Effective Emergency Messaging in WAVE based VANETs

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***Abstract*- Vehicular communications is regarded as being a major innovative feature for in-car technology. At present, all major industrialised countries are actively promoting research focusing on these issues and car manufacturers are pushing product development through in-house research and standardisation efforts. Vehicular communications can be used in a diverse range of applications for improving road safety through the dissemination of warning/emergency messages to alert drivers of accidents, road conditions etc. and to provide Internet access to passengers via gateways along the road. Nevertheless, the main purpose of Vehicular communication is disseminating emergency information immediately after an emergency situation or car crash incident and distributing the information to local vehicles instantly.**

Broadcasting information is usually very costly and without limiting techniques this will result in serious data redundancy, contention and collisions. The broadcast problem is often referred to as the *broadcast storm* problem [4] which is a complex problem requiring a robust solution. Protocols for information dissemination play a fundamental role for effective realisation of vehicular network applications.

In this paper, we present an extension to VRR, Vehicular Reactive Routing protocol [7], based on a broadcast algorithm called *Restricted Mobility-Based* which improves information dissemination. VRR is a multi-channel protocol that is specifically designed for Wireless Access in Vehicular Environments (WAVE) based VANETs. The protocol takes advantage of the multi-channel scheme defined in WAVE and uses the Control Channel (CCH) for signalling, and relies on one of the multiple Service Channels (SCHs) for payload data dissemination. For the purposes of evaluation of the proposed protocol, a simplified version of the WAVE system with a CCH and one SCH without timeslots is used. The OPNET [10] simulation tool is used for system evaluation over simple static and dynamic highway scenarios.

Index Terms-VANET, WAVE, IEEE P1609, broadcasting, broadcast storm problem

I. INTRODUCTION

One of the major goals of vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) wireless communications is to improve driving safety and in-vehicle comfort. At present the IEEE is completing a final standard IEEE 1609 "Standard for Wireless Access in Vehicular Environments (WAVE)" [11, 12, 13 and 14]. Due to the success of IEEE 802.11 in the area of data communication, it presupposes that this standard will be one of the main wireless technologies implemented in vehicular network, more specifically 802.11p which is defined by an IEEE working group. In the WAVE specification seven channels each of 10MHz bandwidth are defined. These channels are split over one Control Channel (CCH) and six Service Channels (SCHs). The CCH channel consists of beacon messages, which are periodically broadcast, each being 100ms and are called WAVE Service Advertisement (WSA) frames and these further contain high priority WAVE Short Messages (WSM) used for dissemination of safety messages. A SCH is switched optionally and used for non-safety applications.

The simplest way of broadcasting information to all nodes in ad-hoc network is by using flooding. This method involves each node that receives the initial packet rebroadcasting this packet. This method is significantly ineffective and leads to many redundant data packets and results in an expensive over-use of an already restricted communications medium. Broadcasting techniques for ad-hoc networks have been addressed by many researchers with a summary of such broadcasting techniques being presented in [3]. The authors briefly describe these broadcast techniques and categorise them.

Broadcasting schemes which would be possible use for Vehicular communications have been presented in [4]. These schemes are classified under the subset called *Probabilistic, counter, and location based scheme by* [3]. Authors Sze-Yao et al. of [4] define the *broadcast storm* problem and present techniques to decrease redundant rebroadcast packets using the following schemes:

1. Probabilistic
2. Counter-Based
3. Distance-Based
4. Location-Based

Results show that Location-Based scheme offers the best performance in terms of saved rebroadcast packets and reachability of mobile hosts in the MANET network.

The principle of Location-based scheme relies upon calculating the additional area that can be covered if the host rebroadcast the message. This principle significantly decreases redundancy in comparison to simply flooding but still there is some redundancy. Nodes which are distant from the source node based on some threshold will rebroadcast as they are able cover an additional area. In the case of very dense networks this can lead to the rebroadcast of hundreds of redundant packets.

Another family of broadcast approaches as specified by [3] is S*ource-dependent dominating sets* and used [5] presents a protocol from this family - the broadcast Multipoint Relaying protocol. The principle is that a sender determines a small subset of neighbours which is called *multipoint relay* (MPR). Only nodes inside this subset can rebroadcast information from the source. The disadvantage is that in order to determine the subset knowledge of one and two-hop neighbours are needed. Another disadvantage is if the MPR node has not received a packet from the source node due to overhearing and a non-MPR node has the non-MPR node is precluded from rebroadcasting. Consequently broadcasting from that MPR node is effectively stopped.

Another family of broadcast approaches is called *Neighbour elimination* where in general a receiver node decides to rebroadcast data or not based on all of its neighbours being covered by the information. One of these elimination protocols has been proposed for use with MANETs in [6]. In this paper, receiver nodes calculate neighbour coverage and if its neighbours are not covered then it sets up a random number of backoff time slots in a contention window for rebroadcasting. The random number range can be found to limiting when considering denser networks where tens (or possibly more) potentially rebroadcasting nodes set up the same number of backoff time slots, as the contention window has a small possible range between 0 and 15.

Another protocol presented in [1, 2] and is classified under the subset called *Probabilistic, counter, and location based scheme* [3]. The authors are focusing on a *probabilistic* scheme where the probability of a rebroadcast depends on the distance from a transmitter. They propose the *Distributed Vehicular Broadcast* (DV-CAST) protocol which is focused on Vehicular Communications and is entirely based on the local information established by each node. They propose three schemes called:

1. Weighted p-Persistence
2. Slotted 1-Persistence
3. p-Persistence

Where p is probability depending on the distance between a transmitter and a receiver. A Higher probability is chosen for nodes further from the source and vice versa with a lower probability for closer nodes. After determining the probability a rebroadcasting node waits a specific time WAIT_TIME before rebroadcasting.

Slotted 1-Persistence is similar to weighted p-persistence but instead of calculating the re-forwarding probability it calculates the wait time to retransmit.

Because the authors present current state of art with respect to broadcasting in VANETs we compare our VRR protocol broadcast limiting performance against DV-CAST. In this paper, we have not implemented DV-CAST but we have used the same simulation setup to compare our performance results against those presented in [1, 2].

The rest of the paper is organised as follows. In section II we describe previous work and ongoing research; in section III we present the proposed scheme which we call the *Restricted Mobility-Based* scheme. In section IV we define scenarios where we have simulated and evaluated the proposed scheme. In section V we compare the VRR protocol against the DV-CAST protocol and in the last section we present the conclusions drawn from this work.

II. Ongoing Research and Previous Work

The paper extends our previous work presented in [7] and describes the principles of the VRR protocol.

A. Protocol design

The Vehicular Reactive Routing (VRR) protocol is integrated with the WAVE stack and is embedded at the Logic Link Control layer. VRR is a multi-channel protocol which exercises efficient route discovery, route maintenance and data deliver processes with the use of the Control Channel (CCH) and a Service Channel (SCH). The Standard WAVE messages WSA and WSM are transmitted over the CCH as defined by the WAVE standard and IPv6 packets are transmitted over the SCH. To obtain a current neighbour location the WSA frame is modified to carry position information (this incurs an additional 4 Bytes). Route request and route reply demands are transmitted inside WSA frames (additional 40 Bytes) over the Control Channel and data acknowledgment and all application data (IPv6 packets) are sent over the Service Channel.

Due to these modifications, a route is firstly established over the CCH and afterwards data is transmitted over the SCH.

B. VRR Broadcast Limiting

In [7] we presented a technique to reduce redundant broadcast data. This algorithm was based on the *Neighbour elimination* family of schemes where receiving nodes themselves decide to rebroadcast data or not on base of network coverage. If all nodes in transmit range of receiver node are covered by the information, then the receiver node does not rebroadcast. If some node is not covered by the information in transmit range of the node then the node prepares data to rebroadcast.

The main difference with this algorithm and [6] is that rebroadcasting nodes do not set a random number of backoff time slots for rebroadcasting packets. The number depends on the distance from the transmitter, speed and motion vector. Due this method, the nodes are able forward information based on their mobility and based on local information they determine how appropriate they are for rebroadcasting. We have called this method a *Mobility-based* scheme that is efficient in high-mobility scenarios.

C. Ongoing research

The previously proposed scheme works well in high-mobility scenarios, but it collapses if nodes get into traffic jams and in low-mobility scenarios where the motion behaviour of nodes becomes similar. The question of determining a backoff time slot is reduced to depend only on distance from a transmitter (speed and motion vectors are similar). Because in the 802.11 MAC is possible to use only 15 backoff time slots then many nodes (in high-density, low-mobility scenarios) in the same distance range may calculate the same backoff time slot. As result of this, nodes which set the same backoff time slot transmit the data in the same time which in turn leads to collisions and subsequent retransmissions.

In this paper, the *Mobility-Based* scheme is extended and is renamed as the *Restricted Mobility-Based* scheme.

III. RESTRICTED MOBILITY-BASED SCHEME

The new proposed scheme takes advantages from the *Mobility-Based* scheme (*Neighbour elimination* family) and its mobility-cast and adds some characteristics from the family of *Source-dependent dominating sets.* This scheme relies only information from 1 hop neighbours. The working principle is defined as follows: a transmitting node defines a set of nodes (based on its 1 hop neighbours) which are the most suitable for rebroadcasting. The nodes are called *multipoint relay* (MPR) and are chosen depending on their distance from the transmitter, their motion vector and speed. The threshold on distance is set by the transmit range based on the Free-space path loss model, the speed threshold is set at 80m/s and motion vector can be in range from 0-360^0. A maximum of 4 MPR nodes can be selected, 1 in each direction – i.e. forward, backward, left and right. This set of nodes is placed in a packet and is transmitted. Subsequently receiving node determines their own priority to rebroadcast depending on whether it is an MPR node or not. If the node is a member of the set of MPRs it sets up the shortest backoff time and if not, it then calculates its backoff time depending on the distance, motion vector and speed. This backoff time is always higher then the highest backoff time for MPR. Some non-MPR nodes can assign the same backoff time when their mobility behaviour is similar but each MPR node always assign a unique backoff time which is smaller than non-MPR node backoff times.

The main difference between the *Mobility-Based* and *Restricted Mobility-Based* schemes is that the *Mobility-Based* scheme does not use MPR nodes for rebroadcasting. It relies solely on all 1-hop neighbour nodes setting their backoff time depending on their mobility behaviour.

- The principle of the *Restricted Mobility-Based* scheme is illustrated at Fig. 1 and is described as follows: A source node (node S) has data to rebroadcast (packet).
  1. Node S seeks the most suitable nodes (its MPR subset) from its 1 hop neighbours as:
     a. The nodes in the subset are identified as those being within 50^o of S, i.e. (nodes 2, 3 and H2).
     b. S calculates the rebroadcast probabilities for each node X in the subset as:

$$prob_{dist} = \frac{dist_{\max} - |S-X|}{dist_{\max}}$$
$$prob_{vector} = \frac{180^o - abs\left|\vec{S}-\vec{X}\right|}{180^o} \tag{1}$$
$$prob_{speed} = abs\frac{speed(\max) - speed\left|S-X\right|}{speed(\max)}$$

     Where $dist_{max}$ is calculated as the maximum distance using the Free-space path loss model and received power threshold..
     c. The node X with the highest probability is chosen as the most suitable node (H2) and is called an MPR.
     d. Node S calculates a coverage map of its 1 hop neighbours for the chosen MPR (H2) based on the transmit power of the MPR. If some node is not covered by the MPR (nodes H1, 1 and 5 are not covered by H2 as determined S), this procedure is then repeated by seeking the next MPR in a backwards direction (afterwards on the left and right side). The premise is that up to 4 MPRs would coer all 1 hop neighbours, failing this the non-MPR nodes also have an opportunity to rebroadcast.
  2. The source node gets a set of MPRs (nodes H1 and H2) and the set is put in a packet and is rebroadcasted.

- A node receives the broadcast information (e.g. node 3).
  1. The node calculates if it is to rebroadcast by calculating network coverage.
  2. The network coverage is calculated from all previously transmitted nodes which sent the same information in a packet.
  3. If the network is covered or the information was already received by the node, then a routing table is updated with the information and information with the same ID is discarded from its MAC buffer (if it exists). Finally the information is discarded and node goes to listening mode.
  4. If the network is uncovered then the node decapsulates the broadcast packet to get the set of MPRs.
  5. If it is one of the MPRs, it assigns a backoff time slot depending on its sequence in the set of MPRs in range from 7-10 (slots 0-6 are reserved for RREP [7]).
  6. If the node is not one of the MPRs then:
     a. It calculates a probability depending on its distance from the transmitter, speed and motion vector.
     b. Based on this probability a backoff time slot in range between 11 and 15 [7] is assigned (slots 7-10 are reserved for MPR).
  7. The node determines its set of MPRs and this set is put in the packet.
  8. The packet is then sent to the MAC buffer for rebroadcasting with an assigned backoff time slot.
  9. The information waits in the MAC buffer until the end of the backoff time and afterwards it is rebroadcasted or is discarded based on the network coverage process.

This is the main principle of the proposed scheme. An advantage of this approach is that all receiving nodes (MPR and non-MPR nodes) have some opportunity to rebroadcast packets, but only MPR nodes have the best opportunity (i.e. the shortest backoff time) to rebroadcast. The Advantage of this is that in the case of MPR node not always receiving the broadcast due to collisions (in a dense busy network) the other (non-MPR) nodes who overhear can transmit the information instead.

IV. Simulation Scenarios

A simulation environment has been developed using OPNET V.12 to evaluate the VRR protocol in a WAVE system. In the current implementation, multi-channel units have been realised with the VRR protocol running over a simplified WAVE system with one CCH and one SCH. Our results are compared against the DV-CAST [1, 2] routing protocol. The DV-CAST is chosen for comparison as this represents the current state of art for broadcasting in Vehicular communications. The DV-CAST protocol was not implemented but is used for comparison based on the results presented in [1, 2] using a similar simulation setup.

The network behaviour was tested using different densities from 10vehicles/km to 100vehicles/km on a 10 km road section in multi-lane network in a static scenario. Results presented are averaged over 100 simulation runs.

V. Performance Analysis

In this section VRR is compared against 1-persistence (simple flooding), p-persistence, slotted 1-persistence and slotted 0.5-persistence schemes as presented in [1, 2].

TABLE I
Comparison of VRR and DV-CAST protocol

Protocol/testing parameters	VRR	DV-CAST
Physical layer	802.11a	802.11a
-Bandwidth of the radio channel	10 MHz	10 MHz
-Sensitivity threshold	-95dBm	-95dBm
Transmit power	0.020 W	0.020 W
-Approximately maximum range	1000m	1000m
Link layer	802.11e MAC	802.11 MAC
Type of Beacon message	Modified WSA	Modified AODV HELLO
-Size of Beacon	392 b	23 b
-Size of broadcasted information	1.6 kb (routing information)	25 kb
-Beaconing interval	1s*	1s
-Maximum number of hops	10	NA

* WAVE defines a beaconing interval of 100ms but for comparability with DV-CAST the interval is set to 1s.

A. Normalized link load

The normalised link load is calculated as the amount of received broadcast information at each node divided by the number of nodes in whole network over unit time. A low value indicates a higher throughput. The results are presented in Fig. 2.

From the results in Fig. 2 it is seen that the VRR protocol generally needs less broadcast packets for data dissemination than the schemes proposed in the DV-CAST protocol. In most cases there is a 10% improvement over the best scheme in DV-CAST and 90% improving against simple flooding. In traffic densities of 100vehicles/km, the network is congested with beacon messages. With VRR some MPR nodes have not received broadcast information properly and so other nodes have to substitute the MPR nodes and broadcast the information instead. Due to this, the number of broadcast packets was slightly increased.

B. Number of hops to cover a 10 km network

The second test measures the average number of hops to reach the last vehicle at the end of the 10 km road section. The results are plotted in Fig. 3.

In Fig. 3 it can be seen that the VRR protocol produces results that are similar to Slotted 1-persistence and Slotted 0.5-persistence schemes. The minor difference between these schemes can be attributed to inaccurate readings based on the values presented graph in [1, 2].

In VRR the average number of hops has decreased at the 100vehicles/km point. The reason for this is that broadcasted information was colliding with other transmitted frames due to a high traffic density. Consequently the information could not reach last node in the network and finished somewhere on half way to the last node. The number of hops was then calculated up to the middle node (where the information finished) instead of the last node in the network as in previous lower density scenarios.

Further research will consider with the issue and will propose control mechanisms to ensure that data is disseminated correctly.

C. Total end-to-end delay

Total end-to-end delay is the time taken for the last node to receive a packet. Results are shown in Fig. 4.

In Fig. 4 it can be seen that there is significant difference between the schemes proposed in DV-CAST and in VRR. The end-to-end delay is approximately 65 ms in DV-CAST against 6 ms in VRR. This is a 90% improvement against DV-CAST. The increase in total delay is partly due to the number of hops chosen by the DV-CAST but mainly due to the scheduling and waiting time of 5ms required before contending with other nodes for retransmission at each hop [1].

The Slotted 1-persistence principle is that if a node receives a packet for rebroadcasting it calculates a waiting period called WAIT_TIME which is derived from the transmission and propagation delay. It also calculates a TIME_SLOT derived from the distance from a transmitter such that the distance is split to 5 equal parts (per 200m of a max transmit range of 1000m). The Size of TIME_SLOT can be in the range 1-5. A node which has a packet to rebroadcast waits:

$$DELAY = TIME\_SLOT \times WAIT\_TIME$$

and then sends the packet to the MAC layer. There it is assigned a random backoff time slot and the packet waits until end of the slot. Afterwards the packet is transmitted. If the same packet is received during the WAIT_TIME period, the period is extended for a delay of one-hop transmission plus a propagation delay.

The Slotted 1-persistence relies on a wasteful long data delay. The time slot of the WAIT_TIME period is set to be the same for all nodes in an area of 200m. All nodes inside this area of 200m send a packet to MAC layer in the same time and the MAC layer assigns the packets a random backoff time slot. If the area contains many nodes then some nodes will set the same backoff time which means that the data will be transmitted at the same time, will collide. These collisions produce long delays (transmission and propagation delay) at other nodes.

Slotted p-persistence is very similar to the Slotted 1-persistence from the view of data delay with the difference being that if no neighbour rebroadcasts then the retransmission probability 1 and if some neighbour rebroadcasts then the probability is less.

Again as in the previous scheme, all nodes in the same area of 200m have the same slot time. None of nodes can retransmit the packet because all of them (in the same area) wait until end of the same WAIT_TIME. At the end of this period, the nodes send packets to MAC layer again at the same time like in previous scheme. After assigning backoff time slots, many nodes can transmit packets in the same time and collisions occur as in the previous scheme.

In the *Restricted Mobility-Based* scheme, all packets wait in MAC buffer where they are assigned with a number of backoff time slots where one slot takes approximately 50µs. The nodes selected as the most suitable for rebroadcasting have the smallest backoff time, these nodes were chosen as previously explained and set the shortest backoff time (slots 7-10). Other suitable nodes not included here set the next most preferred slot time in the range 10-14 and those most unlikely to rebroadcast have the worst backoff time (slot 15). The most suitable nodes rebroadcast immediately after the medium becomes free.

D. Delivery ratio

The delivery ratio measures how many nodes receive the broadcast information versus how many nodes are in a 10 km network. Results of this are plotted in Fig. 5.

In Fig. 5 are results from VRR protocol and the simple flooding protocol (1-persistence) are shown as [1] only displays results for the 1-persistence.

The strip "VRR Delivery Ratio" means how many nodes have received broadcasted information versus the number of nodes in the network. Here it is seen that in low-traffic almost all nodes (99% in the 10 vehicles/km or 98% in the 20 vehicles/km) have received broadcasted information even if they are far from the source (10 km). Due to increasing traffic density the ratio decreases down to around 55%. The results do not look good if almost half of all vehicles have not received the information but this can be explained by looking at another strip in the graph.

The strip "1 Hop Ratio" shows how many nodes were covered by the information up to 1st hop. Results show that over traffic density from 10vehicles/km to 100vehicles/km the source node can cover approximately the same area with the information. In the case of 10vehicles/km, 20 vehicles are in range of the 1st hop (transmit range 1000m in radius, based on the WAVE standard) and in the case of 100vehicles/km 200 vehicles are covered (the radius is still the same).

For the strip "4 Hop Ratio" the principle is the same as previously and shows how many nodes were covered by the information up to 4th hop. In the case of 10vehicles/km 50 vehicles are covered and in the case of 100vehicles/km 500 vehicles are covered. Results show that over traffic density from 10vehicles/km to 100vehicles/km the source node can cover approximately the same area with the information. The radius for 4 hops is approximately 3 km.

The results mean that the probability of receiving a broadcast packet is decreasing with increasing distance from a source. Further, the results show that nodes closer to the source are less likely to be impacted by traffic density as with increased traffic density and increasing distance form the source, far nodes will suffer more from interference and multiple hops may be needed for transmission.

The result also shows that all nodes in the range of 3 km (4 hops) are covered by the information over a traffic density from 10vehicles/km to 100vehicles/km.

E. Dynamic highway scenario

As this paper presents the *Restricted-Mobility based* scheme and up to now all results were taken from static scenarios in Fig. 6 we show the broadcasting effect of VRR in a dynamic scenario.

The dynamic scenario presents a 10 km highway section consisting of two directions where each direction contains 2 traffic lanes. In each lane of both directions there are vehicles moving at different speeds. All vehicles inside a lane are moving with the same speed. To better understanding this in Fig. 6, on the x-axis are the values [A]/[B] which means that all vehicles are moving in the first direction in first lane with speed A, in the second lane with speed B and in the opposite direction in the third lane with speed B and in the fourth lane with speed A. All speeds are in m/s.

A source node broadcasts information in this 10 km network every second. The velocity of the source node is plotted as "Speed of a source vehicle". Afterwards nodes selected by the *Restricted Mobility-Based* scheme rebroadcast the information. The velocity of these rebroadcasting nodes was collected, averaged and plotted as "Average speed of rebroadcasting vehicles" in Fig. 6.

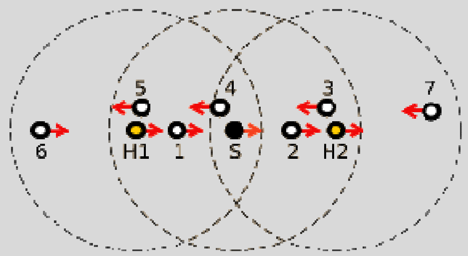

Fig. 1: Principle of Restricted Mobility-Based scheme

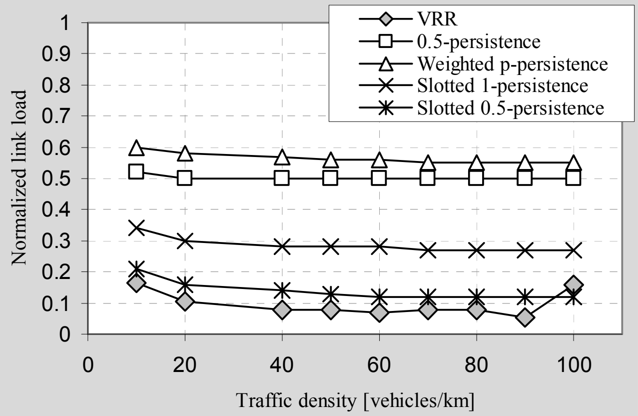

Fig. 2: Normalized link load

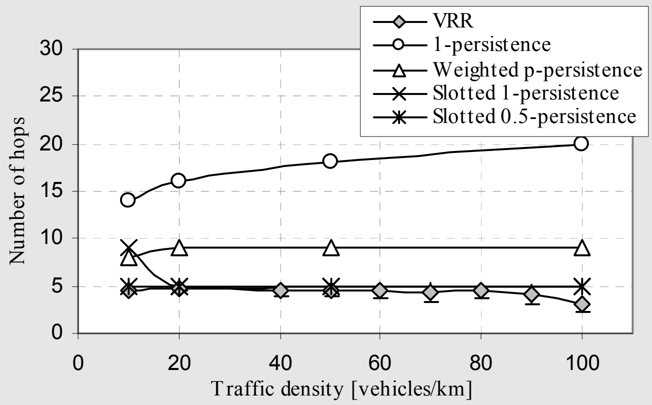

Fig. 3: Average number of hops to coverage a network

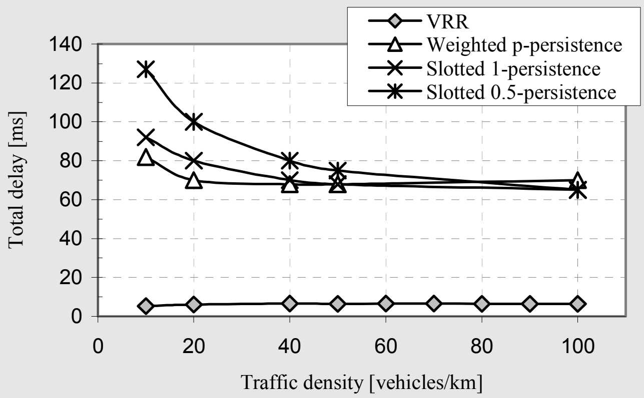

Fig. 4: Total end-to-end delay

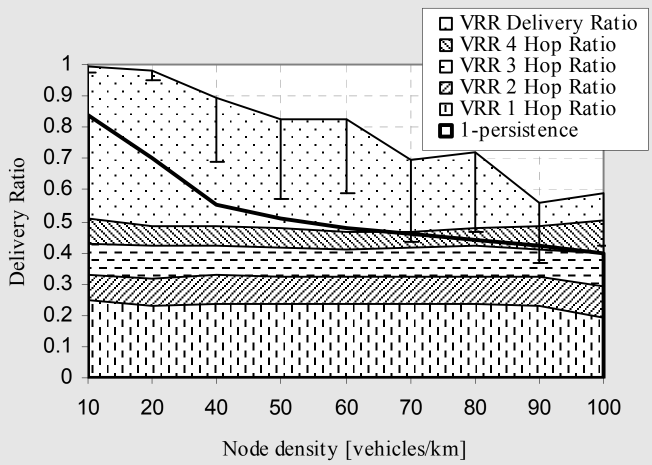

Fig. 5: Delivery Ratio

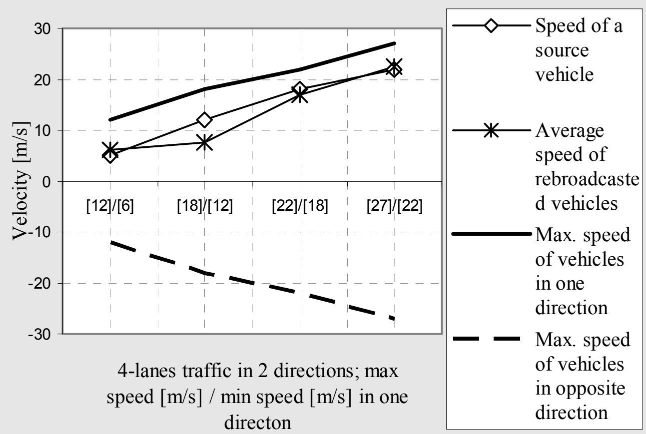

Fig. 6: 4-lane highway dynamic scenario

From these results in Fig. 6 it shows how this scheme selects next-hop nodes with motion behaviour similar to that of the source node. The proposed scheme does not choose next hops (MPR nodes, non-MPR nodes) depend only on distance from the source but also on speed and motion vector. Suitable hop nodes are selected along a direction and disseminate broadcast information.

In a real scenario, a node travelling over the highway would start to broadcast, using the proposed scheme rebroadcasting nodes are selected in the same lane in the same direction while in DV-CAST, the rebroadcasting nodes would be chosen randomly e.g., one node with 50 m/s in one direction, another node with 30 m/s with opposite direction on so on.

For simple broadcasting this feature does not have a major benefit but for example with the Route Discovery process it has significant advantage as routes will be established over nodes with similar behaviour (speed, motion vector), which means that the route will be more likely to be stable than other routes.

VI. CONCLUSION & FUTURE WORK

Routing protocols have a fundamental role in the effective realisation of vehicular network applications. The routing protocol is charged with providing efficient and successful delivery of the application data. This paper introduced Extended VRR, a Vehicular Reactive Routing protocol with a broadcasting algorithm called *Restricted Mobility-Based* scheme which can effectively deliver vehicular application broadcast data within the required temporal and transmission constraints.

The VRR protocol is a multi-channel protocol integrated with the WAVE standard protocol stack and is capable of exercising efficient route discovery, route maintenance and data deliver with the use of the Control Channel (CCH) and a Service Channel (SCH).

To improve the performance of broadcasting in vehicular network we have proposed the *Restricted Mobility-Based* scheme which reduces the impact of broadcast storms. The scheme is based only on obtaining information from beacons messages from 1 hop neighbours.

The proposed scheme was tested in most cases against 1-persistence (simply flooding), p-persistence, slotted 1-persistence and slotted 0.5-persistence schemes presented in [1, 2]. Static and dynamic scenarios were tested in multi-lane topology.

In the most case, the results show improvements against those presented in [1, 2]. In Fig. 2 (Normalized Link Load) we achieved a 10% improvement against slotted 0.5-persistence and in Fig. 4 (Total Delay) we achieved a 90% improvement against all schemes proposed by [1, 2].

The proposed scheme with respect to Delivery Ratio in Fig. 5 is not able ensure 100% coverage of far nodes by broadcasted information but on other hand it is able ensure that nodes close to the source are covered by the information independent of traffic density (based on densities from 10 vehicles/km to 100vehicles/km).

One dynamic highway scenario was tested at Fig. 6. This illustrates how nodes using the proposed restricted mobility-based scheme select next hop nodes based on similar behaviour. This method has significant advantages for establishing stable routes during the Route Discovery process.

Further research will consider increasing the Delivery Ratio for distant nodes by repeating the broadcast data and expanding tests for the dynamic scenarios to fully evaluate the performance of the proposed scheme.

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