Efficient Dissemination to Ensure Active Safety in Vehicular Networks

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ABSTRACT

Exchange of geographical movement information is an important and potential life-saving feature for vehicular systems. By exchanging and processing their movement information, vehicles can easily detect dangers such as intersection collisions or notification of accidents ahead, thus improving the safety of drivers and passengers on the road. Many applications for active safety in Vehicular Ad-Hoc Networks (VANETs) operate in a decentralized fashion, namely by Vehicle-to-vehicle (V2V) communications without using any infrastructure. This paper describes such a kind of vehicular communication system that uses an efficient dissemination mechanism known as MHVB for the exchange of geographical location information at the network layer. The system targets active safety applications that have high requirements with respect to transmission delay and packet loss probability. The paper then proceeds to explain the process of communication that takes place between the nodes in the VANET. Finally we try to analyze the NS2 simulation results and provide some conclusions on the system.

1. INTRODUCTION

Vehicular Networks are an envision of the Intelligent Transportation Systems (ITS). Vehicles communicate with each other via Vehicle-Vehicle Communication (V2V) as well as with roadside units via Vehicle-to-Infrastructure Communication (V2I). The optimal goal is that vehicular networks will contribute to safer and more efficient roads in the future by providing timely information to drivers and concerned authorities.

V2V communications are regarded suitable for active safety applications because of their nature to be available anywhere, to require the strict latencies and to cover localized communications. Active Safety mechanisms require essential functionalities like the periodic broadcast beaconing of position and speed to the neighborhood and at the same time a strict latency and large area of dissemination will also have to be taken into account.

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It is for that purpose we, in Hitachi Europe designed an algorithm for efficiently disseminating information over a wireless vehicular network: the Multi Hop Vehicular Broadcast (MHVB) algorithm [1], [2], [3]. It can be used for event-driven dissemination (typically started by an application) or for periodic dissemination (such as beaconing for neighbors' movement awareness). MHVB forwards or periodically broadcasts messages while taking into account the limited bandwidth and satisfying the mentioned requirements.

Wireless communication technologies can support road safety by two means: by the periodic exchange of "status" messages and by the dissemination of emergency messages [4]. The first type of messages, also called beacons, will contain vehicles' status information such as position and speed vector. Upon reception of beacons issued by neighboring vehicles, a safety system is aware of its surrounding and is able to detect potential dangerous situations. The second type of messages,also called event-driven, will quickly disseminate emergency information to make possible to alert other drivers of an existing danger.

The reader may ask why is there a need to go for Multi-Hop communication? "Distance" is one of the major factors that determine the quality of service of an active safety application. For any application to perform with a reasonable quality of service, it needs to be aware of its' surrounding as much as possible. When this seems to be the case, single-hop neighbors' information is not sufficient. When considering city-like scenarios where there are intersections and buildings in-between, the multi-hop communication thus helps to ensure reliable dissemination and thus assure higher levels of active passenger safety. By dealing with Active safety applications, we speak of non-trivial time constraint too. So the delay time required for broadcasting the messages has to be given due importance. As an example, consider the urban scenario in Figure 1, where tall buildings at intersections can hinder the radio wave propagation.

In the above example having only having single hop communication does not help the other vehicles (e.g., car Y) to be aware in advance of behind-the-corner vehicles (e.g. receiving the information on the emergency vehicle Car X). Thus having a "multi-hop" communication here ensures reliable dissemination and assures higher levels of active passenger safety. Please refer Figure 2

The rest of the section are organized as follows: Section 2 shows the communication process involved in information exchange between the vehicles in the network, section 3 giving insight into the potential architecture and system specificities and sections 4 and 5 being evaluation results and

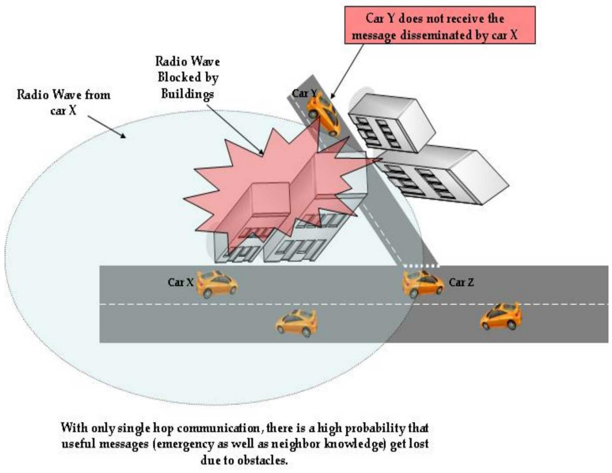

Figure 1: Information blocked due to obstacle (building)

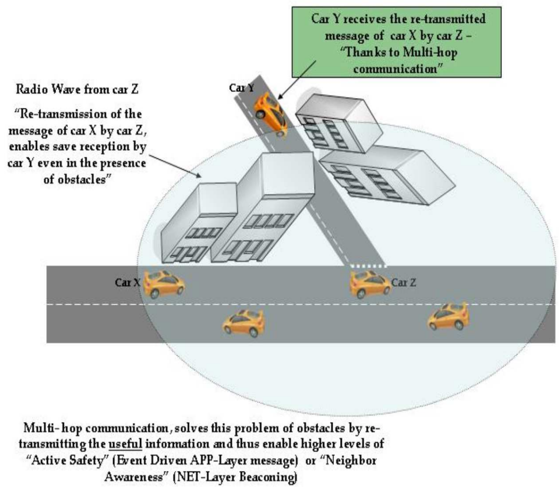

Figure 2: Necessity for Multi-Hop Communication

conclusion respectively.

2. COMMUNICATION PROCESS

Before trying to understand the communication process of the NET- Beaconing system, let us focus on the format of MHVB-B (MHVB-Beaconing) packet. The packets are just containers of position and velocity information with respective node identities and timestamps of creation of the message. In order to have an idea of the packet format transmitted, please refer to Fig. 3.

A MHVB-B packet can contain one or multiple messages in a packet and thus the packet size is not fixed. The header part contains the information about the type of the packet sent (i.e. MHVB-B in our case) and also the number of messages inside the packet. This will enable the receiver to separate the messages inside the packet as they are received.

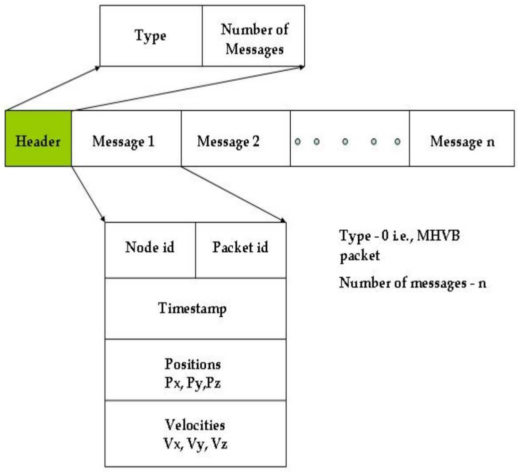

Figure 3: Packet Format

The node has a sender part and the receiver part that work asynchronously. Every node contains a message cache where the received information of other nodes and that of itself are stored. The target neighbor dissemination is considered on a "node-by-node" basis in MHVB-B. Before transmitting its own information, every node checks its neighbor table and finds potential (meaning awareness within distance constraint) neighbor nodes' information that could be forwarded (re-transmitted). There is no complete packet duplication as such. Please note that in our case, a packet contains single or multiple information (i.e., one or more nodes). One of the basic functionalities of MHVB is the "Area Based suppression" which does not forward (re-transmit) packets that do not satisfy the requirements of an application or the system. When a node receives a packet, it checks information for validity, processes them according to the node and information identities and stores them in the message cache. Figures 4 and 5 briefly explain about the communication procedure.

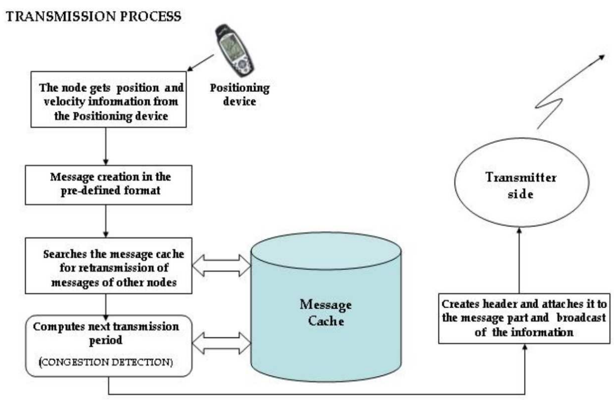

Figure 4: Transmission Process

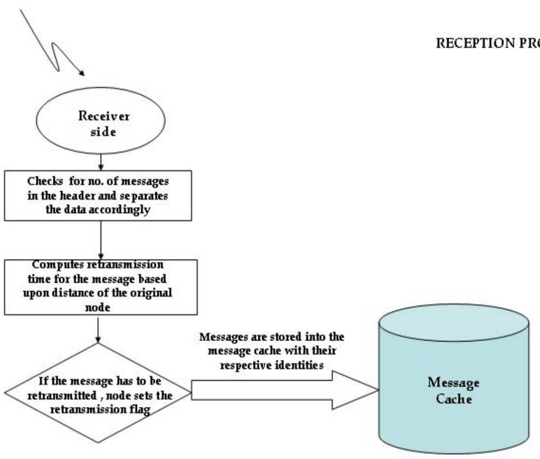

Figure 5: Reception Process

3. POTENTIAL GLOBAL ARCHITECTURE AND BEACONING SYSTEM SPECIFICITIES

3.1 Potential Global architecture

The architecture is named global in the sense that it also includes eventual application layer services that use MHVB algorithm. Here our focus is on the NET layer beaconing system and a complete description of the entire architecture is out of scope of this paper. This section is supposed to give the readers a brief idea of where the system fits into the global architecture and how other applications use the neighbor table or message cache maintained by the MHVB-B system.

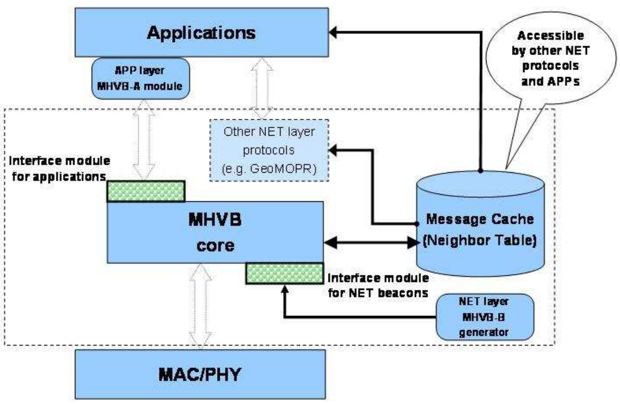

Figure 6: Potential Global Architecture

Figure 6 shows the potential architecture proposed for "MHVB"-based systems. It shows that MHVB-B output (the Neighbor Table) can eventually be used by applications as well as by other NET-layer protocols such as GeoMOPR [5], [6]. The Neighbor table is maintained by the mutual exchange of geographic location information between the vehicles cautiously taking into account the prescribed system constraints like coverage area and message freshness. The interface modules act a message processors for each application.

There are different types of messages that can be disseminated using the MHVB algorithm.

At Application layer, we can have:

- Permanent-periodic (Cooperative Awareness (CA), safety-critical) and

- Temporary-periodic (Event-driven, safety-critical) messages to be efficiently disseminated.

At Network layer, we have the permanent-periodic NET beacons (safety-critical) to be efficiently disseminated.

In summary: MHVB core can be used to efficiently disseminate above mentioned periodic messages, both at APP and at NET layers with the specificity to satisfy certain system requirements related to the area of dissemination (distance from originator) and to the latency of such messages.

3.2 MHVB-B specificities (NET layer)

The following are the specificities of the beaconing system

- Periodic messages issued at NET layer (beacons, but not just single-hop broadcast in our view, we instead take "distance and time" as dissemination constraints)
- Permanent dissemination only
- Every node in the network acts as source/forwarder
- Different dissemination criteria: number of hops, geographical area, time to live, etc.,
- There are predefined system constraints for NET layer beaconing (in our case: distance and time)
- Message format is defined (in our case: position, time stamp, velocity, vehicle ID, message ID)
- Each packet transmitted by a node contains at least the local information and only if dissemination constraints allow other nodes' information in the payload (in case of distance limit set to 1m or to hop limit set to 1, the packets will be always related to local information only).

4. SIMULATION RESULTS

In this section, we present and discuss some simulation results of the MHVB-B system. We have used the network simulator ns-2.28 [7], which was extended as described in [8] in order to model vehicular networks utilizing IEEE 802.11p technology.

4.1 Bandwidth Consumption

Bandwidth consumption is one of the important factors to be noted for any network layer communication system. As the world has become more and more bandwidth-hungry, it is essential to design systems in such a way that it does not hinder other high priority systems by taking extra bandwidth that could be have been used otherwise.

In order to evaluate the MHVB-B system, we have used the following settings.

Parameter	*Value*
NET-layer Beaconing Frequency (min.)	10 Hz
Beacon size	Variable
Radio Wave Frequency	5.9 GHz
802.11p Data Rate	3 Mbps
Communication range	250 m
Radio propagation model	Two-ray ground
Vehicle Density	Variable
Max. number of lanes	6
Average Speed of cars	90 kmph
Intended Dissemination distance	400m

Table 1: Simulation parameters

The beaconing frequency is kept at 10 Hz in order to test the system at extreme load conditions. The value will be well below this level after standardization. Figure 7 shows how much MHVB-B uses the given bandwidth in terms of maximum radio communication range and node density. The traffic scenario included around 150 cars distributed uniformly with some randomness on six lanes. The vehicular traffic was bi-directional with three lanes for each direction.

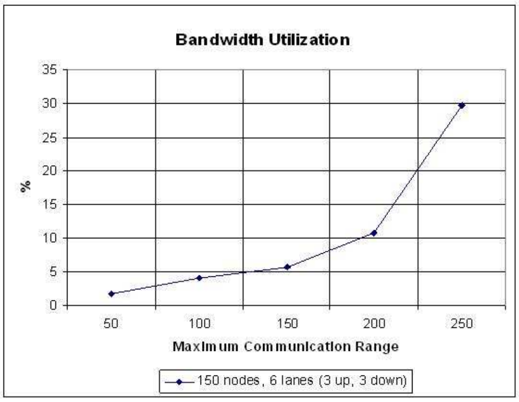

Figure 7: Utilization of Bandwidth as a function of maximum radio communication range

We show another result obtained for variation of node density (nodes / km) in Figure 8. The result gives an idea about the number of nodes that can be put in a defined traffic area without breaching channel usage limit for our particular communication system. Thus when other applications and/or protocols try to use the same channel, we will come to know more or less how much comfortably (i.e., how much bandwidth is left out for other systems) we can operate with our system. Also the plot has been made for varying maximum communication range.

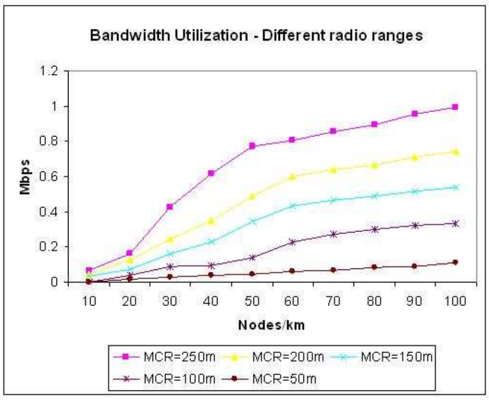

Figure 8: Utilization of Bandwidth for varying node densities

4.2 Dissemination delay

For Active Safety Communications, information latency is a fundamental performance factor and plays a vital role in design of a vehicular communication system. Such systems must not allow transmission of obsolete information and at the same time ensure that a transmitted information reaches the desired destination within acceptable safety requirements.

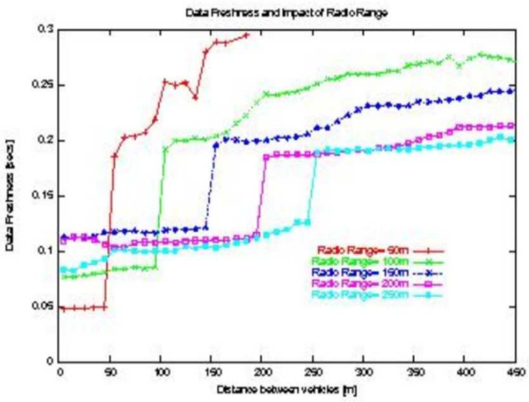

Figure 9: Dissemination delay

We provide another set of results which show the dissemination delay (see Figure 9) as a function of distance between sender and receiver. It is obvious that it is not efficient to use smaller transmission radius to cover the distance required for active safety. The freshness of the information becomes older when more hops are required to achieve the required area because the information waits at the cache of each forwarder in that particular hop before it gets forwarded to the next hop. This is one of the key issues to be dealt while designing any vehicular system to work with active safety.

4.3 Influence of node density on packet size

Here, we present another important performance parameter from a system design perspective: the average packet size as a function of node densities. Figure 10 typically gives us an idea how big our packet can be if we want to have an optimal functioning of the system for a particular density. This data is especially useful for high density scenarios which is a normal case in all modern vehicular scenarios.

The evaluation is done for different maximum communication ranges (MCRs). Interestingly, there seems to be a density around 50-60 vehicles / km beyond which the average packet size decreases and thereby any further increase in packet size will only result in high collision rates and a wastage of extra bandwidth. This point is still open for further investigations and will be carried out as future work.

5. CONCLUSION

In this work we have presented the concept of MHVB based vehicular communication systems for wireless information exchange. In particular an efficient NET-layer protocol MHVB-B was described, which provides geographic movement awareness of neighborhood to the vehicular communication system, satisfying latency and distance requirements. MHVB-B output, the Message cache, also called Neighbor Table, can be used by other NET-layer protocols and upper layer active safety applications. The communication process which is explained forms the base for other systems that require to exchange messages between different nodes on the network. For detailed reading of MHVB algorithm, please refer [1], [2], [3]. The evaluations show that the utilization of channel capacity is fairly reasonable considering high active safety requirements, respecting the transmission delay and the dissemination area to be covered.

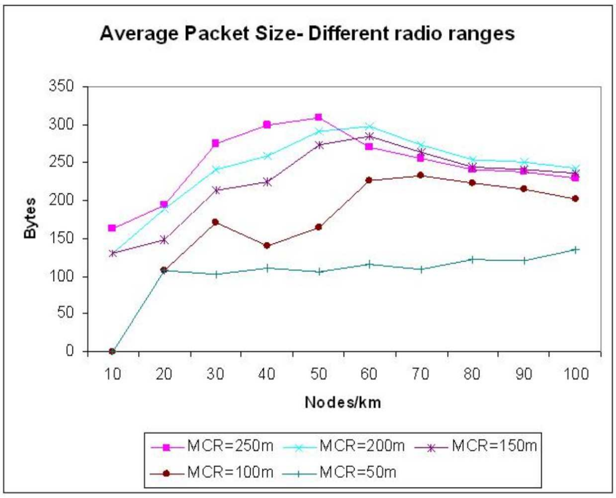

Figure 10: Influence of node density on packet size

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