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RESEARCH ARTICLE

MQBV: multicast quality of service swarm bee routing for vehicular ad hoc networks

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ABSTRACT

Vehicular ad hoc networks (VANETs) are witnessing in recent years a rapid development for road transmissions and are considered as one of the most important types of next generation networks, in which drivers can have access anywhere and anytime to information. However, vehicles have to deal with many challenges such as the links failures due to their frequent mobility as well as limited degrees of freedom in their mobility patterns. In this paper, we propose a new quality of service multicast and multipath routing protocol for VANETs, based on the paradigm of bee's communication, called multicast quality of service swarm bee routing for VANETs (MQBV). The MQBV finds and maintains robust routes between the source node and all multicast group members. Therefore, the average end-to-end delay and the normalized overhead load should be reduced, while at the same time increasing the average bandwidth and the packet delivery ratio. Extensive simulation results were obtained using ns-2 simulator in a realistic VANET settings and demonstrated the efficiency of the proposed protocol. Copyright © 2013 John Wiley & Sons, Ltd.

KEYWORDS

vehicular ad hoc network; routing; bee swarm; quality of service; road safety

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1. INTRODUCTION

The need for improvement of road safety and comfort for passengers by avoiding accidents and traffic congestion has given rise to intelligent transportation systems known as VANETs [1]. An interest in such networks has been growing in the last few years as they are capable of providing several services for drivers and authorities in both rural and urban areas. VANETs provide timely and accurate information to the vehicle drivers offered by the network members or by Internet access that correspond to their requirements such as traffic and collision avoidance, breakdown services, and fuel station locations.

Vehicular ad hoc network is a unique type of mobile ad hoc network and consists of a set of heterogeneous nodes, which could be divided into mobile nodes (vehicles) that move according to a realistic mobility model and fixed equipments described as road side units (RSUs). It is a distributed, adaptive and packet radio network, characterized by fast and frequent changes of network topology [2] caused by the very high speed variation of vehicles and a certain degrees of freedom in their mobility patterns due to many factors including road course, encompassing traffic and traffic regulations [1]. The main purpose in such networks is to provide communications among vehicles via inter-vehicle communication and between vehicles and road side units via roadside to vehicle communication such as the Internet access points placed along the road in order to improve the road safety [3]. It is worth noting that VANET entities can be deployed at critical locations such as slippery roads, service stations, accident warning, dangerous intersections, or places well-known for hazardous weather conditions [4]. In these situations, one of the most important requirements is the transmission of safety messages with a certain level of quality of service (QoS) from a source node to a set of endangered vehicles. This transmission mode is known as multicast mode. The endangered vehicles can perform an evasive maneuver before a certain critical time so as to avoid a road accident or collision. To deliver such QoS safety messages, it is essential to decrease the average end-to-end delay and increased bandwidth of the transmission. Furthermore, vehicle's transmissions should warrant a high packet delivery ratio (PDR) in a less congested network. In this context, the following problems will arise: when communication endpoints are not within their respective ratio of a transmission range, how is it possible to establish communications between vehicles or between vehicles and roadside units (RSUs) in a multicast mode while maintaining QoS conditions to ensure road safety?

To take up these challenges, we propose in this paper a QoS multicast routing protocol called multicast Qos swarm Bee routing for VANETs (MQBV). It is a bio-inspired protocol adapted from the bees' communication method for their food search. MQBV is considered as an on-demand and spatial routing protocol. It broadcasts its route request to a limited number of neighbors (spatial zone) to find the multicast group. This type of broadcasting is called stochastic broadcasting, in which the number of neighboring receivers is always below a threshold value [2]. Moreover, MQBV can detect and maintain multiple paths between the sender and the receiver. They can be used to send out packets in a parallel manner in order to optimize data transmissions. The effectiveness and performance of this proposal were evaluated by a set of simulations using a network simulator (ns-2) [5], carried out in a realistic mobility model dedicated to VANETs. The results were compared with RObust VEhicular Routing (ROVER), which is a well-known protocol [6] as multicast routing protocol conceived for VANETs. Our performance evaluations were based on the average end-to-end delay, average bandwidth, PDR, and normalized overhead load (NOL).

The rest of this paper is organized as follows. Section 2 reviews the spatial multicast routing and spatiotemporary multicast routing protocols as a state-of-the-art. In Section 3, we describe the MQBV protocol. Section 4 is devoted to the ns-2 simulations and experimental results. Finally, Section 5 concludes the paper and proposes some ideas for future work.

2. STATE-OF-THE-ART

In general, the routing process in VANETs is carried out through many intermediate nodes, in particular when the sender and destination nodes do not reside in the same transmission range. When the sender wishes to send data to some network nodes in multicast mode, it is called upon to find different paths toward all these nodes. Nevertheless, it is hard to use the found paths for a long time due to the VANETs' nature such as the mobility and high speed of vehicles, the velocity variation between each pair of vehicles, and the instability of the distance between consecutive vehicles. These features lead to an important problem for the multicast routing in VANETs known as the temporary network fragmentation [7]. This problem affects the efficiency of the multicast applications. Consequently, two major classes of multicast routing have been proposed to overcome the VANET limitation: spatial and spatiotemporary protocols.

The following subsections review these two kinds of multicast routing.

2.1. Spatial multicast routing protocols

Spatial multicast routing is based on the idea of starting to disseminate multicast packets from the source node to a set of nodes, which should be situated at a prescribed geography zone in order to prevent the temporary network fragmentation problem. In this category, the sender decides to transmit multicast packets to the adequate nodes without any time constraints.

Under this category, the distributed robust geocast multicast routing for inter-vehicle communication (DRGM) has been proposed [8]. Similar to other protocols of this class, DRGM delivers packets to vehicles belonging to a specific geographic area. A drawback of this protocol is that a multicast group receiver should accept a packet only if this receiver is located to this specific geographic region, otherwise, the received packet is dropped. The authors of DRGM called this region zone of relevance (ZOR). In addition to ZOR which is usually small, another zone is defined by DRGM and called zone Of forwarding (ZOF). It is used to forward packets by intermediate nodes, the objective is to enhance the reliability of receiving multicast packets against the frequently changeable topology. It is worth noting that ZOF usually surrounds ZOR due to the limited number of multicast receivers in the network. To cope with the network fragmentation, the authors proposed a periodic retransmission mechanism. Moreover, a distance-based backoff algorithm is suggested to reduce the redundant broadcasts and the number of hops traveled to reach the destinations. Despite the special properties of this protocol, it still has some drawbacks such as the assumption that the defined geographic regions are static. Furthermore, DRGM is applied only to the highway systems.

Overlay multicast in VANETs (OMV) is a spatial multicast routing algorithm proposed in [9]. Using a dynamic application layer overlay, this algorithm allows live multimedia streaming multicast to vehicles of the same group. OMV is more adaptive to urban VANETs with high mobility and full of obstacles. The algorithm starts with the idea of joining a multicast group by interested vehicles, which would establish an application layer overlay organized as a tree or mesh structure. This overlay constructs logical paths between group nodes. OMV appears to be more suitable for urban scenarios than the highways, the algorithm builds on an overlay network, it can suffer from latency, which is crucial and vital for vehicular networks.

As a spatial routing protocol for VANET, ROVER was proposed in [6]. It is a geographical multicast routing algorithm described for the end-to-end QoS requirements.

ROVER is very similar to ad hoc on-demand distance vector routing (AODV) [10] protocol, which flood only control packets in the network. ROVER transmits messages to all the VANET nodes located in a rectangle zone called ZOR specified by its corner coordinates. This approach is also similar to geographic protocols that uses a ZOF because the zone includes the ZOR and the source node. In order to discover destinations, a multicast tree from the source to all multicast group should be built. This route discovery process is initiated by a zone route request flooding to the nodes in the neighborhood, and it continues until a multicast tree is constructed. All exchanged data should be saved at the routing tables of the visited nodes. The obtained results showed a good PDR, but the network was very congested because of the flooding process used to build the multicast tree.

2.2. Spatiotemporary multicast routing protocols

Spatiotemporary multicast routing principle takes into account the spatial factor, in addition to the time factor. For this, the transmitter sends multicast packets to all nodes that are located in a prescribed region at a particular point in time.

One of the most important protocols in this category is the mobicast routing protocol [11]. It is characterized by forwarding multicast messages to vehicles, which are located in some geographic zone denoted as ZOR at time t. In other words, this protocol disseminates a multicast messages to all vehicles that will be present in the ZOR defined over some time interval $[t_{start}, t_{end}]$. When a vehicle moves at a high speed, a temporary network fragmentation problem can occur. To cope with this situation, ZOF was defined. This latter is a geographic zone that includes ZOR and helps to ensure the multicast messages being sent to vehicles, which move out of ZOR. The novelty of this proposal against the prior studies [8] is that mobicast routing can be applied to transmit real-time messages to a dynamically prescribed region, which is surrounded by a moving vehicle at time t. In this protocol, the transmitter vehicle estimates an elliptic zone ZOR_t relevant to time t. When the vehicle moves out of ZOR_t (in case of temporary network fragmentation problem), a growing phase is needed. Here, a new zone is presented and denoted as zone of approaching (ZOA_t). ZOA_t is an elliptic area considered as the extension of ZOR_t. Also, ZOA_t is used to forward messages more close to destined vehicle and it continues until it reaches the destinations. Note that ZOR_t and ZOA_t are defined using a formal model proposed in [11]. However, a study for the reduction of the routing overhead is suggested in order to limit the control packets when trying to construct routing zones. In addition, urban environment tests have to be performed to access the effectiveness.

Another state-of-the-art approach defined in this category [12] is the multicast routing scheme focused on the dissemination scheme for warning messages to improve road safety rather than fast packet delivery. The basic idea of the protocol is disseminating packets to all vehicles within the transmission range of the transmitter. After that, the receiver decides whether to rebroadcast the message to relevant vehicles or not. This transmission can be performed only if the delay does not exceed a specific time. To do so, authors reformulated this problem into a delay-constrained minimum Steiner tree (D-CMST) problem as D-CMST problem, bounded shortest multicast algorithm [13], has been proposed to offer a sufficiently low computation time to improve road safety. However, this heuristic is very limited to small networks due to its deterministic property and the computation time to give the optimal solution, especially if the network is dense.

Drawbacks of multicast routing approaches are summarized in Table I. To address such limitations, this paper proposes a new protocol called MQBV. It is a spatial type QoS multicast routing protocol and tends to avoid two major disadvantages of the spatiotemporary approaches: the routing overhead and dropped packets. MQBV is inspired by bees' communication principle and used two important ideas to avoid all prior drawbacks presented by the multicast protocols. The first idea is to discover multiple paths used to disseminate safety messages in order to decrease the average end-to-end delay while increasing the average bandwidth. The second idea is to search these multiple paths in a stochastic manner in order to increase PDR and to reduce routing overhead.

3. MQBV PROTOCOL

In this section, the proposed QoS multicast routing protocol (MQBV) is presented. First, a brief explanation of the bees' communication phenomenon is given. Then, a projection of this phenomenon on the QoS multicast routing for VANETs is described, and finally, the MQBV principle and a description of their different phases will follow.

3.1. Bees' communication principle

The bees' communication is because when a bee finds a food source, the bee will immediately inform his follow bees in the nest about the available food source. This is possible by means of a language composed of the bee's dance movement. At the beginning of this process, the area is explored by the workers in order to find the food. These workers are called scouts, and if the food is discovered, the scouts return to the beehive and perform one of the two types of dance to communicate the food information at the dance floor. A round dance movement indicates that the food is close, whereas a waggle dance expresses that the food location is beyond a 100-m radius.

After the dance communication, the discovery is exploited by a larger number of recruits. They are called foragers, and their number is proportional to the quantity of the food found. At the harvesting stage, the bees (foragers)

Table I. Main benefits and drawbacks of state of the art multicast routing protocols applied to VANETs.

Protocol category	Protocol	Environment	Reality of mobility model	Performance characteristics: Delay	Bandwidth	Packet delivery ratio	Normalized overhead load
Spatial	DRGM [8]	Highway	No	−	+	++	−−
	OMV [9]	Urban	No	−−	+	−	++
	ROVER [6]	Highway	No	+	+	++	−−
	MQBV (our proposal)	Urban/highway	Yes	++	++	++	++
Spatiotemporary	Mobicast [10]	Highway	No	+	+	−	−−
	BSMA [12]	Theoretical work	Theoretical work	+	+	−	−

DRGM, distributed robust geocast multicast; OMV, overlay multicast in VANET; ROVER, RObust VEhicular Routing; MQBV, multicast quality of service swarm bee routing for VANET; BSMA, bounded shortest multicast algorithm.

Notation: ++, more suitable; +, suitable; −, less suitable; −−, unsuitable.

collect the food and calculate its quantity to make a new decision for the next move. They would either continue collecting the food based on the memory of the best food location or leave the food source location and return to the beehive as simple bees [14].

3.2. Focus on the vehicular ad hoc network

In [2], we proposed a QoS bee swarm protocol successfully applied to the *unicast* routing for VANET. In this paper, we propose a *multicast* routing based on the same concept. The VANET is represented by the bee environment in which beehive is considered as the source node. The destination nodes are the multicast group members that correspond to the food sources with the same nature, that is, the same type of flowers. In other words, each multicast group gathers a set of nodes, which share a unique multicast address represented by the same nature of food (flowers). Intermediate nodes are seen as workers flying in the area and used to relay data between the source and the destination (Figure 1).

3.3. MQBV principle

In MQBV, each node in the network is defined by a unique node identifier. The multicast traffic starts with a unicast traffic from the source node to the destination node. The source node should recognize at least one of the list group members to transmit the appropriate packets. Note that the source node possesses a unicast routing table, which serves to direct packets to its destination via multiple paths as the same way as the unicast described in [2]. The destination is identified by the multicast destination address of the first recognized members.

The second step in the multicast traffic aims to disseminate the same packet from the first receiver member to the other members. This step is accomplished by a tree structure, which gathers all the multicast group nodes. These nodes can be divided into multicast group members and other nodes that are not multicast group members; to link distant member, their existence in this tree is mandatory. They do not have the multicast destination address unlike the multicast group members (we call them linkers). The tree root represents the head of the group and is the first node that joins the multicast group.

Each node in the multicast tree knows the next hop node toward the head of the group. It is used to transport packets from the first multicast member that receives the packets launched by the source node to the other members through the head of the group. This group head contains new routes table called multicast routes table in which each entry represents data of each route toward one member in the group. Packets, multicast routes table, and detailed steps of the MQBV are explained in the following paragraphs.

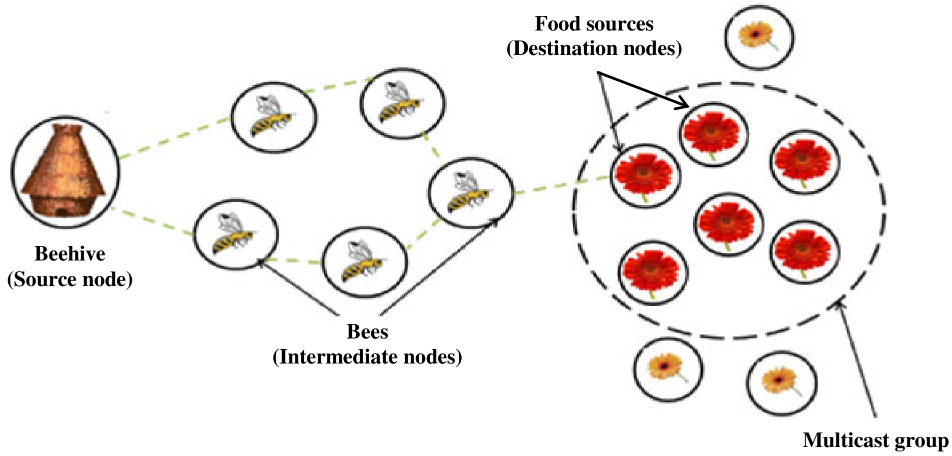

Figure 1. Projection of the MQBV components on bee area.

3.4. MQBV packet type

The first step in the multicast route discovery is the same forward and backward scout packets used in the MQBV [2]. Likewise, the same forager data packet [2] is also applied to transmit data packets. However, unlike [2], three specific multicast routing packets are employed in MQBV.

The first multicast routing packet is called a local scout and transmitted at the multicast tree nodes level by a new multicast member to join the group. Once a local scout reaches the head of the group, the newer packet is listed on the multicast routes table. This second packet is named distant scout. The latter is used to inform different nodes in the network on the existence of the multicast group represented by its head. It transports the group head identifier and the next hop node to this head. The last multicast routing packet is labeled multicast scout. The multicast scout is used to discover the route if the source node does not know the path to one of the multicast group members. There are two types of multicast scouts on this mission: the multicast forward scout (abbreviated as MF_Scout), which is launched to discover the route, and the multicast backward scout (abbreviated as MB_Scout), which transmits discovery information from the multicast member to the source.

3.5. Multicast routes table

Only the head of the multicast group establishes this table. It allows packet routing from the group head to all the multicast group members. It consists of a set of entries. Each entry corresponds to one member and serves as its node identifier (food identifier). If available, the last local scout identifier is recorded on the entry to indicate a new head selection of the multicast group. The complete path from the head to the member is recorded on the entry. The table contains also a multicast identifier that represents the joining sequence number of this member. Moreover, the entry memorizes a stamp field used to record the transmission time, which is employed to compute the available bandwidth and the measured delay and then to decide if this path satisfies the QoS requirements. The recorded path is evaluated using weighting factor calculated on the basis of the QoS data and the hop count as cost coefficient, and then the result is used to make a decision of whether keeping or changing this path.

3.6. MQBV description

3.6.1. Route discovery (from the source to the multicast group).

We will present here two cases for the source node. The first one is that the source node knows the head of the multicast group through the distant scout sent by the group head itself. In this scenario, the sender uses its unicast routes table to relay the data packets in a hop-by-hop manner until reaching the head of the group. The head disseminates the data packets to its members using the multicast routes table. In the second case, where the source node does not know the group head, the source node generates and clones a new MF_Scout in order to launch and broadcast them stochastically to its immediate neighbors. Each cloned MF_Scout has a scout identifier, source identifier, and a multicast address as the requested destination, which are all identical. This process is repeated until reaching a multicast group member or until encountering a node, which knows the route to one of these members. It is worth pointing that the route is considered found if MF_Scout encounters a member of the multicast group that can forward packets to its header, then to the other members using the multicast tree.

In future transmissions, all the packets will be guided by this link to reach the head of the group and then to access different multicast group members. Note that the QoS requirements are checked at each MF_Scout hop and should be satisfied. Otherwise, the MF_Scout is dropped.

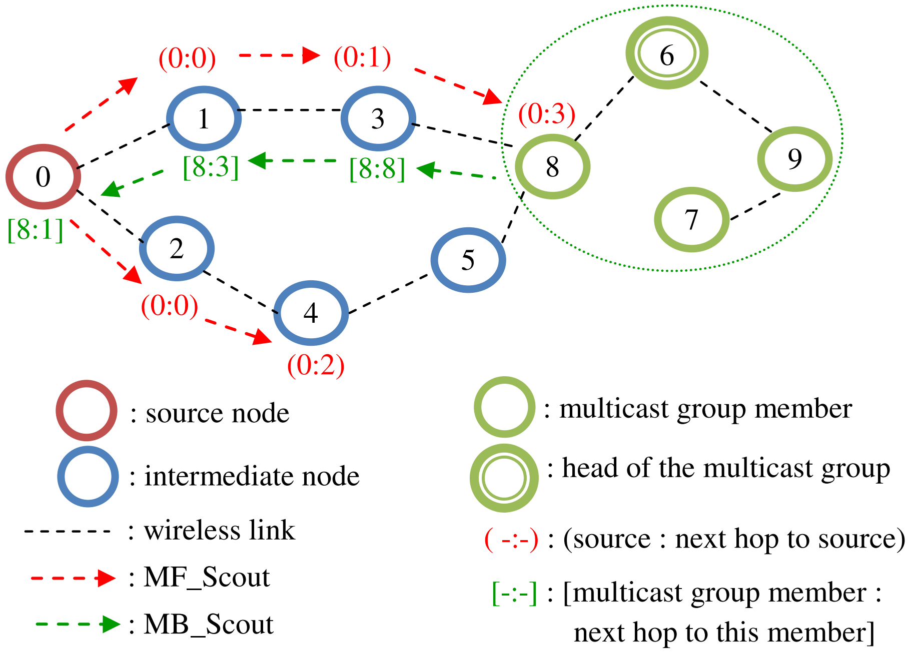

Figure 2. Route discovery from the source to a multicast group.

After discovering the route toward the multicast group, the MB_Scout is sent to the source node along the reverse path. This is performed by looking at the prior hop field recorded in the forward trip at the intermediate unicast routes tables or each visited unicast routes table, the MB_Scout saves its current sender as the absolute next hop, which will be used to transmit future packets. Figure 2 is an example of the MQBV route discovery. The source node 0 generates clones and disseminates MF_Scout to its neighbors (nodes 1 and 2). The MF_Scout contains the source identifier and knows the next hop to this source in the reverse path. Each neighbor (in Figure 2, nodes 1, 2, 3, 4, and 5) performs the same way as node 0 until reaching a multicast group member such as node 8. Moreover, node 8 generates and sends out MB_Scout to node 0 through the traversed path (via nodes 3, 1, and finally 0). MB_Scout includes the identifier of the multicast group node and knows the absolute next hop to this member.

3.6.2. Multicast tree construction (from the head of the group to its members).

Each node that desires to join the multicast group takes and records the multicast group addresses, which allows it to belong to the group. The node broadcasts a local scout to its neighborhood in order to search a group member and finds the head of the group, which lists this new member in the multicast routes table. After a certain limited time, this new member receives a local scout acknowledgement as a control packet to confirm its joining. Otherwise, it is assumed that there is no multicast tree, and the node is the first node that joins the group. Thus, this node represents the root of the multicast tree, which is the head of the multicast group with the initial identifier (equal to 0). The new node of the multicast group is responsible for constructing and maintaining the multicast tree.

However, if the head of the group encounters a new member request via a local scout, a new entry in the multicast routes tables is devoted to this new member. It contains the complete path traversed by the local scout, the identifier of the novel member, and a new multicast identifier attributed by the head of the group in an incremental fashion. Moreover, the new member keeps its multicast identifier and the next hop toward the group head. This next hop helps to find the complete path toward the head, which can be used to join the multicast group by other nodes through this member. Note that the local scout performs its multicast group searching trip until it expires. In other words, local scouts transverse the network while searching the nodes until reaching the end of its lifetime in order to prevent the infinite loops. If the local scout does not find any member during its lifetime, then its hop count is extended for another round. An example of the multicast tree construction is shown in Figure 3. Let us assume that node 10 wants to join the multicast group represented by its head, node 6. In this scenario, node 10 broadcasts a local scout to its neighbors, nodes 5 and 7. Here, only node 7 helps node 10 to reach the head (node 6) via local data (i.e., the next hop) node 9. Next, node 9 informs the head (node 6) directly, as it is the next hop. After that, the head inserts a new entry in the multicast routes tree for the new member (node 10). In this entry, the complete path from the head to node 10 is saved. Following this process, the multicast tree is mounted via the multicast routes table.

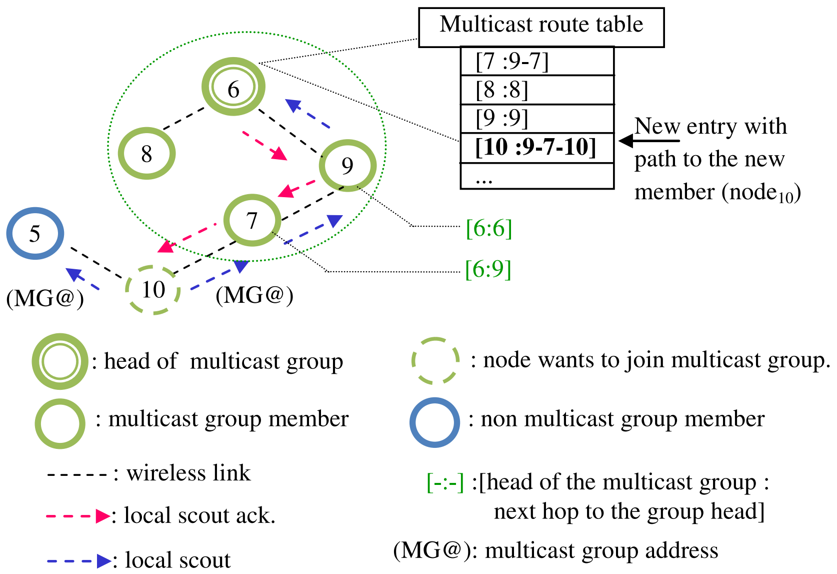

Figure 3. Multicast tree construction through the multicast routes table.

3.6.3. Multicast group publication.

This step improves the routing data of the non-members of the multicast group, which helps them to reach the head of the multicast group and the other members. This can avoid or reduce the delay when launching the multicast group discovery.

First, the head of the multicast group generates, clones, and disseminates distant scouts in the whole network when the multicast tree is updated. The cloned distant scouts communicate only with the next hop or the hop count toward the group head. They will be saved in the unicast routes tables of the non-members. Furthermore, the address of the multicast traffic is also saved to distinguish it from other multicast traffic in the same network.

Figure 4 illustrates the communication of the multicast group data to the non-member. Here, the group head (node 6) generates, clones, and broadcasts distant scouts to its neighbors, and the rest of the nodes do the same thing. The distant scout communicates only with the next hop or the hop count between the head and the visited node. For example, node 3 receives the distant scout and informs that it is mandatory to take two hops through node 8 to reach the head (node 6), once the packet arrives to node 8, there is only one hop to go before reaching the head. Another example is that node 0 saves two data relevant to two paths. The first one sends the packets through node 1 and takes four hops to reach the head (node 6), and the other sends the data via node 2 in five hops to reach the head (node 6).

3.6.4. Multicast tree maintenance.

As VANET has a dynamic nature, several multicast nodes frequently join and leave the group. The new members still can be detected and integrated in the multicast tree, by launching local scouts. By doing so, the multicast tree is updated.

If the head of the group leaves the multicast tree, its immediate neighbor member will detect the departure, resulting in a selection of a new head of the multicast group. Note that, there are hello messages transmitted to the nodes neighborhood in order to detect the link failures. After the new group head is selected, it reconstructs a multicast tree and board casts this information to the network nodes by distant scouts.

3.6.5. Complexity analysis.

In the worst case, MQBV route discovery phase uses $O(\rho D_1 N + N)$ time units to reach the first multicast group member where ρ represents the stochastic broadcast ratio ($0 < \rho < 1$) used when packets are transmitted toward N nodes from the sender to its D_1 neighbors. The complexity of the MQBV route discovery is calculated in the forward direction ($\rho D_1 N$ packets) and in the backward direction (N packets) using stochastic broadcast mode and unicast mode, respectively.

When a new node desires to join the multicast group, the tree multicast is then reconstructed. In this phase, we propose $O(D_2 N + N)$ packets transmission. D_2 is the number of the newer nodes of a neighbor, and N represents the number of intermediate nodes between the newer node and the head of the multicast group. Note that this phase is ensured by two subphases, searching the group head and confirming this discovery.

The last step of the discovery routes in the MQBV is the multicast group publication. It uses $O(D_3 N)$ unit times to inform the VANET nodes about the multicast group table updating. Here, D_3 is the number of the head neighbors, which is used to reach the N VANET nodes.

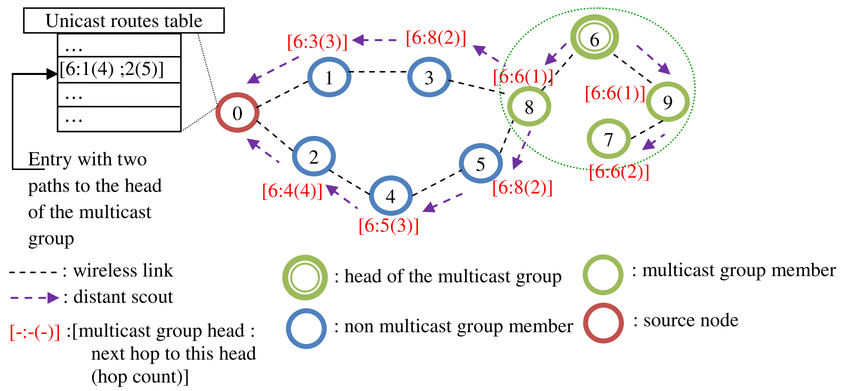

Figure 4. Multicast group publication.

$O(\rho D_1 N+N)+O(D_2 N+N)+O(D_3 N) \approx O(\rho D_1 N)+ O(D_2 N) + O(D_3 N) \approx \boldsymbol{O((\rho D_1+D_2+D_3)N)}$

Multicast quality of service swarm bee routing for VANET transmits at most $\boldsymbol{N}$ packets during the routes discovery. It indicates that MQBV performs in a linear complexity, meaning that the other protocols have similar or higher complexity.

4. EXPERIMENTAL STUDY

In order to evaluate MQBV in terms of QoS requirement, a set of simulations has been carried out. The ROVER protocol [6] was compared with our proposed method due to its efficiency and effectiveness. It was also formulated for multicast routing for VANET with respect to the QoS constraints. One of the major advantages of ROVER protocol is its multicast routes discovery policy using the on demand principle to ensure QoS requirements. In addition, this spatial protocol enables high PDR and low dropped packets, reduces end-to-end delay, and gives a good exploitation of the bandwidth. ROVER uses spatial addressing to construct a multicast tree.

4.1. Simulation environment (mobility model and parameter settings)

Multicast quality of service swarm bee routing for VANET has been simulated using ns-2 [5] version 2.26. Many VANET studies have used the ns-2 in its native form to evaluate different routing protocols. However, it is known that ns-2 simulates city traffic and vehicle movements in a theoretical form. Instead, VANET should be simulated with realistic traffic models, which reflect the complexity of the urban traffic features such as the limited capacity of the roads and the existence of intersections, obstacles, and buildings. In addition, highways should be considered to simulate the high speeds of vehicles.

In order to evaluate our proposal extensively, we propose a realistic vehicular propagation model in our experiments that take into account the traffic features of real places located in downtown of Biskra city in Algeria in a surface of 1500 × 1500 m^2 [15], as shown in Figure 5. We enable this scenario using ns-2, which contains an urban area as well as a highway. Therefore, we have considered various speeds of vehicles as follows: from 1 to 20 m/s in urban scenario and from 1 to 30 m/s in the highway. The simulated network consisted of four sets of tests where each set contains 50, 100, 150, and 200 nodes, respectively. We propose that each set of tests consists of four RSUs, which are positioned according to a uniform distribution on the experimentation area to ensure large radio coverage as shown in Figure 6. It is worth noting that the variation in vehicles velocities and network density is used to demonstrate MQBV adaptability.

For each set of tests, we have considered five different scenarios distinguished by their numbers of multicast group members, which are fixed at 5, 10, 15, 20, or 25, respectively. The variation of nodes and multicast group members aims to evaluate the efficiency of MQBV for several network densities according to the network congestion The details of these scenarios (for each set of tests) including ID numbers of the nodes are summarized in Table II, and the criteria of the group member selection are as follows: there should be at least one RSU in the group. Moreover, at least one vehicle should move on the highway, whereas the others are driving in the urban area. Here, a mobile node (vehicle) is considered as the source node for our experiments instead of RSU; in fact, both vehicle and RSU have the same property except for their mobility.

These scenarios were simulated on the basis of IEEE 802.11p wireless access in vehicular environments standardized specifically for VANETs. The User Datagram Protocol is used as a transport layer protocol, which is the most suitable for multicast transmission mode [16] and a constant bit rate model as an application layer model, to achieve the main objective of receiving safety messages with low latency and high throughput. In the experiments, the source node sends two multicast data packets per second and each packet with 512 bytes long. Each scenario was tested for 600 s, and each multicast member should join the multicast group at the beginning of the simulation.

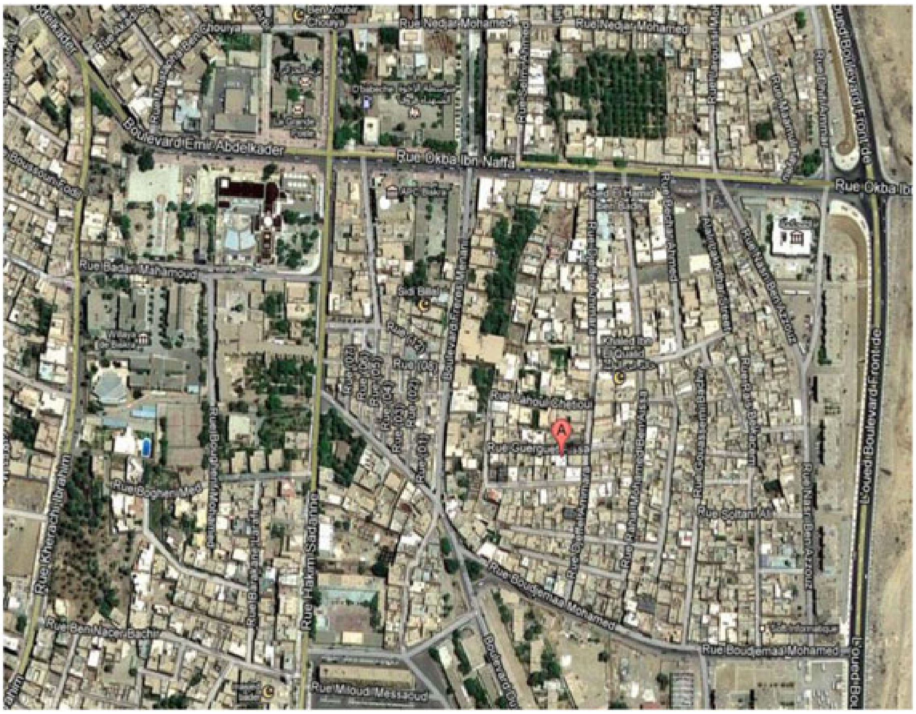

Figure 5. Downtown of the Biskra city: (urban and highway scenario) map representation [15].

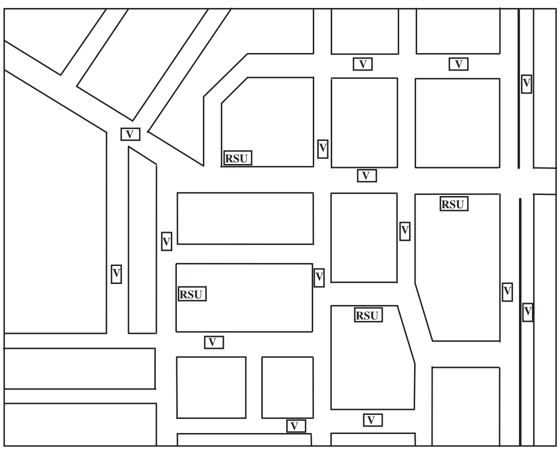

Figure 6. Abstract of the mobility model used in our simulation with vehicles (V) and roadside units (RSU)—an approximate schematic.

4.2. Performance metrics

To analyze the performance of MQBV protocol, four metrics have been considered for the QoS routing level [17]. These metrics are presented as follows.

4.2.1. Average end-to-end delay (measured in milliseconds).

This metric represents the average time for token data packets to reach the destination. It is calculated by subtracting the time to send the first packet by the source node from the time of its arrival to the destination node. The value includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation, and transfer times [17].

4.2.2. Average available bandwidth (measured in kilobits per second).

This parameter computes the total number of the delivered data packets divided by the total duration of the simulation time [18]. It is also an important metric regarding QoS paradigm, the goal is to transmit maximum data in minimum time. This bandwidth measures the data transmission speed.

4.2.3. Packet delivery ratio.

Packet delivery ratio is calculated by dividing the number of packets received by the destination node through the number of packets originated that from the application layer of the source nodes. PDR specifies the packet loss rate. The better the PDR, the more complete and correct the routing protocol is [19].

4.2.4. Normalized overhead load.

It represents the total number of routing packets divided by the total number of delivered data packets. This metric provides an indication of the extra bandwidth consumed by

Table II. ID for source node and multicast group members for each scenario.

Scenario ID	Source node ID	Number of multicast group nodes	ID of multicast group nodes: RSUs	Vehicles in urban area	Vehicles on highway
1		5	45	46, 47, 48	49
2		10	45	40, 41, 42, 43, 46, 47, 48	44, 49
3	0 (located at center of the area)	15	35, 45	36, 37, 38, 40, 41, 42, 43, 46, 47, 48	39, 44, 49
4		20	35, 45	30, 31, 32, 33, 40, 41, 36, 37, 38, 42, 43, 46, 47, 48	34, 39, 44, 49
5		25	25, 35, 45	26, 27, 28, 30, 31, 32, 33, 36, 37, 38, 40, 41, 42, 43, 46, 47, 48	29, 34, 39, 44, 49

RSU, roadside unit.

overhead to deliver data traffic. It is crucial as the size of routing packets may vary [17].

4.3. Results

Simulation results are depicted in the following graphs (Figures 7–10). Each figure shows the four sets of tests (50, 100, 150, and 200 network nodes). In each set of tests, the five scenarios of multicast group members are displayed as follows.

Figure 7 lists MQBV and ROVER average end-to-end delay made by the packets disseminated from the source node toward the different multicast group members for each of the fourth sets of tests as follows: 50, 100, 150, and 200 network nodes. It can be readily seen from this figure that MQBV has reached the reduced end-to-end delay, either for the low density network, for the medium density network or when the network is very dense. Also, the recorded end-to-end delay results of MQBV are better compared with ROVER, for different multicast group sizes: small, medium, or large. These results have been reached because MQBV discovers multiple paths, which are used to disseminate different packets from the source to the destination. Consequently, less time is consumed to transmit messages, and then the relevant information is received by the endangered vehicles to take the appropriate decision to avoid road accidents or collisions.

The average bandwidth obtained during these experiments is depicted in Figure 8, which confirms that MQBV throughputs are better than the ROVER values. Indeed, in the various density scenarios, MQBV provides the improved throughputs, which are recorded for different multicast group receivers. As seen by investigating multipath transmission principle, MQBV performs better because of the mechanism of the multiple unicast transmission between the source node and the discovered head of the multicast group. This mechanism relieves mediums, and hence, more packets are sent simultaneously in a time unit.

Figure 9 depicts the packed delivery ratio for both protocols regarding the number of multicast group nodes for different network densities. It clearly indicates that MQBV has a very high rate of successful packet reception in all cases of network density and for all multicast group numbers. However, ROVER dropped more packets. The main reason is because routes robustness is ensured by using the maintenance phase of MQBV in which the hello messages are used to maintain any detected link failure. On the other hand, the MQBV network is less congested because of the multipath principle, which increases the packet exchange with less congestion. This helps to successfully receive more packets.

The NOL in Figure 10 shows that MQBV provides better results in all cases of network density and for various cases of multicast receivers. Here, the network is less congested by MQBV in terms of routing packets compared with the ROVER protocol. This is the result of

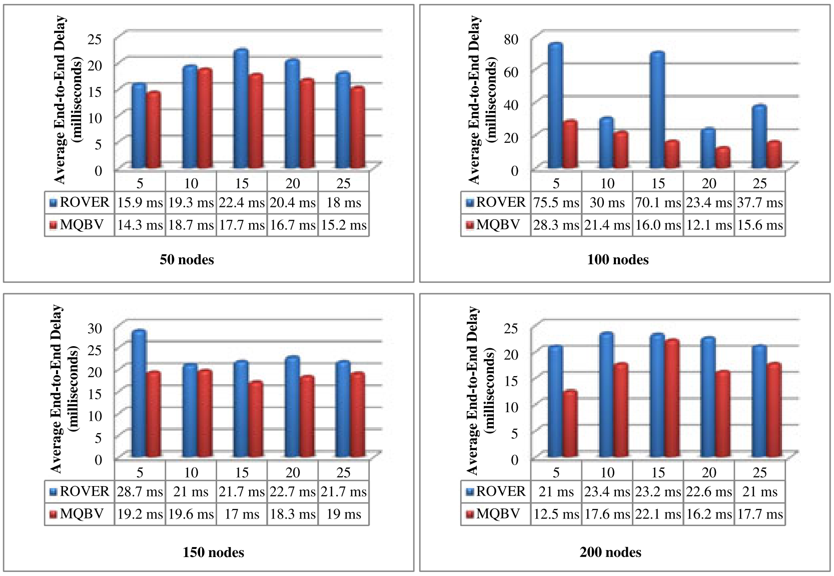

Figure 7. Average end-to-end delay versus multicast group receivers' number for different network densities.

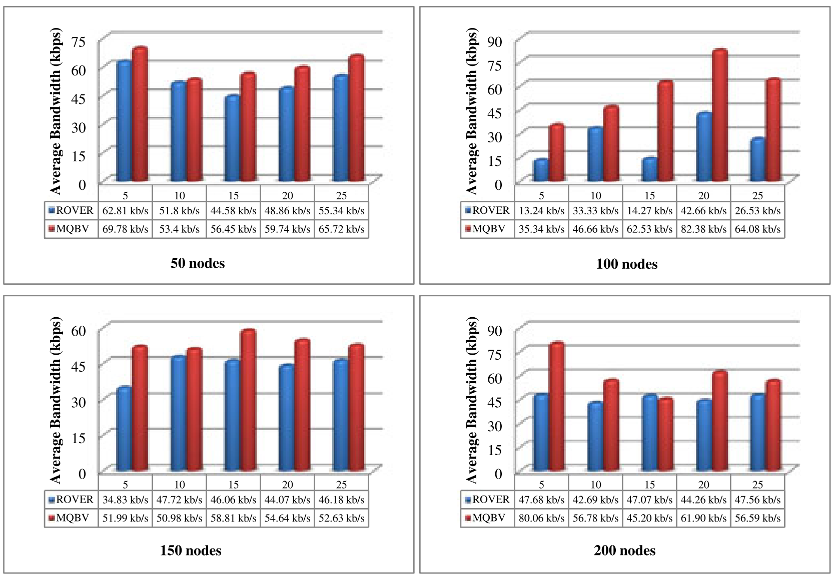

Figure 8. Average bandwidth versus multicast group receivers' number for different network densities.

the stochastic broadcasting mechanism used to discover routes in which only a limited number of routing packets is sent to search the desired route. Consequently, the network is less congested in terms of control packets, and then the transmission time is reduced.

From these results, regarding our testbed conditions, it can be seen that the proposed MQBV protocol outperforms ROVER protocol in all QoS metrics and in different cases of network density.This ensures transmitting packets and messages from the source node to all multicast group nodes in a limited time with success. Also, the network is used more efficiently and less congested, which helps to receive the appropriate safety messages to take the good decision aiming to avoid critical circumstances.

In summary, the obtained results from our proposal are due to the optimal route searching mechanism performed by the stochastic broadcast of the route request when the source node does not know one of the multicast group members. This stochastic broadcast helps to reduce the control packets and the trip latency while increasing the

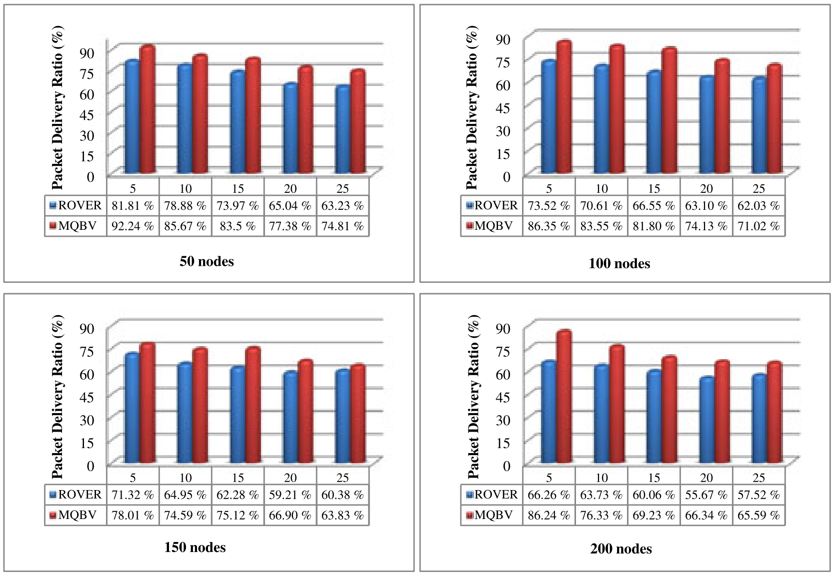

Figure 9. Packet delivery ratio versus multicast group receivers' number for different network densities.

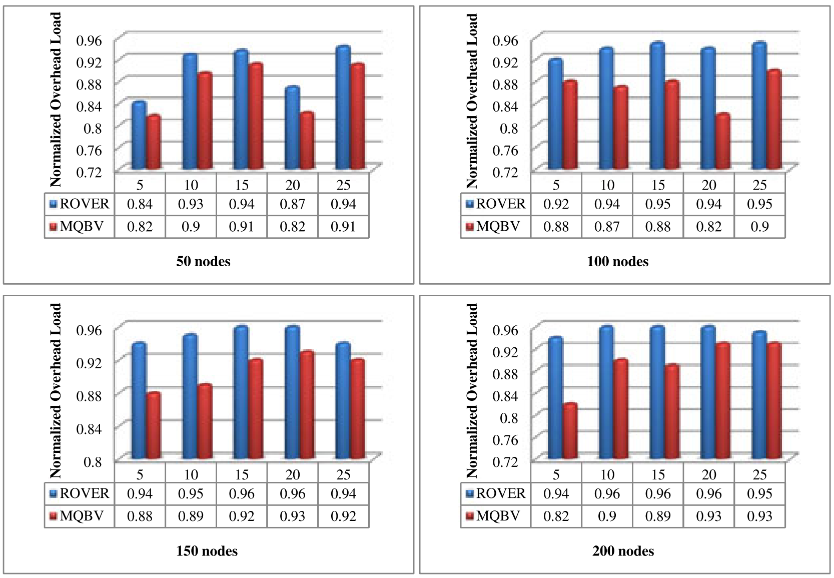

Figure 10. Normalized overhead load versus multicast group receivers' number for different network densities.

bandwidth. Another optimization aspect of MQBV is the transmission of packets through multiple paths between source node and the head of the group, which prevents the network congestion and decreases delays while increasing bandwidth values by dividing the transmitted packets fairly over the different found routes. Furthermore, by containing the entire route from the group head to its members in the route cache of the MQBV, this plays an important role in this improvement. It mitigates the treatment process at the level of the multicast tree nodes for reaching destinations and thus decreases the average delay and increases the average bandwidth in the MQBV. Also, MQBV has been demonstrated as an adaptive protocol, which keeps its better results regardless the velocity of vehicles or network density.

5. CONCLUSION

As a novel autonomic QoS multicast routing protocol for VANETs, MQBV has been proposed in this paper. It is a reactive, adaptive, and tree-based protocol inspired by the bees' communication behavior, which presents a linear complexity. MQBV routes multicast packets after finding the path from the source to the multicast group members organized in a tree structure. It takes two phases: the first one aims to find one of the group members using the combination of unicast and multipath routing, and the next phase disseminates packets by this member to the other members through the head of the group. In order to evaluate the performance and effectiveness of this proposal in terms of the QoS parameters including average end-to-end delay average bandwidth, PDR and NOL required in such networks and their applications, a set of simulations has been conducted using ns-2.

We plan to use MQBV protocol across hybrid networks in the future in order to achieve end-to-end QoS. In particular, the scalability of our proposed protocol should be investigated more extensively on larger and more scalable VANETs. In addition, we propose study of the security aspects of MQBV packets exchanges as a future work.

REFERENCES

1. Nundloll V, Blair GS, Grace P. A component-based approach for Reconfigurable routing in VANETs, In *8th ACM International Workshop on Adaptive and Reflective Middleware*, Urbana Champaign, USA, 2009.
2. Bitam S, Mellouk A. QoS swarm bee routing protocol for vehicular ad hoc networks, In *IEEE International Conference on Communications (ICC)*, Kyoto, Japan, 2011; 1–5.
3. Ledy J, Boeglen H, Hilt B, Abouaissa A, Vauzelle R. An enhanced AODV protocol for VANETs with realistic radio propagation model validation, 2009; 398–402.
4. Li GS, Wang WL, Yao XW. An adaptive and opportunistic broadcast protocol for vehicular ad hoc networks. *International Journal of Automation and Computing* Springer 2012; **9**(4): 378–387.
5. ns-2 Simulator. http://www.isi.edu/nsnam/ns/ (last accessed on February 2013).
6. Kihl M, Sichitiu M, Ekeroth T, Rozenberg M. Reliable geographical multicast routing in vehicular ad-hoc networks, wired/wireless Internet communications, in conjunction with 5th International Conference on Wired/Wireless Internet Communications, Lecture Notes in Computer Science (LNCS), Springer, Coimbra, Portugal, 2007; 315–325.
7. Lin YW, Chen YS, Lee SL. Routing protocols in vehicular ad hoc networks: a survey and future perspectives. *Journal of Information Science and Engineering, Institute of Information Science,* Taipei, Taiwan 2010; **26**(3): 913–932.
8. Joshi HP, Sichitiu M, Kihl M. Distributed robust geocast multicast routing for inter-vehicle communication, In *WEIRD Workshop on WiMax, Wireless and Mobility, in conjunction with 5th International Conference on Wired/Wireless Internet Communications*, Lecture Notes in Computer Science (LNCS), Springer, Coimbra, Portugal, 2007.
9. Hsieh YL, Wang K. Dynamic overlay multicast for live multimedia streaming in urban VANETs. *Computer Networks,* Elsevier 2012; **56**(16): 3609–3628.
10. Perkins C, Belding-Royer EM, Das S. Ad hoc on-demand distance vector (AODV) routing, Internet engineering task force request for comments RFC 3561, 2003; 1–38.
11. Chen YS, Lin YW, Lee SL. A mobicast routing protocol in vehicular ad-hoc networks. *ACM/Springer Mobile Networks and Applications* 2010; **15**(1): 20–35.
12. Alvin S, Tang M, Fenf Y, Looi M. A multicast routing scheme for efficient safety message dissemination in VANET, In *IEEE Wireless Communications and Networking Conference (WCNC)*, Sydney, Australia, 2010; 1–6.
13. Parsa M, Zhu Q, Garcia-Luna-Aceves JJ. An iterative algorithm for delay-constrained minimum-cost multicasting. *IEEE/ACM Transactions on Networking* 1998; **6**(4): 461–474.
14. Bitam S, Batouche M, Talbi E-G. A survey on bee colony algorithms, In *24th IEEE International Parallel and Distributed Processing Symposium (IPDPS)*, NIDISC Workshop, Atlanta, Georgia, USA, 2010; 1–8.
15. Downtown of Biskra city. https://maps.google.com/ (lastaccessedonFebruary2013).
16. Kusum D, Chaudhary P, Dahiya P. Performance evaluation of TCP and UDP protocols in VANET scenarios using NCTUns-6.0 simulation tool. *Performance Evaluation* 2011; **36**(6): 6–9.
17. Li J, Zhou Y, Lamont L, Richard Yu F, Rabbath CA. Swarm mobility and its impact on performance of routing protocols in MANETs. *Computer Communications,* Elsevier 2012; **35**(6): 709–719.
18. Subramaniam PR, Arunkumar T, Sivanandam SN. A QoS adaptive routing scheme (QARS) for highly dynamic vehicular networks with support to service and priority. *World Applied Sciences Journal* 2011; **13**(5): 1259–1268.
19. Alasmary W, Zhuang W. Mobility impact in IEEE 802.11p infrastructureless vehicular networks. *Ad Hoc Networks,* Elsevier 2012; **10**(2): 222–230.

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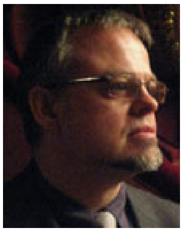

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