limited number of nodes, in some cases channel is not fully utilized. IEEE proposed 802.11p MAC and the authors in [31] focused on the high density scenarios, but they ignored speed of vehicles.

In [2], the authors proposed an enhancement in 802.11p for multimedia and delay sensitive applications, which is called Vehicular MAC Protocol Data Unit (V-MPDU) to improve the channel access efficiency. In [4], the authors evaluate the Rician and Rayleigh fading for vehicular environment and proposed suitable parameters that can help to reduce fading effects. In [26], the authors discussed the evaluation of IEEE 802.11p with IEEE 802.11n and IEEE 802.11ac and concluded that 802.11n and 802.11ac perform comparatively well for delay sensitive and bandwidth hungry applications in urban environment with limited speed. However, latest standards include frame aggregation, reverse direction algorithm and MIMO techniques to improve throughput, but can only support limited mobility and transmission range.

The performance of the adhoc network mainly depends upon the successful packet transmission to the destine node through intermediate nodes using best available path. The research shows that VANET routing protocols focused on traditional topological based routing protocols and depends upon the nature of the networks. A number of factors affect on the routing strategies like type of networks, mobility patterns, QoS requirements for different applications. Thus, a single routing method is not sufficient to meet all the different types of required scenarios. Different adhoc routing protocols proposed for the different scenarios, and were analyzed to figure out which routing metrics are considered to provide *in time* and *scalable* routing. Most researchers focused on single environment of VANET, i.e., either on highway or a city, to evaluate the performance of different routing protocols. Due to aforementioned problems there is continuous need to study various adhoc routing methods in order to select appropriate method for different environments of VANET. Routing metrics are the basis of any routing protocol on which it selects a best path. Here, we summarize different metrics against different types, approach used for path selection, and route update mechanisms of routing protocol in Table 2.

Link life is one of the important routing metrics, as longer link life shows good link quality. Since link quality is measured on the demand of the path, this routing metrics is mostly used for reactive and flow-based scenarios [17, 30]. *Node hight* is another routing metrics, which is useful in scenarios with low mobility. Therefore, proactive protocols [33] and also flow-based protocols [17] use this metric in similar context, but with some limited benefits. Reactive protocols like Temporally-Ordered Routing Algorithm (TORA) [33] and Dynamic MANET On-demand (DYMO) [13] and proactive protocols including Dynamic Source Routing (DSR) [24], Better Approach to Mobile Ad hoc Networking (BATMAN) [1], Hierarchical State Routing (HSR) [35], Intrazone Routing Protocol (IARP) [20], Mobile Mesh Routing Protocol (MMRP) [18], Optimized Link State Routing (OLSR) [16], Optimized Link State Routing Version 2 (OLSRv2) [32], Topology Dissemination Based on Reverse-Path Forwarding (TBRPF) [8] and Link Quality Source Routing (LQSR) [12], both types of routing protocols use *Hop Count* for the path selection, and route update is only required when it is timed out. In some scenarios, the same metric is also used where these two type of protocols are used as hybrid form, e.g., Hazy Sighted Link State Routing (HSLS) [39]. However, with the involvement of high mobility using only this metric is not enough to find a good path and may also introduce delays for larger networks. To resolve this problem, some protocols are proposed which are cluster-based. Each cluster must have a cluster head and these *Cluster Heads* take part in routing. Then *Hop Count* routing metric is used on cluster heads for the route selection. These protocols [14, 29, 34] also apply for route update on time-out. *Expected Transmission count (Expected Tx Count*) is a routing metric which is used by proactive routing protocols [22] for route selection. This routing metric count is good only for specific applications.

Proactive routing protocols build an priory table for routing path. Therefore, *Link Cost* is also a routing metric, and protocols [6, 36] use this metric to calculate the total cost of the path. The minimum cost count use for the best path selection. However, with frequent link breakage, the calculation of link cost introduces delays. Some Hybrid protocols also use *Link Cost* and *Virtual Link Predecessor* for route calculation. Table 2 summarized this analysis with the additional information of each protocol and their corresponding approach used for metric calculation.

As VANET involves the wireless communication of vehicles in adhoc mode, it consists of multiple participants including roads, Road Side Units (RSU) and On-board Units (OBU), mobile nodes (Vehicles), and taffic signals. Networks constraints exist when dealing with safety applications. As safety applications require small but frequent data packets to circulate in the network, network constraints exist. Table 3 includes some of these constraints for safety applications in VANET.

Table 2 Routing protocols comparison on the basis of selected parameter

Metric	Type	Protocols	Approach	Route Update
Link life	Reactive	LBR [30]	Signal strength	Link break
	Flow	LMR [17]	Directed acyclic graph and link reversal	
Node height	Reactive	TORA [33, 44]	Directed acyclic graph	Link break
	Flow	GB [9]	Directed acyclic graph and link reversal	Automated flow and link break
Hop count	Reactive	AODV [38]	Distance vector (DV)	Timed
	Reactive	DYMO [13]	Distance vector	Timed
	Proactive	DSR [24]	Distance vector	Timed
	Proactive	BATMAN [1]	DV and collective intelligence	Timed
	Proactive	HSR [35]	Hierarchical routing & cluster-head	Timed
	Proactive	IARP [20]	Link state (LS) and zone radius	Timed
	Proactive	MMRP [18]	Link state and sequence number	Timed
	Proactive	OLSR [16]	LS and multi point relay	Timed
	Proactive	OLSRv2 [32]	LS and multi point relay	Timed
	Proactive	TBRPF [8]	Link state with differential data	Timed
	Proactive	LQSR [12]	Weighted cumulative expected Tx time	Timed
	Hybrid	HSLS [39]	Link state timed and link break	Timed
Cluster-head/ hop count	Proactive	Guesswork [34]	Distance vector and cluster head	Timed
		DFR [29]	GPS and cluster head	
		CGSR [14]	DV and cluster head	Timed
Expected Tx count	Proactive	AWDS [22]	Link state	Timed
		Babel [15]	Distance vector	

(continued)

Table 2 (continued)

Metric	Type	Protocols	Approach	Route Update
Link cost	Proactive	DBF [6]	Bellman ford	Timed
		DSDV [36]	Bellman ford and sequence number	Timed
		WRP	Bellman ford	
	Hybrid	OORP [21]	Hierarchical routing and cluster head	Timed and link break
Virtual link predecessor	Hybrid	SSR [28]	Source routing and virtual ring routing	Timed and link break
Not specified	Hybrid	ZRP [7]	Zoning	Timed and link break

Table 3 Network constraints for safety applications

Constraint Type	Constraints Value
Aggregation bandwidth	6 Mbps
Maximum received packets/sec	4000
Maximum allowable latency	100 ms
Maximum packet size	200 bytes
Transmission channel for safety	CCH
Maximum tolerated delay (between two packets)	300 ms
Minimum delay	50 ms
Channel switching time (between CCH and SCH)	50 ms

3 Proposed Framework

Considering the literature review and evaluation of VANET in different scenarios, we selected some parameter to be considered for the path selection. The proposed solution approach is discussed in Sect. 3.

In VANET, the channel condition information is varied in different scenarios and can be very helpful for decision making for routing. If we consider quality channel parameter as a routing metric, then the results will be very different than for traditional routing protocols. We analyzed MAC and routing protocols, and identified their suitable scenarios. From our literature review, we concluded that a number of routing protocols are proposed which consider one or more routing metrics. These protocols are proposed for specific scenarios and metrics were chosen with respect to the selected scenario. Some information about channel quality can be helpful for the path selection, e.g., channel fading or Signal to Noise Ratio (SNR). Therefore, merging this information can help to improve the route selection. As routing protocols are at the network layer and we have channel information at MAC layer, we also require a method for the flow of information from Physical Layer to Network Layer. As we can get most recent information at the MAC layer easily, and if we introduce routing mechanism at MAC layer, we can use the required information without any delay. Path selection at MAC layer can help to simplify and improve path selection on the basis of local available information. So there is need to make a link layer routing protocol for VANET. The performance of this method depends heavily on the value of the decision threshold. Yet, it is difficult to choose a value that results in good performance across all scenarios. Node density, spatial distribution pattern, and wireless channel quality all affect the optimal value. Broadcast protocols tailored to vehicular networking must be adaptive to variations in these factors. In this work, we address this design challenge by creating a decision threshold function that is adaptive regarding the number of neighbors and their speed. The proposed protocol is implemented on the Layer 2 (MAC Layer) considering SINR and rate of delivery. Based on our literature survey, we decided to consider channel quality parameters to get our initial result analysis.

We assume that the wireless channel and the medium access control protocol deliver messages between nodes located within transmission range of each other with perfect reliability. In practice, wireless signals in the system interfere with themselves and with each other in unpredictable ways, leading to apparently non-deterministic message reception. When two nodes transmit messages at the same time, the wireless signals may interfere and cause one or both of the messages to be lost at the destination node. *Fading*, the phenomenon where multiple parts of the same signal traveling along different paths interfere with each other, degrades communications even when only a single node is transmitting. Multihop wireless broadcast protocols must be abled to operate effectively even when communication reliability is poor. The *threshold function*is designed to decide about the good and bad path for routing on the basis of channel conditions. The paths with values lower than the threshold is discarded. Threshold function also included channel level metrics like SINR, packet retry rate, percentage availability of channel for measuring quality of channel Fig. 2.

The proposed framework includes four type of circulating massage format for path calculation i.e. path request (PREQ), path reply (PREP), Path Error (PERR) and path reply acknowledgement (PREP-ACK). The participating node may include three types of messages to take a decision. Figure 3 shows three decision points of the participating node. This routing protocol is working on the MAC layer, therefore, for the first proof of concept we consider MAC parameters for the path selection as discussed in the previous paragraph.

We divided protocol mechanism into two steps as it is shown in Fig. 2. In first step, we used two algorithms to compute *SINR* value and *delivery rate* (if previous link exists) of direct links and maintained table for each link. These values are computed periodically. In second step, routing algorithm identify best path on the basis of values available in the table. When a node initiates or receives a PREQ, it checks value in the tables and selects best one on the basis of available information. If node has no delivery history about a new link, it only considers SINR value to forward PREQ. If

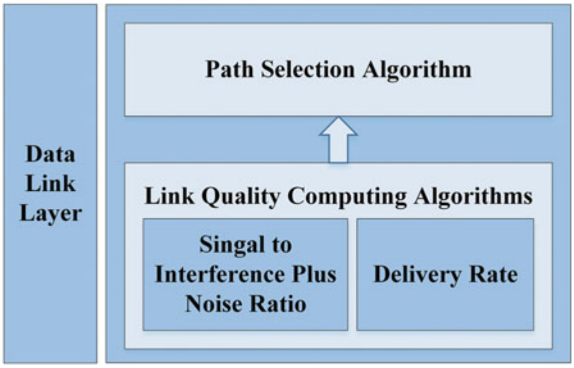

Fig. 2 Proposed routing framework

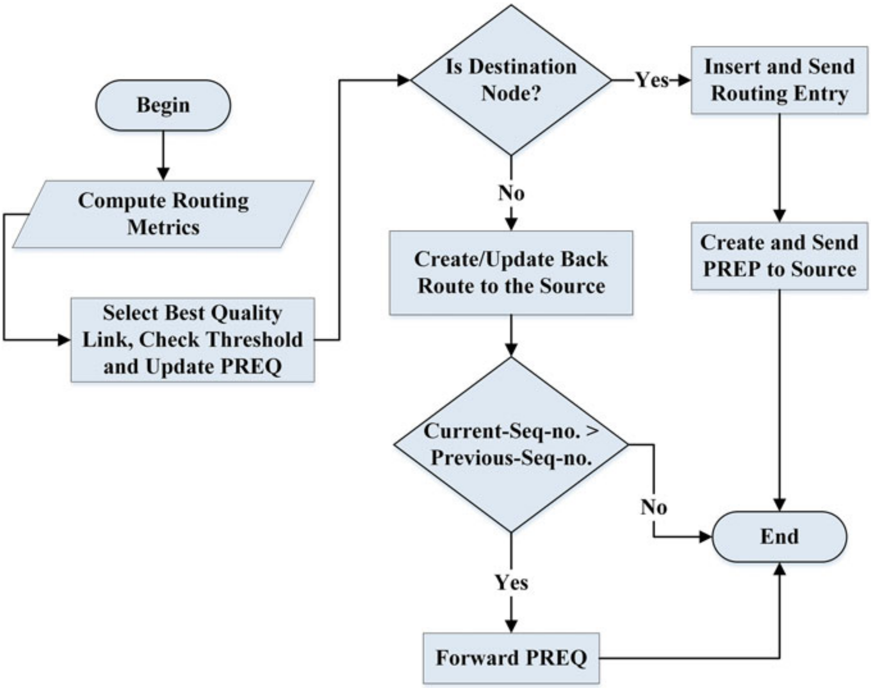

Fig. 3 Flow chart of proposed routing protocol

PREQ receiving node is a destination node, it inserts route and sends routing entry to source node using PREP. In case of intermediate node, it only creates and updates back route to the source and forwards PREQ, however, the latest copy is checked using usual procedure, i.e. sequence number. If flag is set for the reply to previous node, then PREP-ACK is used to send reply back. PERR is used to send path error to the source node.

4 Simulation Setup and Basic Results

To analyze our problem, we used simulation implemented in Omnet++. We used *Vehicles in Network Simulation (veins)* framework, which includes a number of simulation models for VANET and used SUMO for simulation mobility pattern. This framework is open source and allows to write and test our own model and provides rich support of VANET MAC layer options like IEEE 802.11p and it also supports various routing protocols for ad-hoc networks like proactive, reactive and geographical protocols. We implemented our proposed protocol and tested it for the basic results, i.e. goodput and delay.

The proposed framework is designed considering challenges for the city, highway and rural areas. However, this paper only includes scenario of city logistic to analyze initial results for goodput and delay. For city logistic scenarios, Table 4 includes the parameter setting. The considered parameters include the environment size, total number of nodes, type and speed, packet size and type and considered simulation time. In such a scenario, where vehicles may responsible for transporting material for production unit to prepare product or delivering products from production unit to the distributors, retailers and warehouse. Consider an application, which is responsible for managing safety guideline and information flow for this particular scenario. A vehicle is performing a specific task and on each movement information is sent back to control room. Here, we are dealing only in city scenario where we considered constraints of safety application listed in Table 3 and changed speed of vehicles while moving sparse to dense network. For the comparative analysis, we selected

Table 4 Parameter setting for city scenario

Parameter	**Setting**
Environmental size	2000 m
Total no. of nodes	60 (variation of 10, 20, 30, 40, 50, 60)
Node type	Mobile nodes (vehicles)
Node speed	Maximum 50 Kmph and minimum 30 Kmph
Packet size	200 bytes for safety applications
Packet type	UDP
Simulation time	600 s
Number of receiver	1
No. of lanes	3
RSU	10
Traffic signals	4 in each cross

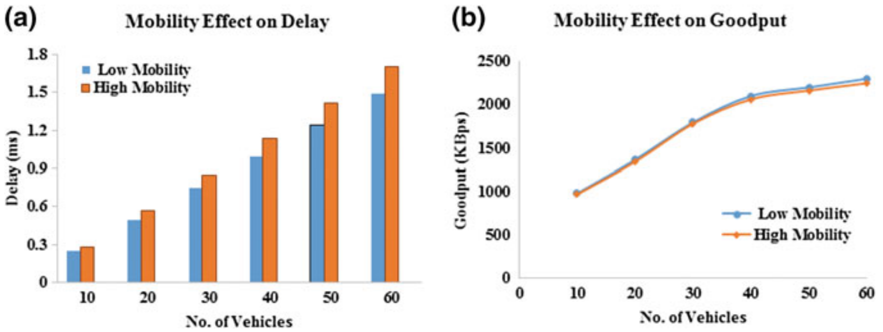

Fig. 4 **a** Effect of mobility on delay; **b** Effect of mobility on goodput

node density and speed of vehicle in urban areas and for the comparison we calculated goodput and packet delay.

For evaluation, we examined the effect on the goodput and delay at low and high mobility. Constant-bit Rate (CBR) traffic flows were used in the simulation with packet size of 200 KB, which was kept constant. We imposed two other CBR flows of 500 Kbps, which acted as background traffic. Total 60 nodes were used in the scenario, which were moving at 50 km/h maximum speed and 30 km/h minimum speed. Results are shown in Fig. 4a and b. We observe that the goodput increases with the increase in number of vehicles in the network. A constant goodput is observed for safety packets with increase in number of nodes, and when we increase the speed of vehicles, the goodput remains same as it was observed at low speed due to link quality consideration for path selection at run time. As we mentioned, we considered only safety applications and the packet size in safety applications are small. Therefore, the graph shows a constant line for small packets with increased number of vehicles. In case of delay, with increase in number of vehicles, the increase in delay is negligible.

5 Conclusion and Future Work

The Intelligent Transportation Systems (ITS) address issues regarding traffic management and road safety in Vehicular environment. VANET is the one of the enabling technology in ITS used for road safety, traffic management and logistics applications. It can also be deployed in the logistics and transportation to cope challenges of information flow with mobility of materials. With increase in number of vehicles, speed and the requirements of high bandwidth for new applications, VANET requires special attention for route optimization and security provisioning. In our work, we focused to improve routing mechanisms to tackle challenges in vehicular environment for reliable communication. Literature showed that VANET routing protocols focused on traditional topological based routing. The selection of these routing methods depends upon the nature of the networks and most focus on the particular scenario. Thus, a single routing method is not sufficient enough in meeting all the different types of required scenarios. In this work, we rapted on designing a routing protocol, which can provide a reliable and efficient solution for the path selection. In our work, we analyzed different adhoc routing protocols proposed for the different scenarios to figure out suitable routing metrics in each case. We also designed a basic framework to cope new application requirements. However, we only included basic results for city logistics scenario considering mobility. We are focusing on designing a routing protocol considering MAC and network layer parameters to cope with challenges in multiple scenarios. We will extend this model for other scenarios with particular parameters to make it adaptive in different scenarios.

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