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QoS Measurement of Single-hop Periodic Communication in Vehicular Environment

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ABSTRACT

Life safety on road is the key motivation behind the research in Vehicular Ad-hoc Network (VANET). As basic communication mechanism VANET-equipped vehicles broadcast periodic safety beacons to keep the neighboring vehicles aware of the situation at all times. Well known broadcast communication problems i.e. hidden/exposed nodes, collisions and inherent challenges in VANET e.g. dynamic environment, limited bandwidth, are prone to hinder the exchange of potentially lifesaving information. Furthermore, the most of vehicle-to-vehicle broadcast communication will comprise of single-hop periodic safety beacons thus it becomes important to measure their Quality of Service (QoS) under congested vehicular environment. With the help of extensive simulations, a detailed analysis is presented to assess the performance of single-hop periodic safety beacons. Parameters i.e. communication range, beacon generation interval and safety beacon size are effective in controlling the QoS levels. The QoS metrics used for the evaluation are packet delivery ratio, per-node throughput, end-to-end delay and Packet loss ratio breakup. Simulation results show that in congested environment it is very difficult to meet the safety application's QoS requirements.

KEYWORDS

VANET; safety beacons; single-hop; PDR; PLR

1 INTRODUCTION

Vehicular ad-hoc network (VANET) is essentially a part of Intelligent Transportation System (ITS) and inherits some of its technological background from Mobile Ad-hoc Network (MANET). Primarily VANET applications are designed to human life safety however many applications not related to safety are also envisioned e.g. toll collection, internet etc. All the information exchange between vehicles takes place via periodic or event-driven messaging.

Providing efficient safety messaging scheme is a challenging task due to some specific characteristics of VANET i.e. high mobility, limited channel bandwidth, very short communication duration, and highly dynamic topology. Furthermore the broadcast nature of communication in VANET, may lead to saturated/congested channel. Being basic safety communication mechanism, single-hop periodic safety beacons (SBs) will predominantly occupy the control channel communication and may easily consume entire available bandwidth. Most of the previous research work is focused on multi-hop communication.

Thus for developing efficient safety messaging schemes it is imperative that effects of single-hop periodic SBs on overall VANET performance be known beforehand. Furthermore it is also necessary to evaluate the parameters involved in controlling the behavior of periodic safety beacons i.e. beacon generation interval (BGI), safety beacon size, and communication range (CR)/transmission power. In this study, extensive set of simulations are carried out to measure the impact of single-hop periodic safety beaconing on VANET performance and also to gain insight into parameters that control periodic beaconing. Packet Delivery Ratio (PDR), per-node throughput and end-to-delay (e2e delay) are quality of service (QoS) metrics used for the evaluation. In addition a breakup analysis of Packet Loss Ratio (PLR) is also provided.

Successful and timely delivery of SBs is essential for saving lives in potentially dangerous situations on the road. The simulation results presented in this study can be potentially helpful for VANET application designing and standard development.

The rest of the paper is organized as follows. Section-2: related work, Section-3: Simulation Setup, Control Parameters, QoS Metrics, Section-4: Simulation Results and Analysis, finally this paper is concluded in section-5 followed by references.

2 RELATED WORK

A broad review regarding VANET communication challenges is given in [1]. VANET primarily uses broadcasting as the basic communication mechanism. Mostly safety beacons are broadcasted in single-hop range while event-driven messages can be disseminated over multiple hops. Multi-hop broadcasting, i.e. flooding has been extensively studied in the literature [2-5]. However one-hop broadcasting has lacked similar attention in VANET studies.

Many studies such as [6-11] partially explored the periodic safety beaconing effects on VANET. Some of these studies simply propose performance enhancement schemes based on general assumptions regarding broadcast communication behavior. Thus these studies lack in-depth analysis of single-hop periodic safety beaconing. Perhaps the most closely related work to this study is [12][13][14], in which the authors performed simulation studies for exploring some predefined VANET message dissemination characteristics.

Priority access is the main focus of [12] and evaluation parameter used is one hop broadcast message reception rate. As the focus is priority access evaluation, simulation are carried out with limited configurations i.e. communication range of 100m, 200m and packet size of 200B, 500B only. Different data rates and somewhat similar communication range, packet size for simulation settings are chosen by the authors of [13], which is also one the earliest works in this area. Furthermore evaluation parameters used are probability of reception failure and channel busy time. Simulations performed in both of these studies basically use earlier version of NS-2 with several shortcomings in 802.11 MAC and PHY layers e.g. the inability to handle collisions, path loss calculations and interferences. A detailed analysis on the shortcomings of 802.11 in previous versions of NS-2 and comparison of 802.11a/802.11p can be found in [15] and [16] respectively.

Yousefi et al. use different adjustable network parameters in [14] i.e. power/CR, packet size and packet dissemination interval, which is similar to current study. However their choice of values for these parameters is an important aspect to look into. Such as simulating packet size of 100 and 200 byte only is not realistic, according to [17]actual message size will be rather large i.e. between 280 to 800 bytes including the security overhead. Furthermore a communication range of up to 300m is a reasonable choice in jammed traffic scenarios but does not cover various traffic situations where a wider range is required e.g. sparse traffic conditions. Similarly 100ms and 200ms packet dissemination intervals do not provide significant insight into the overall behavior of the parameter which we find to be very important factor for enhancing the performance of VANET in terms of packet delivery (discussed later).

Limitations mentioned above provide the motivation for this research. In this study, results from extensive set of simulations are presented to measure the impact of adaptable parameters that govern QoS in VANETs. Moreover simulations in this study are performed using enhanced 802.11 NS-2 [15] module that provides more realistic wireless MAC and PHY layer thus furnishing more accurate results.

3 ADAPTABLE PARAMETERS, QoS METRICS, SIMULATION SETUP

Parameters that can be adapted to enhance the QoS level, performance metrics are introduced. Furthermore simulation environment and settings are also described in brief.

3.1 Adaptable Parameters

Three of the adaptable parameters are introduced as under:

Transmission Power/Communication Range: It is the most commonly used parameter in the literature for performance optimization. Transmission power can be increased or decreased to reduce/adjust number of nodes competing for the shared channel thus reducing collisions. For VANET, maximum transmission power corresponding to a communication range of 1000 meters is desirable while lower bounds vary according to underlying application requirement in different road conditions.

Beacon Generation Interval (BGI): The Beacon Generation Interval (BGI) can be defined as the rate at which a node generates messages per unit of time. It is generally assumed that DSRC supported vehicles will exchange safety beacons every 100msec which can be expressed as 10 packets per second (10pkts/sec). However different applications may require different BGIs. Furthermore the BGI constraints defined for safety applications should account for human reaction time, vehicle speed/ acceleration, positioning update frequency of GPS equipment and propagation delay. According to [18], mean human reaction time for close encounters is 700ms or higher, anything beyond this point may have no practical use as the driver is able to react faster than the VANET itself. However taking into consideration the communication delay, a maximum BGI of 500ms is deemed practical.

Beacon Payload Size: Amount of actual information in a message excluding the headers is the beacon payload size. In

VANET beacons may carry various types of information i.e. velocity, position, hazard information and more. Generally more information carried by a beacon means a well informed neighborhood with higher level of safety. However, increasing beacon size contributes towards channel saturation which is certainly not a desired feature in any network particularly in VANETs.

3.2 QoS Metrics

QoS metrics used for performance measurements are briefly described below.

Per-node Throughput: Amount of data delivered to a particular node over the period of time is known as throughput of that particular node. Overall network throughput can be obtained by cumulating throughput of all the nodes in the network.

End-to-end Delay: Time duration between packet's generation at the sender and receiver getting it, is described as end-to-end delay. It can also be described as time taken between packet sent from a specific layer and received at the same layer at the recipient. In current case, the time taken between application layer of the sender and recipient is considered.

Packet Delivery Ratio (PDR): Is one of the most important and widely used QoS metrics in network communication. PDR can be measured over single and multi-hop communication. However in this study, only single-hop broadcast packet delivery ratio is evaluated. PDR can be obtained by two methods, either by calculating percentage of recipients of broadcast packet or by calculating percentage of packets successfully received by receiving nodes from a specific sender. Later method is used in this study and is named as PDR-beacons.

Packet Loss Ratio (PLR) breakup: Packet Loss Ratio is basically the opposite of PDR. In current version of ns-2 802.11, packet drop events are now tagged with appropriate drop reasons. According to [19] following are the drop event tags currently available in NS-2.

DND: Reception power is higher than the carrier sensing threshold but not enough to decode the data even without any interference

PXB: a message is dropped when the PHY interface is in the progress of receiving a frame preamble

SXB: a message is dropped when the PHY interface is IDLE, but busy searching for a valid preamble

RXB: a message is dropped when the PHY interface is busy in receiving a frame

TXB: a message is dropped when the PHY interface is busy in transmitting a frame

There are no standard values for the measurement of above mentioned metrics; however we assume some logical values based on the results obtained via simulations.

3.3 Simulation Setup

Broadly stating, following steps were taken during the course of this study.

- A simulation grid is designed with a 6-lane highway at its centre
- Vehicles are pseudo-uniformly deployed on the highway
- NS-2 built-in 802.11p module's simulation parameters were appropriately set to match VANET draft standard

- Two sets of simulations were carried out,
  - For first set, CR of all nodes was fixed at maximum while BGI and SB size were changed within practical range limits however other settings remain similar
  - In second set, BGI was fixed at 100ms; on the other hand both CR and SB size were changed within practical range limits and step size however other settings remain similar
- Results for each of the given QoS parameters were extracted from simulation traces

Traffic Scenario:

The simulation scenario consists of a six lane 6km long highway with three lanes in each direction. Each lane has a width of 3.66m while lanes on either direction are divided by two meters of separator distance. The results presented are based upon nodes placed at the central 2000m area. A total of 1240 nodes are pseudo uniformly deployed on the highway.

A survey in [20] reveals ns-2 as the most frequently used simulation tool in VANET papers. NS-2 is also a suitable choice considering its credibility and popularity among network research community. In this study version 2.34 of ns-2 [21] with an overhauled 802.11 PHY and MAC. NS-2 is used. Some of the main simulation parameters and their corresponding values used here are shown in Table-1. Details of these parameters and their respective settings can be found in [22].

Table 1. Simulation parameters and their respective settings.

Parameter	**Corresponding value/s**
Comm. Range (m)	50, 100, 200…1000
SB generation interval (ms)	50, 100, 150… 500
SB payload size (B)	200, 300 … 800
Frequency	5.885GHz
Basic data rate	3Mbps
Data rate	6Mbps
Bandwidth	10MHz
Noise floor	-99dBm
RxTh	-91dBm
CSTh	-94dBm
Capture effect	On
SINR_PreambleCapture	4dB
SINR_DataCapture	10dB
Antenna height	1.5m
Antenna gain Gt, Gr	2.512dB
Slot time	16µs
SIFS time	32µs
Preamble length	32µs
PLCP header length	8µs
Contention window	min. 15 / max. 1023
Simulation time	21sec/each

4 SIMULATION RESULTS AND ANALYSIS

Per-node Throughput Measurements:

Figure 1 shows the per-node throughput variations caused by tuning BGI and safety beacon (SB) size. For BGI of 200msec and below, varying the beacon size does not cause major changes. Noticeable variations occur with BGI of 200msec and above as throughput increases significantly with increment in SB size. With SB payload between 700B to 800B throughput increases along with the increment in BGI. Maximum throughput is measured with SB size of 800B and BGI of 500sec. However, for optimal throughput, safety application with strict BGI requirements may chose BGI between 200-300msec with smaller SB sizes, while safety applications requiring larger information exchange and lesser urgency have to use BGI of 400-500msec.

Results in Figure 2 show that higher throughput is achievable with wider CR. To monitor the effect of Communication Range (CR) on per-node throughput BGI was fixed at 100ms while tuning the CR and SB size. Results show that CR of 500m and below with larger SB size is more suited for maximum throughput while overall process is reversed with CR between 500-1000m. Thus when using BGI of 100msec, it is desirable to have maximum CR along smaller SB size for maximum throughput.

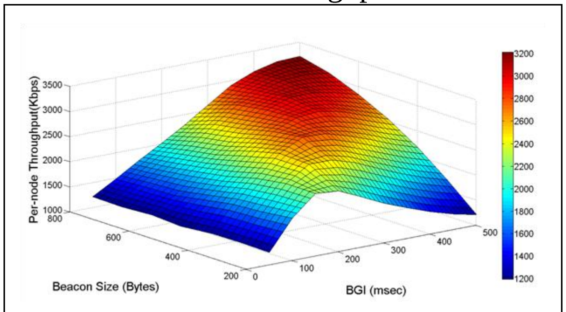


Figure 1. Throughput results for BGI vs Beacon size, (CR=1000m)

Comparison of Figure 1 and 2 reveals that SB interval is relatively the most significant parameter for optimizing per-node throughput. An ideal combination for maximum throughput in the given scenario would be 1000m CR, 800B SB size and 500msec BGI. Moreover it is also evident from the results that techniques relying solely on reducing transmission power/CR will have negative impact on network throughput.

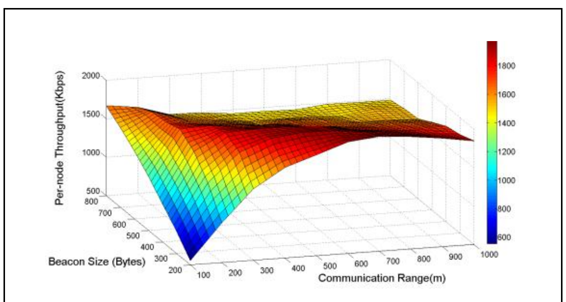


Figure 2. Throughput results for CR vs Beacon size, (BGI=100msec)

End-to-end Delay (e2e delay) Measurements:

We calculate averages of various nodes in a fully deployed network. Although graphs obtained are not smooth in nature however the results shown are useful in determining overall trends of e2e delay within the margins of tuned parameters.

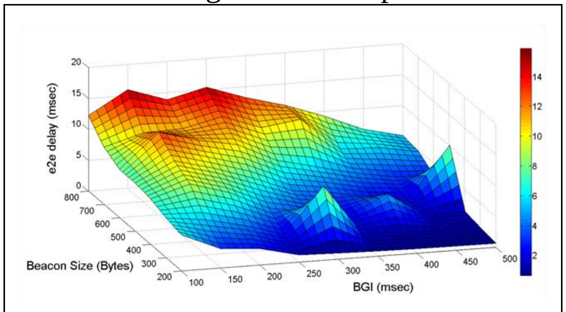


Figure 3. e2e delay results for BGI vs Beacon size, (CR=1000m)

From Figure 3 and Figure 4, it is clearly visible that a smaller SB size is advantageous for least e2e delay over longer distances. Moreover e2e delay with 800B size over longer distances is still within the acceptable limits (10-20msec) and does not require higher BGI. As of the results obtained with BGI interval of 50msec (not shown due to presentation reasons), e2e delay varies from 89msec to 570msec for SB sizes of 700 to 800B respectively. Thus it is apparent that BGI of 50msec and below is not suitable with larger SB size under for safety applications with stringent e2e delay requirements.

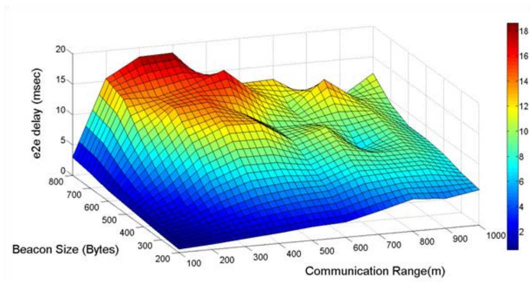


Figure 4. delay results for CR vs Beacon size, (BGI=100msec)

Packet Delivery Ratio (PDR) Measurements:

PDR results in Figure 5 and Figure 6 show that reducing CR improves overall PDR but the variation is significant only in shorter CR i.e. 200m or less. However by carefully adjusting the BGI it is possible to achieve higher PDR-beacons e.g. increasing 50msec BGI almost doubles the delivery rate at CR of 1000m. It is also evident from results that smaller SB size contributes towards higher PDR-beacons but not as effective as BGI or CR.

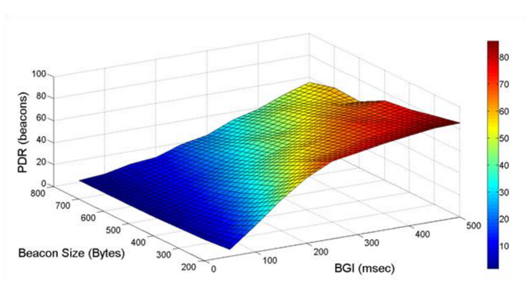


Figure 5. PDR results for CR vs Beacon size, (BGI=100msec)

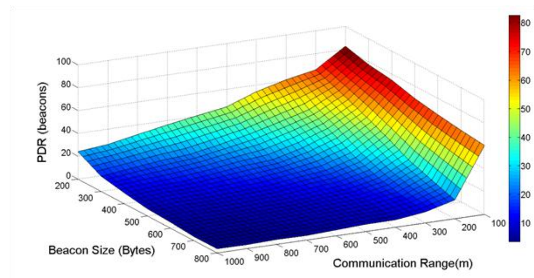


Figure 6. PDR results for CR vs Beacon size, (BGI=100msec)

Packet Loss Ratio (PLR) breakup:

It is now understood that beacon size impact on PDR is relatively less significant, PLR results with only beacon size of 200B, 500B and 800B are shown.

Figure 7 and Figure 8 show overall PLR with the fixed range of 1000m. At 100mec BGI, all beacon sizes have almost similar PLR. With the increment of BGI, reduction in PLR is significant for all beacons payloads. Furthermore the PLR gap between 200B and 500B beacon size initially increases with the increment in BGI and reaches maximum (approx 52% difference in PLR) at 250msec of BGI. However the gap shrinks from this point onwards and is reduced to approx 30%. With communication range of 1000m minimum overall PLR is achievable with maximum BGI and smallest beacon size.

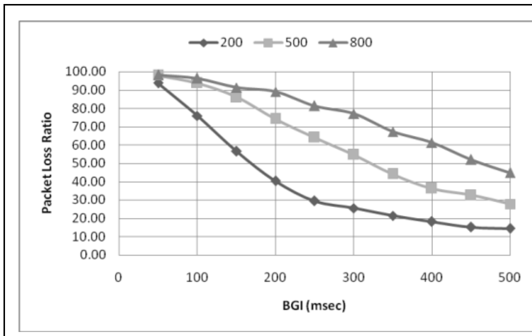


Figure 7: Overall PLR with CR of1000m

With BGI of 100ms PLR increase drastically with communication range of 100 meters and above. On the whole, smaller packet size contributes towards minimizing PLR.

It can be seen from figure 7 & 8 that increasing BGI has significant effect on PLR as compared to solely adjusting communication range. Furthermore relatively beacon size also has significant impact on overall packet loss ratio.

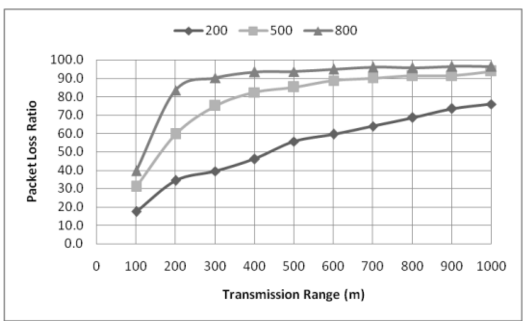


Figure 8: PLR with BGI of 100ms

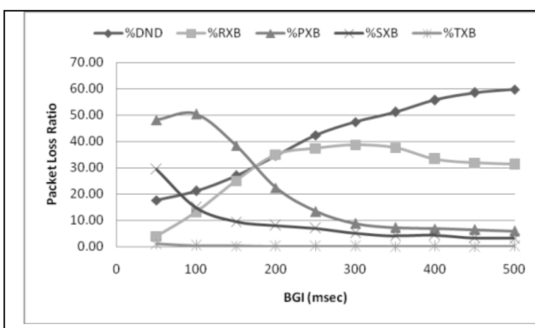
Figure 4a, 4b and 4c show breakup of packet loss ratio. Percentage shown in these figures is from within the lost beacons only. Increasing beacon generation interval also results in higher amount of DND. An increase in dropped packets due to insufficient reception power is a result of higher packet delivery at longer distances. DND effect decreases as beacon sizes increases because larger beacons may require higher energy to transmit.

Higher packet reception caused by longer BGI also results in more beacons lost due to channel busy in frame reception (RXB). With smaller packet size i.e. 200B, RXB consistently remains between 30%-40% after BGI of 200ms.Overall RXB decreases with larger packet size but increase with longer BGI.

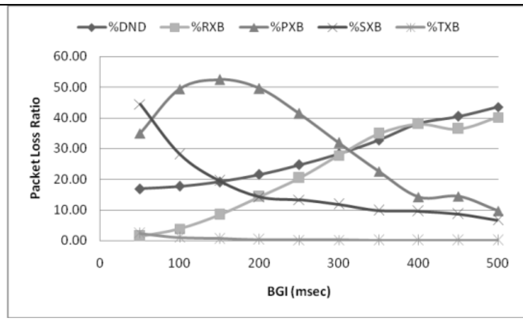
Overall beacon loss due to PXB increases when beacon size increases however longer BGI has positive effect. SXB shows similar behavior to PXB. Beacon loss caused by TXB only comes into play with BGI of less than 100msec. Beacon size almost has no effect on TXB.

Figure 5a, 5b and 5c show breakup of packet loss ratio with BGI fixed at 100ms, with varying communication ranges and beacon sizes. A decrease in CR/transmission power is reflected as an increase in DND, which is attributed to insufficient reception power. RXB loss shows similar behavior especially with larger beacon sizes.

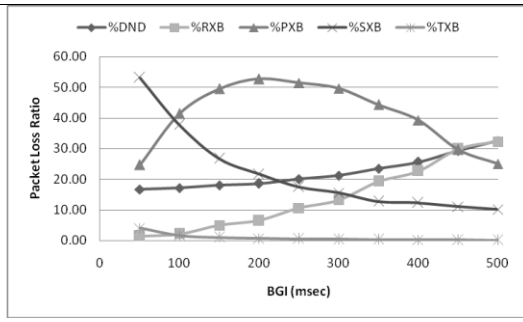
Shorter communication range results in lower beacon loss caused by PXB, however overall PXB loss ratio is more dependent on beacons size instead of communication range. Beacons lost when physical layer is idle but busy searching for a valid preamble (SXB) shows a downward trend when transmission range is decreased and similar to PXB its overall ratio is also dependent on beacon size.



a.

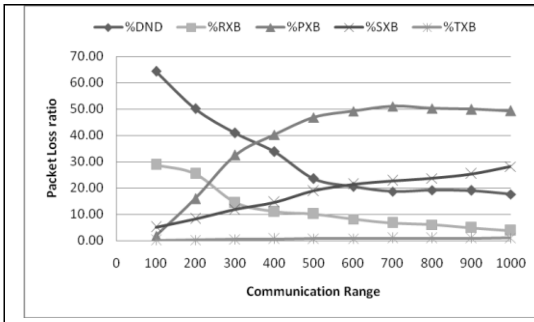


b.



c.

Figure 9: PLR with CR of 1000m and Beacon Size a. 200B, b. 500B, c. 800B



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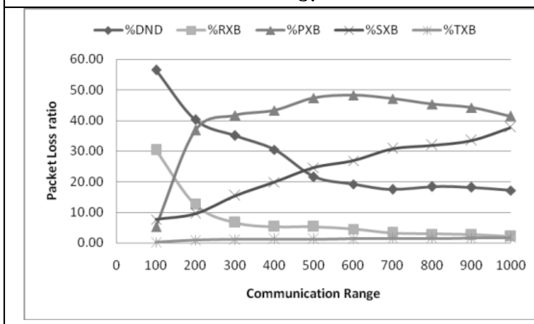
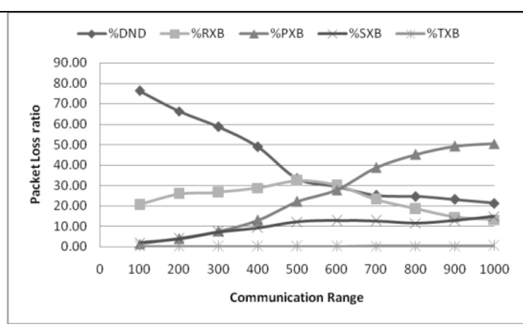


c.

Figure 10: PLR with BGI of 100ms and Beacon Size a. 200B, b. 500B, c. 800B

All the variations in communication range, safety beacon size, and beacon generation interval have the least effect on a nodes ability to transmit periodic safety beacons. Furthermore, BGI of less than 50ms is no desirable especially with larger beacon size.

From the results shown here it is evident that for achieving optimal QoS in VANET, dynamic adjustment of tunable parameters will play a crucial role.



a.

5 CONCLUSIONS AND FUTURE WORK

In this paper simulation based QoS measurement of single-hop periodic beaconing in VANET is presented. It was observed that optimal PDR at maximum CR (1000m) can be achieved at maximal BGI i.e. 500ms. If the BGI interval is fixed at 100ms the CR needs to be reduced significantly (e.g. < 200m) for higher PDR. However for non-safety applications (e.g. multimedia advertisements) per-node throughput may serve as a better QoS metric. Choosing optimal CR and BGI for higher per-node throughput depends on the message size e.g. for the given scenario, with a message size of 800B ideal CR, BGI are 1000m and 500ms respectively. Furthermore, various causes relating to scheduling of safety beacons were discussed. In the light of obtained results it is understood that situation-aware dynamic adaption of CR and BGI is crucial for optimal QoS in VANETs. In the future simulations are to be performed with a probabilistic propagation model such as Nakagami.

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