Performance evaluation of directional broadcast to support Military Convoys communication in unplanned areas

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Abstract
Vehicular ad hoc network is an emerging technology used for dissemination of information generated by several types of VANET applications. Military applications are important VANET applications that needs to be considered for successful VANET deployment. It is vital to classify and characterize military related VANET applications along with traffic generated by these applications. VANET uses various broadcasting protocols for dissemination of information. A variety of broadcasting protocols have been presented in literature. One such broadcasting protocol is directional broadcast. This paper aims not only at classifying and characterizing military related VANET applications but also finding the suitability of directional broadcast for dissemination of military related applications against conventional broadcasting protocols.

***Keywords**: VANET, Directional Broadcast, Military related VANET applications, Routing Protocols, Classification of VANET Applications.*

1. Introduction

Vehicular Ad-hoc Networks is a subclass of MANET where the vehicles act as mobile nodes and the drivers are served with real time traffic congestion and security information in advance. VANETs provide the means of creation of Intelligent Transportation Systems (ITS) which is used to provide safety and comfort to vehicle drivers/operators. Intelligent Transportation Systems (ITS) is the real time use of information and communication technology to the transportation infrastructure or vehicles in the process of moving goods and people from one place to another place[1].High *dynamic* topology, *f*requent *disconnections, m*obility *modeling, b*attery *p*ower and *storage c*apacity, *i*nteraction *with o*nboard *sensors, and h*ard delay constraints are the main characteristics of VANETS. *The general applications of the VANETs are* Safety Oriented, Commercial Oriented, Convenience Oriented and Productive Applications. Unlike commercial use, VANET technology has not yet gain tremendous fame among contemporary armies of the world during their tactical convoy operations. Military related applications of the VANETS are mostly time and reliability critical, failing which may pose life threats to troops of the military convoy.

Following figure give the general overview of military related applications.

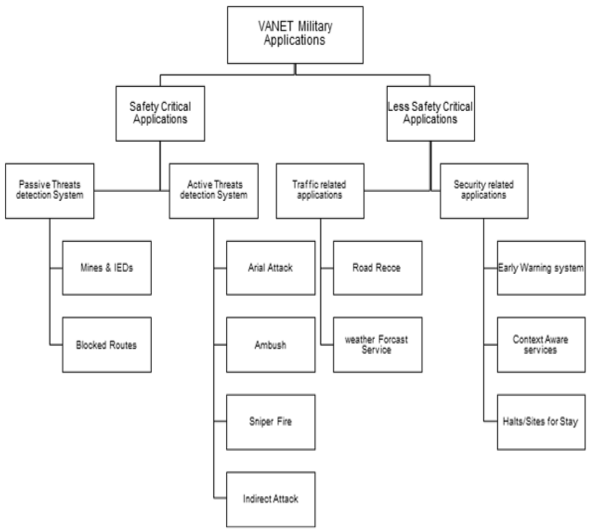

Figure 1:VANET Military Application Classification

Information dissemination in VANET is done through Unicast, Multicast and Broadcast. Unicast routing is specially used for entertainment and commercial applications in which data packets are transmitted by one source to a single destination [2]. Multicast is one-to-many communication, means data packets are transmitted by one source to multiple destination. Multicast communication is the one in which the message is transmitted by a source to arbitrary number of destination nodes, Broadcast stems from multicast as a special case in which the source node broadcast the same message to all nodes in the network[3]. As a special type of self-organizing wireless networks,

VANET selects the appropriate candidate vehicle as a rebroadcast vehicle so that the scheme of multi-hop data delivery may be accomplished [4]. The active /passive threat detection and its subsequent avoidance by the dissemination of safety messages are considered as the haul mark of the services offered by military applications of VANETs. In case of emergency the safety messages may be

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broadcasted among the entire convoy's vehicles that will be covering a specific area of few kilometers depending on the size of the tactical convoy. The degree of implicated causalities and damages may be reduced with the subsequent reduction of dissemination delay which is the time occurred between the emergence of the event and its propagation to the entire vehicles present in the affected area. Due to the limited wireless transmission range, convoy's vehicles will adopt multi-hop broadcasting for relaying safety messages. In case of military convoy movement, two issues are of main concern that include which type of multi- broadcasting may be adopted which is fully capable of achieving very tight message delivery time along with high degree of message delivery reliability. High dynamic and restricted mobility patterns of military convoys pose a challenging task in designing message propagation scheme having high reliability and low delay ratio.

As all the vehicles of the convoy are sharing the same wireless channel, the flooding broadcasting give birth to packet collision and transmission contention among the network vehicles, that degrades efficiency and reliability [5, 6].Many researchers have contributed widely in investigating the problem of safety messages dissemination in MAC-layer standard of VANET which is IEEE 802.11p protocol. Generally, in multi-hop broadcast, the farthest vehicle is designated as the next rebroadcast vehicle that leads to the reduction of end-to-end rebroadcast delay. In this paper, a mathematical and simulation analysis is used to demonstrate that in case of high density the farthest rebroadcast vehicle may experience large number of collisions, which become cause of high contention delay. An efficient broadcasting scheme is chalk out based on the results of the simulations which is capable of addressing low, medium and high density scenarios against various vehicle mobility modes and give optimal end-to-end delay that meets the convoy deadlines. This paper use simulation results to demonstrate the performance evaluation of directional broadcast (DB) against the omnidirectional conventional broadcast (CB) for military related application with the performance metrics of end to end delay, by varying the speed and number of vehicles of the convoy. With the increase in vehicle density the farthest rebroadcast vehicle may experience high degree of packet collision and will give birth to high contention delay. Thus an efficient directional broadcast algorithm is proposed to be used for the propagation of message dissemination in military tactical convoy operations. The directional broadcast algorithm adaptably selects the suitable rebroadcast vehicle according to the density and obtain a pretty good tradeoff between forwarding hops and contention delay. Rest of the paper is organized as : Section 2, give a brief picture of literature review. System and simulation design are given in section 3. Results and discussion are included in section 4 and section 5 give conclusion of the paper.

2. Related work

In VANET, dissemination of Info across the network via broadcasting is assumed to be good due to the reason that the traffic information is for a group of individual rather to attract a special one individual, it also eliminates route discovery complexity, topology management and address resolution. Where as in unicast routing a vehicle is required to be aware of the destination address along with the route running to a specific destination. A variety of broadcasting protocols has been reported in the literature but mainly it may be divided into Multi-hop broadcasting and Single-hop broadcasting. Multi-hop broadcasting uses flooding for the propagation of packets across the network. However, in Single-hop broadcasting information is not flooded in the network instead the receiving vehicles carries the received information, in its on board data base, and then it selects some of the record from its data base in order to broadcast it. Achieving an efficient coverage and multi-hop broadcast is always remained highly desirable and challenging task in VANETs [7, 8].

A Pure flooding scheme in Multi-hop broadcasting is inefficient due to the two main reasons scalability and packet collision. In denser network the redundant dissemination of same information packet will not only waste the limited bandwidth but also give birth to packet collision because a huge number of network vehicles will rebroadcast the same packet in the same vicinity at the same time which will cause broadcast storm and wastage of available bandwidth [9]. Packet collisions, packet redundancy and contention will give rise if flooding is initiated blindly. Reductions in redundant rebroadcasts and differentiating rebroadcast interval are the two main directions discussed in the literature to alleviate broadcast storm [10]. These issues may be solved by a good multi-hop broadcasting protocol. Most of the researchers urges that problems of scalability and collision may be resolved by reducing the redundant rebroadcast packets. This can only be done by constraining the number of the relying vehicles and select few vehicles to rebroadcast the information instead of letting every vehicle to rebroadcast. This way leads to the mitigation of channel contention caused by flooding in multi-hop broadcasting.

A Delay-Based Multi-hop Broadcasting approach assigned different waiting delays to the relaying vehicle, this assigned delay is inversely proportional to the distance between the transmitter vehicle and the next rebroadcast vehicle [11]. This way farthest vehicle is assigned the shortest delay which is the waiting time and is implicitly chosen the next rebroadcast vehicle[12]. The redundancy is curbed by not letting every vehicle to rebroadcast except the nominated one The reliability and hidden node problem in multi-hop broadcasting are addressed the efficient 802.11 based protocol known as urban multi-hop broadcast (UMB) protocol [11]. The UMB after dividing the road inside the transmission range into small segments delegates the rebroadcast priority to the vehicle belonging to the farthest segment and assigned it a long black burst duration. UMB is not a packet collision free protocol. Gokhan Korkmaz urges that further splitting of road segments into Nmax sub segments will resolve the conflict of black burst transmission duration and subsequently it will lessen the collision[13]. When there exists an intersection in packet dissemination's path, there will be a dire need to initiate a new directional broadcast at all road directions present at the intersection. A repeater is used at the intersection, to serve the purpose directional broadcasts. Repeaters had the best line-of-sight at the intersection to all the road segments, specifically when tall buildings exist around the intersection[14]. Smart broadcast (SB) is another delay based protocols that further alleviate the phenomenon of packet collision by further splitting the road segments into various sectors and delegates the rebroadcast responsibility to the vehicle lying in the farthest sector [15]. Simulations shows that SB performs outclass as compared to UMB in terms of message propagation speed because UMB encounter a high degree of packet collision with the increasing density. SB exhibits constant message propagation speed even if the vehicle density increases, it shows that density changes have almost less impacts on SB as compared to UMB. It is also revealed that SB which is a timer based protocols performs better than UMB[16]. Efficient Directional Broadcast (EDB) is another delay-based multi-hop broadcasting protocol and it work almost similar to UMB and SB protocols with the exception that it does not use RTB and CTB control packets. Furthermore, EDB also utilize the usage of directional antennas. EDB outclass UMB and SB by virtue of long transmission range, low redundancy, low packet collisions and space reuse. It has been observed that EDB performs better than other broadcasting protocols at road intersection [17].

ReC is another delay-based protocol, that uses geographic information for the selection of rebroadcasting vehicle[18]. This protocol, selects the rebroadcast vehicle as the closest vehicle to the neighbor's vehicle centroid, that have not received the message. Immediately after the reception of message the receiving vehicle started retransmission. This way unnecessary retransmission and transmission delays are reduced remarkably. However, in a high dense network, ReC needs complete and updated information about the neighboring vehicle which is a challenging task.

Probabilistic-based broadcasting assigns different rebroadcast probability to receiving vehicles [19]. In weighted *p*-persistence protocol, the receiving vehicle compute its rebroadcast probability, which is a function of the distance between the transmitter and itself [20].The rebroadcast probability is directly proportional to the distance between the rebroadcast vehicle and the transmitter vehicle. Since very few number of vehicles will be rebroadcasting, ultimately it will reduce packet redundancy and packet collision.

Both Probabilistic-based and delay-based broadcasting protocols may be used to enhance the message forward propagation speed. Since the number of forwarding hops are reduced between the transmitter and the farthest message receiving vehicle that leads to a contention problem between the rebroadcast vehicle and the vehicles outside the transmission range. As the farthest vehicle is designated as the next rebroadcast vehicle, and when it starts rebroadcasting, large number of network vehicles will contend with it, and will give rise to the enhancement in back off delay in wireless channel usage.

3. System/Simulation Design

NS 2.35 is used for simulating scenarios in this paper. There exist too many network simulators such as OMNeT++ OPNET , GloMoSim, NS2.35 is selected as the network simulator for this study as large number of institutes and people use NS2 in development and for research use to sustain and develop new routing protocols and also for their evaluation.NS-2 is highly acceptable in research community specially in VANET research studies. Ns2 is an open source Software developed by Using C++ and oTCL.

Cbrgen.tcl script included in Ns2.35 is used to generate traffic files and node movement scenario files are generated by Bonnmtion v2.13. Bonnmotion Is a java based tool, used to create scenario files which can be exported into different simulators such as MiXiM, GloMoSim/QualNet, ns-2, ns-3, ONE.and COOJA. Bonnmotion supports different mobility models including Manhattan mobility model [21]. Due to its support to Manhattan Mobility Model the tools is selected for the study. Both Traffic and node movement files are exported in ns-2 simulation *.tcl files. After simulation run the network communication traces are logged into trace files (having extension *.tr) the results of log traces are extracted by programing awk scripts accordingly and exported to MS Excel 2013 for graphs generation.

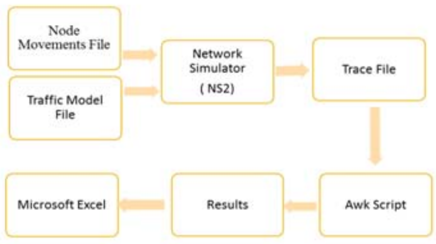

Figure 2 Simulation Method

Manhattan Mobility Model is used because it depicts a city scenario with an uneven traffic pattern which mimics traffic in unplanned areas. The reason to use Manhattan Model to simulate unplanned areas are that it has no traffic management system /traffic signals and defined speed breakers. Manhattan model has the ability to generate unexpected traffic congestion as in unplanned areas by sending different packets rates at different times in the simulation. Uneven traffic pattern may be achieved by varying speed and density of nodes.

Performance Metrics

The performance metrics used for purely military applications is end to end delay, because in Network Centric Warfare (NCW) [22] when the tactical convoy operation is carried out, end to end delay is of a paramount importance. Reducing the end to end delay communication to the lowest level ultimately reduce the degree of casualties and damages inflicted on the entire convoy operation. Reducing the end to end delay to the predetermined threshold give extra reaction time to the convoy commander in the articulation of his command and control at the hours of emergency like attack on the convoy.

Average End to End Delay

These delays have different reasons such as buffering at the time of routing, latency during route discovery retransmission, queuing at interfaces, time taken by transfer and delays at MAC layer. Average End to End Delay is calculated by the sum of time at which the packets received subtracted from the sum of time at which the packets are sent by the source divided by the sample size.

$$\text{Average End to End Delay} = \frac{\sum(\textbf{Revieved Packets time stamp} - \textbf{Sent Packets Time Stamp})}{\textbf{Sample Size}}$$

Acceptable Delay

Acceptable delays of our military applications have been worked out by analytical model of working military applications. Although these delays vary for different applications, dictated by different types of threats, however current values have been worked out explicitly for applications that require dissemination of information for dispersion purpose and asking for help from engagement elements of the entire convoy at the time of attack.

4. Results and Discussion

The results of the simulations are shown in figure 1-6. Figure 1, shows End to end delay that is measured and compared for information dissemination using directional broadcasting (DB) and conventional broadcast. For this special scenario when the vehicle density is low and also the speed of the convoy is quite low at about 5 km/hour, mimics the scenario when the tactical convoy is operated in a mountainous or dessert terrain. It can be seen that DB tends to meet acceptable delay threshold values when compared to conventional broadcast (CB). It may be established that at time 1.5 and 2 seconds the DB almost exactly meets the acceptable delays whereas the CB shows a high degree of variation from the acceptable delay. It may be inferenced that when operating in desert or mountainous terrain having no metaled roads infrastructure, DB outclass CB by having less end to end delay, which will facilitate convoy commander in executing his dispersion and necessary battle drills by giving extra allowance of time.

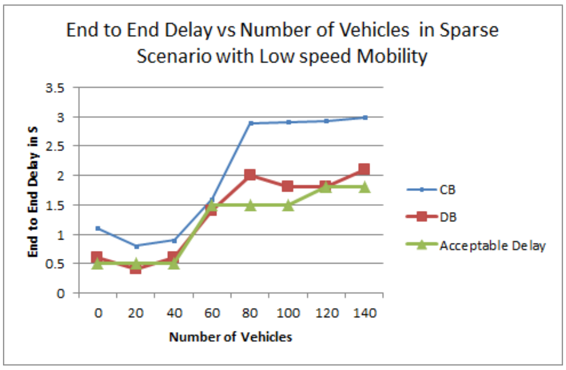

Figure 3 End to End Delay Vs. No. of Vehicles in Sparse Scenario with low mobility

Results presented in figure 3-5 shows, with increasing speed of vehicle, the overall performance in terms of end to end delay decreases, however, DB performs yet better that conventional algorithms for dissemination of information among vehicles in the area of interest. This simulation tested the system for medium speed scenario and high speed scenarios.

In figure 4, when the convoy has increased its speed from 10 Km/hour to 20 Km/hours, a remarkable increase in end to end delay has been observed. However the performance of the DB is still better than that of the CB, which may be quite helpful when calling for engagements elements in Net centric Warfare (NCW) [22]. Almost the same inferences may be achieved by increasing the convoy speed from 20 to 30 Km/hour. The performance of the end to end delay is degraded however, DB outclass CB, by giving an extra allowance of 2 seconds by facilitating the convoy commander having extra reaction time of 2 seconds.

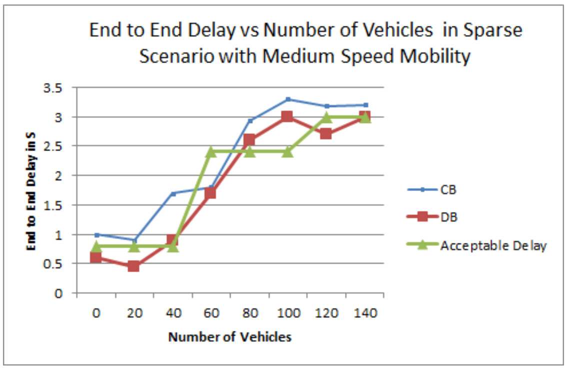

Figure 4 End to End Delay Vs. No. of Vehicles in Sparse Scenario with Medium mobility

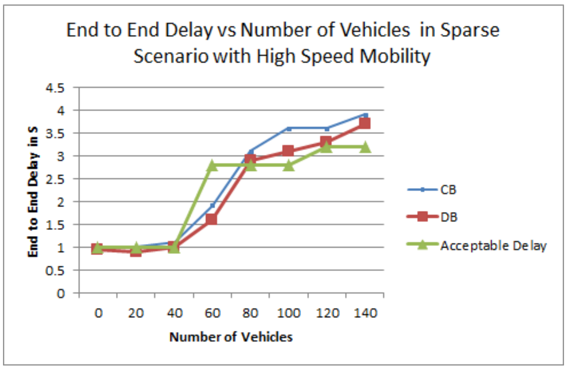

Figure 5: End to End Delay Vs. No. of Vehicles in Sparse Scenario with High mobility

Figure 6, shows End to end delay that is measured and compared for information dissemination using directional broadcasting (DB) and conventional broadcast in Dense scenarios. In Dense scenarios number of vehicles in military convoys varies from 160 to 300. It can be seen that DB tends to perform better in meeting acceptable delay threshold values when compared to conventional broadcast (CB).

Results presented in figure 6-8 shows, with increasing speed of vehicle in the high density scenarios, the overall performance in terms of end to end delay decreases, however, DB performs yet better in meeting acceptable delays for military related critical applications than conventional algorithms for dissemination of information among vehicles in the area of interest. This simulation tested the system for medium speed scenario and high speed scenarios, and found the similar results. The results are justified with following advantages of DB over CB.

A. DB only directs messages in the direction of area of interest and contribute towards security of information as the information propagation area is in a specified direction.
B. It gives better bandwidth utilization as the information is flooded in a specified direction instead of Omni direction.
C. Chances of broadcast storms are minimized
D. Overhead is minimized.

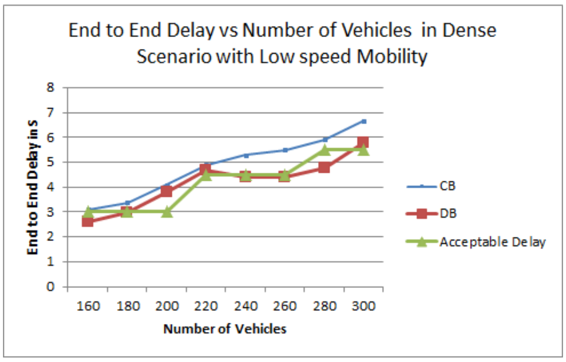

Figure 6: End to End Delay Vs. No. of Vehicles in Dense Scenario with Low mobility

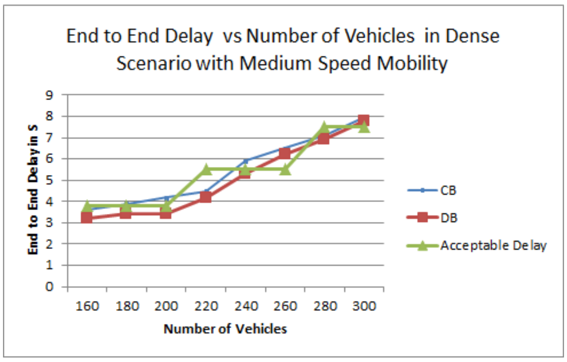

Figure 6: End to End Delay Vs. No. of Vehicles in Dense Scenario with Medium mobility

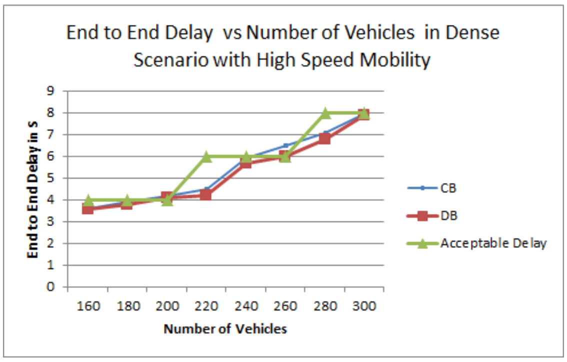

Figure 6: End to End Delay Vs. No. of Vehicles in Dense Scenario with High mobility

5. Conclusion and Future Work

The objectives of this research were to identify the problems faced by the VANET routing and then broadcasting in Military related applications. The problems were identified and simulated in this research were characterized by military movement in different terrains. Different military related application scenarios were designed with varying speed, different packet sending rates and varying density to show unexpected traffic density speed and congestion in the operation of tactical convoy. The mobility model used for the study had no traffic signals or speed breakers thus mimics military applications and its traffic.

In particular Average end to end delay, threshold values were computed for Active threat detection application explicitly based on experience for the purpose of convoy dispersion and asking for help from shooters grid of the convoy. Validated the efficacy of directional broadcast against the conventional Omni-directional broadcast for end to end delay. It was found that Directional broadcast for information dissemination gives 13% better results. The research couldn't improve the results further because of the several factors like simple and non-intensive traffic generation.

Future work continues to investigate and determine the threshold values of throughput so as to validate the performance of Directional broadcast against the conventional Omni-directional broadcast with effective throughput.

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