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QOS-AWARE SNR ADMISSION CONTROL MECHANISM

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ABSTRACT

Vehicular Ad-hoc Network (VANET) becomes a fundamental subcategory of mobile ad-hoc networks which provides vehicles to communicate with each other and with roadside infrastructure in a smart way. Various VANET performance challenges are considered in terms of Quality of Service (QoS) due to vehicles speed and transmission rates. Different problems cause performance degradation as performance anomaly where high rates vehicles has to meet the speed of the low rates vehicle while transmitting data. In this paper a QoS-aware Signal to Noise Ratio (SNR) admission control mechanism (QASAC) is proposed to handle the performance anomaly problem while maintaining the QoS levels for different traffic types. QASAC has been compared against the latest SNR based admission control mechanism. QASAC has enhanced the performance of data delivery up to 23% in terms of data dropping rates for high priority traffic.

KEYWORDS: *Signal to Noise Ratio (SNR), Vehicular Ad-hoc Network (VANET), admission control, Quality of Service (QoS)*

1. INTRODUCTION

Recently, Vehicular Ad-hoc Networks (VANET) becomes more popular and widely deployed all over the roads across the world. Most of modern cars are equipped with Wireless modules which provides vehicles to communicate with each other's and with communication control points [1]. Enhancing Inter-Vehicle communication and roadside communication are considered as the most popular wireless communication research topic. VANET allows road vehicles to notify other vehicles about traffic jams, sudden stops and other hazardous road conditions[2]. The huge number of expected benefits of VANET and number of supporting vehicles are likely become the most realized implementation of mobile Ad hoc networks Short range IEEE 802.11 can be used for vehicles communications using suitable radio interface technology[3]. However a new slandered for both physical and MAC layer has been developed to meet the requirement of communication between vehicles, IEEE 802.11p [4] is an approved amendment to the IEEE 802.11 standard which provides Wireless Access in Vehicular Environments (WAVE). Enhancements were applied to 802.11 to support the applications of the Intelligent Transportation Systems[5].

The fundamental different that can be encountered between Mobile Network (MANET) and VANET is the absence of infrastructure in the case of MANET[6]. On the other hand, VANET includes access points locations along the vehicle road sides and these vehicles access services based on predefine infrastructure. VANET implementation encounter different challenges. Adjusting Quality of Service (QoS) parameters is considered as one of the most critical challenges[7]. Frequent VANET topology changes and vehicles high speed make the task of maintaining QoS parameters a very complicated issues in contrast to wired networks where only it described in terms of delay and throughput. Vehicle high mobility and state information required for routing procedure add extra difficulties for reliable QoS mechanisms[8]. Rapid advances were proposed in wireless communication mechanism to support advanced safety of vehicle applications. Dedicated Short Range Communication (DSRC) [9] is short to medium communication range service which support both private and safe communication. DSRC were proposed to provide reliable, safe and high rate vehicle to vehicle (V2V) and Vehicle to Roadside communication which can minimize latency inside a relatively small communication zone[10]. Higher speed mobility of VANET nodes can make the problem of performance anomaly more critical where channel quality become much lower and thus lower data rates. The results of higher speed vehicles movement has not been investigated in terms of performance degradation and anomaly problem. The consequences of starvation problem is also can be catastrophic, particularly in the case of VANET safety application where human lives are on the line.

VANETs support a wide range of applications where different classes of data is exchanged, VANET traffic includes traditional data and critical safety data. Traditional data is related to driver assistance, cooperative driving and advertising. However high important data include system vehicle collision warnings, security distance warning, and road emergency alerts[11]. The main contribution of this research is to handle performance anomaly problem using QoS aware mechanism which can apply different handling parameters for different classes of data with different priority to achieve the highest possible values of data delivery of high priority data.

Based on our knowledge, all of the recently proposed performance anomaly mitigation mechanism handle the VANET traffic in the same manner regardless to its priority. Moreover , recent performance handling mechanism are all implemented using the standard IEEE 802.11 for data communication , 802.11p has not been investigated where it was proposed to meet the requirements of VANET networks and vehicle mobility. So the main issue is how to implement a performance anomaly problem handling mechanism while maintaining different priorty class's requirements. The main contribution in this paper is to handle performance anomaly problem using a QoS aware mechanism which can apply different handling parameters for different classes of data with different priorty to achieve the highest possible values of data delivery of high priority data.

The rest of the paper is organized as follows: In section 2 we discuss the state of art related work. Section 3 presents the proposed QoS-Aware SNR admission control mechnism. Section 4 presents the experimental procdures and result discussion. And finally conclusion is made in Section 5

2. RELATED WORK

Different approaches have been proposed to overcome the problem of performance anomaly and QoS issues in VANET. A rate adaptation algorithm (RA-ARF) that takes the extra relay path into account is proposed in [12] , where a new Relay MAC (R-MAC) protocol is proposed to work instead of the MAC protocol of IEEE 802.11. The main objective of the new R-MAC is to eliminate the problem of performance anomaly in IEEE 802.11 by using two relay nodes . On the other hand the second choice allow him to choose two different nodes which will act as relays to help him to complete transmission depending on predefined relay selection algorithm. Relaying technique in [13] is the main mechanisms used in this relaying approach . The main drawbacks include the delay and processing overhead due to relayed paths and maintain relay links. Also the transmitting status reflect the channel quality which cause increased number of packet retransmission and data loss. Transmission Rate-based Packet Size Adjustment (TRPSA) mechanism, is proposed in [14] to overcome the unfair issue under the situation of multi-rate and multi-node. It mainly adjust the size of the packet depending on to the transmission rate. This mechanism guarantees that these nodes with variable transmit rates can fairly access wireless channel. TRPSA is used to tune packet size proportional to transmission rate where higher transmission rate led to larger the packet size that can be transmitted. However the main drawbacks is that packet defragmentation and smaller packet size cause higher processing overhead and channel utilization.Also,Unfair channel utilization where large or small packet size occupies transmitting channels. Nodes starvation due to large packet size and longer channel utilization in VANET environment.

Context Aware multi Rate Control (CARC) is proposed in [15] to avoid unnecessary rate adaptations of Auto Rate Fallback (ARF). In CARC, communication situations or context are categorized into two categories. One is called personal mode, and the other is local/public mode. In the personal mode, ARF or any rate adaptations are turned off and the transmission rate is fixed with the highest rate, for example, 54 Mbps in 802.11g. In the local/public mode, ARF is turned on. However, in the case of Vanet Personal mode is activated where transmission rate is fixed with the highest rate. The Low rate traffic is also completely ignored.

Cooperative channel assignment (CoCA) [16, 17] were proposed. These two protocols is also compared against identical channel assignment (ICA) [18] and Hyacinth [19] which are a common multi-channel protocols that do not address the problem of performance anomaly. The effect of performance anomaly mitigation of RB-CA and CoCA is also investigated. The main problem of CoCA is that most of the links that are available are restricted in single-channel networks and high delay for higher rates traffic where single hop is replaced by multi-hop for higher data rates.

A signal-to-noise ratio (SNR)-based admission control scheme that excludes vehicles with bad channel qualities is proposed in [20]. The Proposed scheme does not allow nodes with low transmission rates to capture the channel at all to prevent the performance anomaly problem via admission control. The amount of time taken from nodes with low transmission rates can be used by nodes with high transmission rates, and thus high rate nodes can transmit more packets than low rate nodes during the same time period. AP estimates the SNR through association procedures. IEEE 802.11 WLAN defines two scanning modes for association: active and passive scannings. In both modes, a vehicle can estimate the SNR by receiving a probe response (in active mode) or beacon frames (in passive mode). After that, the estimated SNR information is reported to the AP by means of an association request frame. Based on the SNR estimation, the AP performs an admission control scheme which key idea is to exclude vehicles with low transmission rates. By doing so, the performance anomaly problem can be mitigated and the overall throughput can be improved. However it does not allow nodes with low transmission rates to capture the channel at all and starvation problem in low rate nodes

3. RESEARCH METHOD

The concept of signal to noise ratio (SNR) is a very common connect in the wireless communication where it represents the difference between the strength of the received signal and back ground noise level in decibels. For example if the strength of the received signal is -70 dBm and the back floor noise is -85dB, then the SNR value is 15 dB. In IEEE 802.11 wireless LANs When the values of signal strength and background noise are very close, data corruption and retransmission attempts can be resulted where throughput and latency are degraded. SNR can be used as an efficient metric to judge the signal quality where RF environment noise level and ambient noise are considered, i.e. a wireless communication signal of -60 dBm with SNR equals to 25dB is much better than a 15 dB SNR signal. SNR values can reflects on wireless communication traffic where VoIP and video streaming require an SNR value higher than 25 dB where other types of less important traffic can afford an SNR of 20 dB[21].

In the proposed admission control, SNR value is used to select between network vehicles for RSU association and start data transmission. To illustrate the flow of the protocol , a system model has been built.

3.1 System Model

In this paper , a vehicle model has been built as shown in Figure 1,the used notation has been described in Table 1 . The space required for each vehicle is defined as , where T_i referred to the maximum wireless range of the RSU , Q is define as the vehicle arrival rate which can be calculated in terms of the vehicle speed S and the number of vehicle in specific time duration N as follow:

$$Q = S * N \quad (1)$$

The number of vehicle in specific time can also affect the speed to moving vehicles , in [22] this relation can be defined using the following equation:

$$S = S_f\,(1 - {}^{N}/_{N_j}) \quad (2)$$

where S_f is the speed of the vehicle in free-flow where no other vehicles are on the road, N_j is the number of vehicles in the case of jammed traffic.

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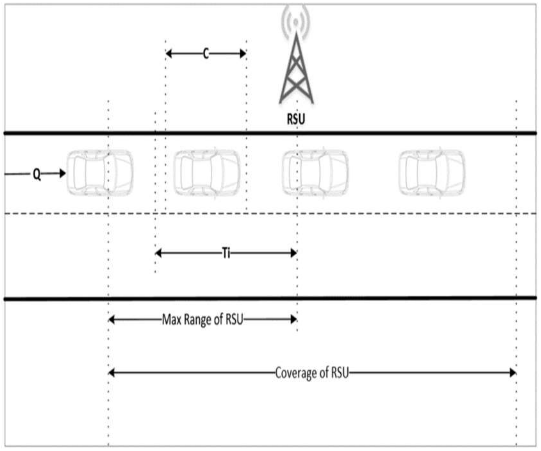

Figure 1: Vehicles System Model

In the Wi-Fi networks, the overall transmission time T(S) can be calculated using the following equation:

$$T(S) = T_{tr} + T_{oh} + T_{cont}(S) \qquad (3)$$

where T_{tr} refers to the transmission time of the MAC protocol data unit, T_{oh} defines the constant waiting timer for MAC protocol including DIFS and SIFS, and $T_{cont}(S)$ is the delay time caused by channel contention.

In a VANET of K vehicles , these vehicles can transmit data using various transmission rate , These vehicles can be divided based on their transmission rate , assume G_i referred to the group of vehicles which transmit data using the i-th transmission rate $R_i$where transmission rates are ranked in ascending order and K_i is the number of vehicles in that group . T_{oh-i} is the constant time overhead for each vehicles in the G_i. We can estimate the overall transmission time of the vehicles in G_i using the following equation:

$$T(S)_i = \frac{MPDU_{size}}{R_i} + T_{oh-i} + T_{cont}(S) \qquad (4)$$

A specific throughput TH can be achieved by each vehicle regardless of the transmission rate as proved by [23] , this value can be estimated using the following equation:

$$TH = \frac{MPDU_{size}}{\sum_{i=1}^{g} K_i * T(S)_i + P_C(K) * T_j * K} \qquad (5)$$

where $\boldsymbol{P_C(K)}$ refers to the probability of conditional collision, g is the number of vehicles groups and $\boldsymbol{T_j}$ is the average timed exhausted in collisions. $P_C(K)$ can be obtained using the following equation:

$$P_C(K) = 1 - \left(1 - \frac{1}{CW_{min}}\right)^{K-1} \qquad (6)$$

where CW_{min} refers to the minimum size of the contention window . The defined throughput can be achieved in terms of vehicles number and transmission time where lower data rates vehicles require longer time than higher data rates vehicles to complete data transmission.

In this model we only considered moving vehicles where the signal strength can vary and data transmission can get worse. Transmitted data priority P is categorized into two main categories: high priority data P_H which include safety application traffic and low priority data P_L which include other non-safety application traffic.

Table 1. Notation Table

Notation	Description
C	space required for each vehicle
T_i	the maximum wireless range of the RSU
Q	the vehicle arrival rate
S	vehicle speed
N	number of vehicle in specific time duration
S_f	the speed of the vehicle in free-flow
N_j	the number of vehicles in case of jammed traffic
T(S)	overall transmission time
T_{tr}	the transmission time of the MAC protocol data unit
T_{oh}	the constant waiting timer is MAC protocol
$T_{cont}(S)$	the delay time caused by channel contention

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K	The number of vehicles in VANET network
G_i	Group i of vehicles ranked in ascending order
K_i	the number of vehicles in that group i
R_i	the i-th group of vehicles transmission rates
T_{oh-i}	the constant time overhead for each vehicles in the G_i
TH	Vehicles throughput
$P_C(K)$	the probability of conditional collision
g	the number of vehicles groups
T_j	the average timed exhausted in collisions
CW_{min}	the minimum size of the contention window
P_H	High Priority factor (1.4)
P_L	Low Priority factor (0.6)

3.2 QoS Aware SNR Based Admission Control Protocol

Proposed admission control protocol is designed to consider both data priority level and SNR of the transmitting vehicles to eliminate performance anomaly and starvation problems. It mainly divided into three main stages:

- Data categorization
- SNR estimation
- Throughput assignment

3.2.1 Data categorization

The traffic of VANET can be different where vehicles can exchange different types of data traffic , VANET application traffic can be mainly divided into two classes : safety application and non- safety application. Safety application data include accidents alerts, nearby vehicles and many other life threaten alerts which means that any data loss can be catastrophic. On the other hand , non-safety application include data informational, music , games and other less important data which can be handled in lower resources and can afford data loss and delay. Proposed admission control protocol divided VANET traffic into two main priority classes:

- High priority class which include safety application traffic
- Low priority class: which include non-safety application traffic

These two classes are handled differently where lower threshold SNR is used for high priority class rather than low priority class. Also higher throughput is granted to higher priority classed than low priority class.

3.2.2 SNR estimation

The SNR estimation is performed when the vehicles are associated with the RSU as shown in Figure 2. In Wi-Fi there is two approach for scanning for the RSU: active scanning and passive scanning. In active scanning vehicles send a probe request for the RSU . However a beacon frame is received from the RSU in the case of passive scanning. In both cases vehicles can estimate the value of SNR when a beacon is received in case of passive scan or probe response in case of active scan. Next vehicles forward the estimated SNR value in addition to the traffic priority to the RSU in the association request.

When RSU receive SNR and traffic priority, these values are used to permit or deny the association request. The threshold value of SNR is defined in term of priority as shown in **Error! Reference source not found.** where higher priority traffic has lower threshold value of SNR to prevent starvation problem for high priority traffic and eliminate data drop which can lead to catastrophic consequences.

Applying this approach can mitigate the problem of performance anomaly where weaker signals and lower data rates vehicles are discarded. The following diagram illustrates the SND estimation stage:

- SNR is estimated by the vehicles using either beacon frame or probe response depending on the used scanning mechanism.
- Vehicle then send an association request to the RSU including both estimated SNR and traffic priority to determine the admission control and send back an association response.
- RSU divide vehicles which require association into g groups starting at G1 to Gg depending on the estimated SNR and priority traffic. For each group a predefined SNR threshold value is defined if the received SNR is higher than the defined threshold then vehicle is admitted and an

association response is send back . However , vehicles with lower SNR is ignored

- Two SNR values is defined for each priority class depending on traffic priority where lower SNR is considered for higher priority vehicles than lower priority vehicles in the following group. So for a group number x is divided into two sub-groups for high and low traffic where $SNR_{xH} < SNR_{xL}$

Table 2. SNR and Priority Admission Table

Groups	HP Throughput	SNR Threshold
G_{1H}	TH_{1H}	SNR_{1H}
G_{1L}	TH_{1L}	SNR_{1L}
G_{2H}	TH_{2H}	SNR_{2H}
G_{2L}	TH_{2L}	SNR_{2L}
…	…	…
G_{gH}	TH_{gH}	SNR_{gL}
G_{gL}	TH_{gL}	SNR_{gL}

3.2.3 Throughput assignment

Each vehicle group is assigned a throughput higher than a specific threshold values depending on the signal SNR and traffic priority where two throughput values is defined depending on the traffic priority which can be affected by Priority factor. The expected throughput of each vehicle groups can be estimated using the following equations for both high and low priority traffics:

$$TH_{xH} = \frac{MPDU_{size}}{\sum_{i=1}^{x} K_i * T(S)_i + P_C(K) * T_j * K} * P_H \qquad (7)$$

$$TH_{xL} = \frac{MPDU_{size}}{\sum_{i=1}^{x} K_i * T(S)_i + P_C(K) * T_j * K} * P_L \qquad (8)$$

Where $1 < x < g$ and PH and PL is defined depending on the traffic priority to provide higher throughput threshold for high priority traffic and lower throughput threshold for lower priority traffic. For example for two different priority vehicles in the same group X, VH and VL then $SNR_{xH} < SNR_{xL}$ and $TH_{xH} > TH_{xL}$. On the other hand for two different group m and n where m < n then $SNR_{mH} > SNR_{nH}$ and $SNR_{mL} > SNR_{nL}$, on the other hand the value of the throughput threshold is varied where $TH_{mH} > TH_{nH}$ and $TH_{mL} > TH_{nL}$.

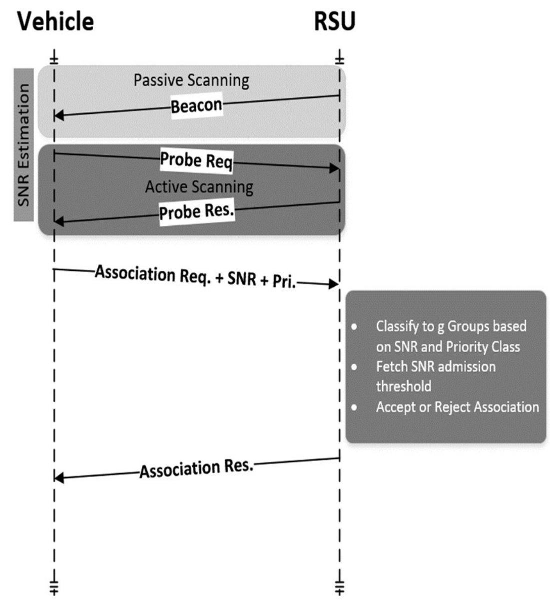

Figure 2: Vehcile - RSU Communication

Guaranteeing a specific level of throughput enhance the performance of data communication for high priority data where delivery delay and packet drop is reduced.c

Utilizing variable SNR admission threshold for both high and low priority data provides vehicles with the ability to communicate with RSUs where performance anomaly problem is tolerated. Higher priority traffic can also tolerate starvation problem where higher opportunity to send data is provided due to lower SNR threshold value.

3.2.4 Proposed mechanism in applied application

Proposed QoS aware performance anomaly problem handling is very helpful in different safety VANET application. Most of high bandwidth application data flow are related to non-safety application like games and video streaming, however other critical data application like traffic information system, road transportation emergency services and on. The road services require reliable data delivery and higher precedence while it is handled by admission control mechanism, proposed mechanism provide higher priority traffic a precedence in term of better values of SNR. QoS-Aware SNR Admission Control Mechanism can provide efficient data delivery for high priority traffic while maintaining an acceptable data delivery performance for lower data priority traffic.

4. RESULTS AND ANALYSIS

Two different types of simulation is required to simulate VANET using Network simulator and mobility simulator. In this section we represent the network simulator NS2[24] as a powerful network simulator that support protocols which are run on the VANET environment. On the other hand we also adopted Simulation of Urban Mobility (SUMO) [25] as a mobility simulation which can represent real road and vehicles mobility efficiently. To evaluate the performance of VANET , a real simulation environment is need to be built. In this study a real highway has been selected. We have utilize the openstreetmap (OSM) project [26] .

4.1 Evaluation of QoS Aware SNR based Admission Control Protocol (QASAC)

To evaluate proposed QoS aware SNR based admission control protocol performance , it has been compared against the SNR-based admission control protocol (SAC)in WiFi-based vehicular network proposed in [20] where both algorithms have been implemented using NS2 simulator. The same network topology which has been used in two previous performance evaluation scenarios is used which represent a real environment of VANET networks with different vehicles speeds. The main idea of the SAC protocol is to accept packets from vehicles depending on the SNR value of the received packet where a predefine threshold value is defined. However this protocol does not differentiate between the priority of the traffic where both high priority and low priority data are handled in the same mechanism.

To evaluate the performance of QASAC against SAC , two main classes of data have been defined: High priority traffic which include safety application traffic and low priority traffic which include non-safety application traffic. In the evaluation scenario , vehicles has been divided into two types , vehicle which are sending high priority traffic and vehicles which are sending low priorty traffic depending on the vehicle ID.

To investigate the improvements of proposed QASAC for handling different priority traffic, the ratio of low data rates and SNR dropped packets based on a predefined SNR values has been measured as an evaluation metric which can be measured by dividing the number of dropped packets in the case of both SAC and QASAC on the number of All received packets in case of no SNR threshold is applied as shown in the following equation:

$$Dropped\ Pkt\ Ratio = \frac{Number\ of\ Dropped\ packets}{All\ Packets\ Recieved} \quad (9)$$

Three different scenarios have been implemented to investigate the performance of QASAC and SAC protocols using different values of SNR threshold for both protocols and two priority data classes. The simulation results is shown in table 3. An adaptation value which indicate the value of SNR admission reference between high and low priority has been set to 6.

Table 3. Simualtion parameters

Parameter	Value
Channel type	WirelessChannel
Radio-propagation model	TwoRayGround
Network Interface Type	Wireless Phy
Antenna type	OmniAntenna

Interface queue type	DropTail/PriQueue
Maximum packet in Queue	50
MAC type	802.11p
Topographical Area	13000 x 13000 sq.m
Routing protocols	DSDV
Number of mobile nodes	40
Number of high priority Nodes	20
Number of Low priority Nodes	20
SNR Threshold	-285 dBm , -290 dBm , -295 dBm
Simulation Time	60 seconds
Data Flow	CBR
Packet Size	256 byte
Data Bit rate	0.5 MB/s
Vehicle speed	10,20,30,40,50,60,70,80, 90,100,110,120,130,140, 150,200 Km/h

4.2 Performance Evaluation Comparison

To compare the performance of the SAC and QASAC protocols, the ratio of high priority data dropping is considered in the three scenarios. In the first scenario, the SAC has a SNR threshold of -285dBm for both high and low priority traffic and QASAC has a high priority of -288dBm and low priority threshold of -282dBm. As shown in [10], the dropping rate of QASAC is much lower than SAC protocol where adaptive handling of traffic quality has been implemented, the dropping rate has been enhanced up to an average of 6.8% in this scenario.

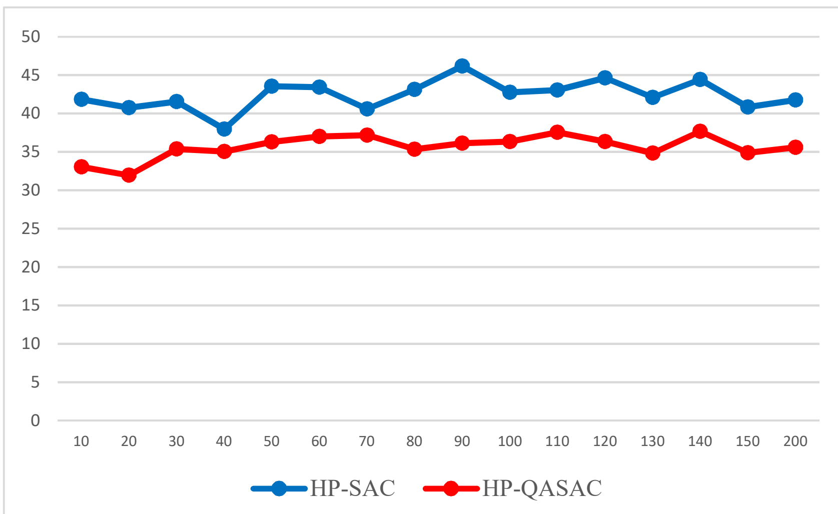

Figure 3: Dropping rate of SAC Against QSAC where Threshold Values are -285dBm, -288dBm and -282dBm

In the second scenario where SAC has a SNR threshold of -290dBm for both high and low priority traffic and QASAC has a high priority of -293dBm and low priority threshold of -287dBm. As shown in Figure 4, the dropping rate of QASAC is lower than SAC protocol where adaptive handling of traffic quality has been implemented, the dropping rate has been enhanced up to an average of 4.3% in this scenario.

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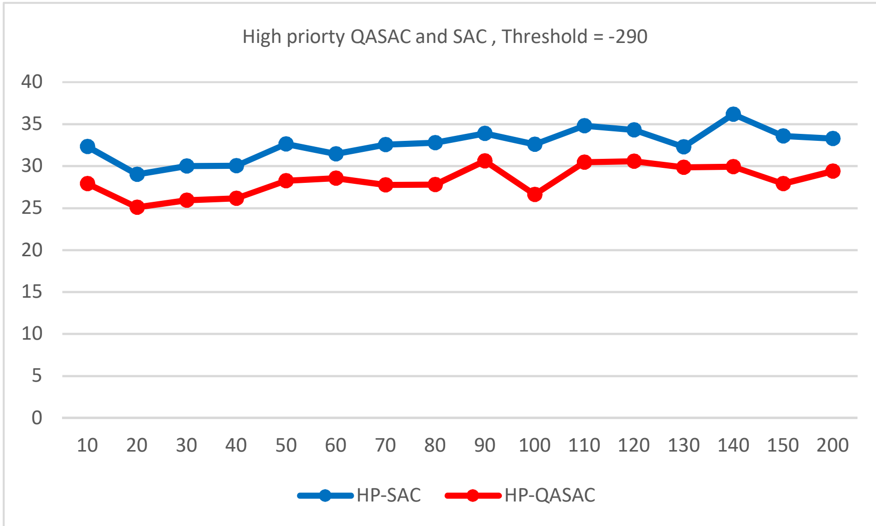

Figure 4: Dropping Rate of SAC Against QSAC where Threshold Values are -290dBm, -293dBm and -287dBm

In the third scenario where SAC has a SNR threshold of -295dBm for both high and low priority traffic and QASAC has a high priority of -298dBm and low priority threshold of -292dBm. As shown in Figure 5, the dropping rate is completely eliminated using QASAC where it approaches to zero due to adaptive handling of traffic quality has been implemented. On the other hand , the dropping rate has been enhanced up to an average of 23.5% over SAC protocol in this scenario.

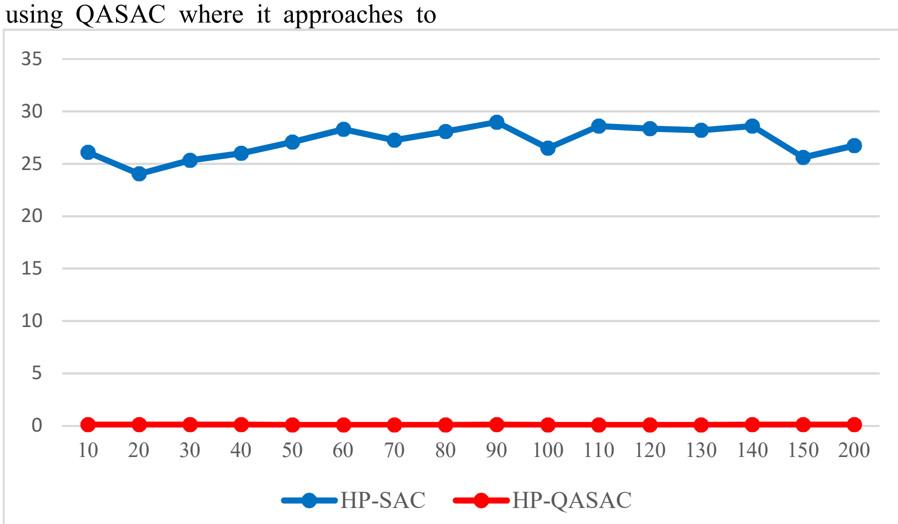

Figure 5: Dropping Rate of SAC Against QSAC where Threshold Values are -295dBm, -298dBm and -292dBm

4.3 Discussion

As illustrated in the results, the SAC algorithm is dump when dealing with different priority traffic classes where the dropping rate of packets for high priority data can be higher than the dropping rate of low priority data where a fixed value of SNR threshold is defined for all classes of data for all vehicle. On the other hand, the adaptive approach provided in QASAC has enhanced the delivery of data in terms of its priority due to different defined value of SNR threshold. Lower value of defined SNR threshold for high priority traffic increase the chance for higher priority traffic to pass and decrease the number of dropped packets. The enhancement of data drop rate has increased up to 23.5% which indicates the enhancement of data delivery. The Proposed QASAC mechanism by depending on SNR threshold for packet admission has also overcome the problem of performance anomaly where lower rate vehicle traffic is all discarded and data are sent in acceptable data rates between vehicles, and between vehicles and RSU.

As shown in the results where the performance compared against the latest proposed admission control for handling performance anomaly , SNR based Admission control doesn't differentiate between high and low data priority so in different simulation scenarios the data delivery performance for low priority data is much lower than it for the high priority data which cause data loss for critical data while less priority data is delivered correctly, QASAC has maintained a precedence for high data in the whole simulation scenarios over the low priority data , on the other hand , the performance of delivering data in low priority data is maintained at acceptable levels.

5. CONCLUSION

VANET is a very critical network which mainly control the vehicle travel paths , the importance of exchanged data led to QoS requirements where safety application data should be delivered on time and delivered correctly. Different performance challenges affect data delivery in VANET in terms of QoS due to vehicles speed and transmission rates. Performance anomaly is one of the most critical issues where high rates vehicles has to meet the speed of the low rates vehicle while transmitting data a QoS-aware Signal to Noise Ratio (SNR) admission control mechanism (QASAC) is succeeded to overcome the limitation of the performance anomaly problem while maintaining the QoS levels for different traffic types. QASAC has been compared against latest SNR based admission control mechanism. QASAC has enhanced the performance of data delivery up to 23% in term of data dropping rates for high priority traffic.

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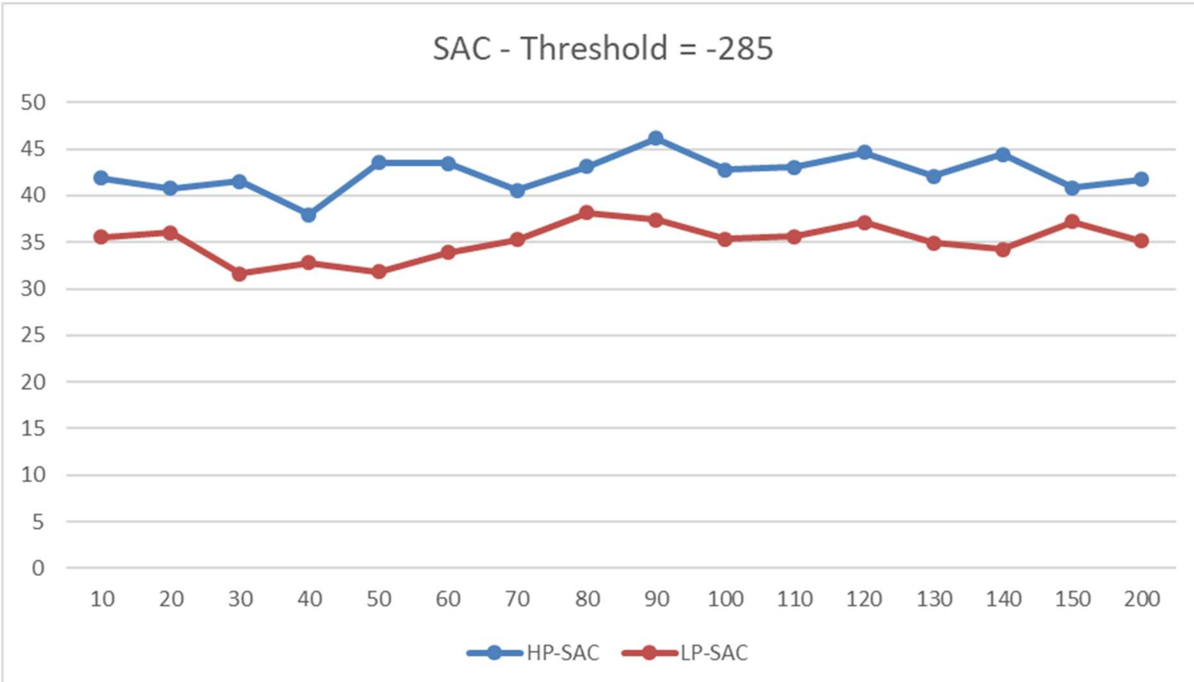
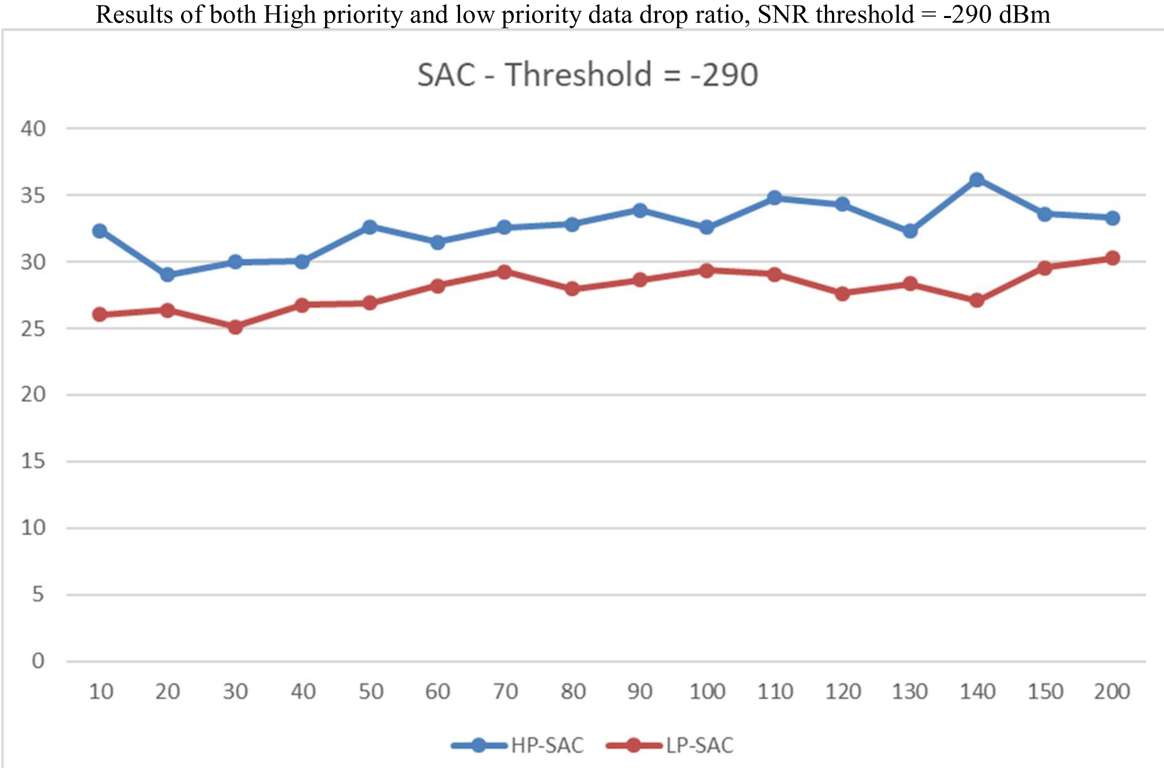
Appendix A1

Results of both High priority and low priority data drop ratio, SNR threshold = -285 dBm



Appendix A2

Results of both High priority and low priority data drop ratio, SNR threshold = -290 dBm



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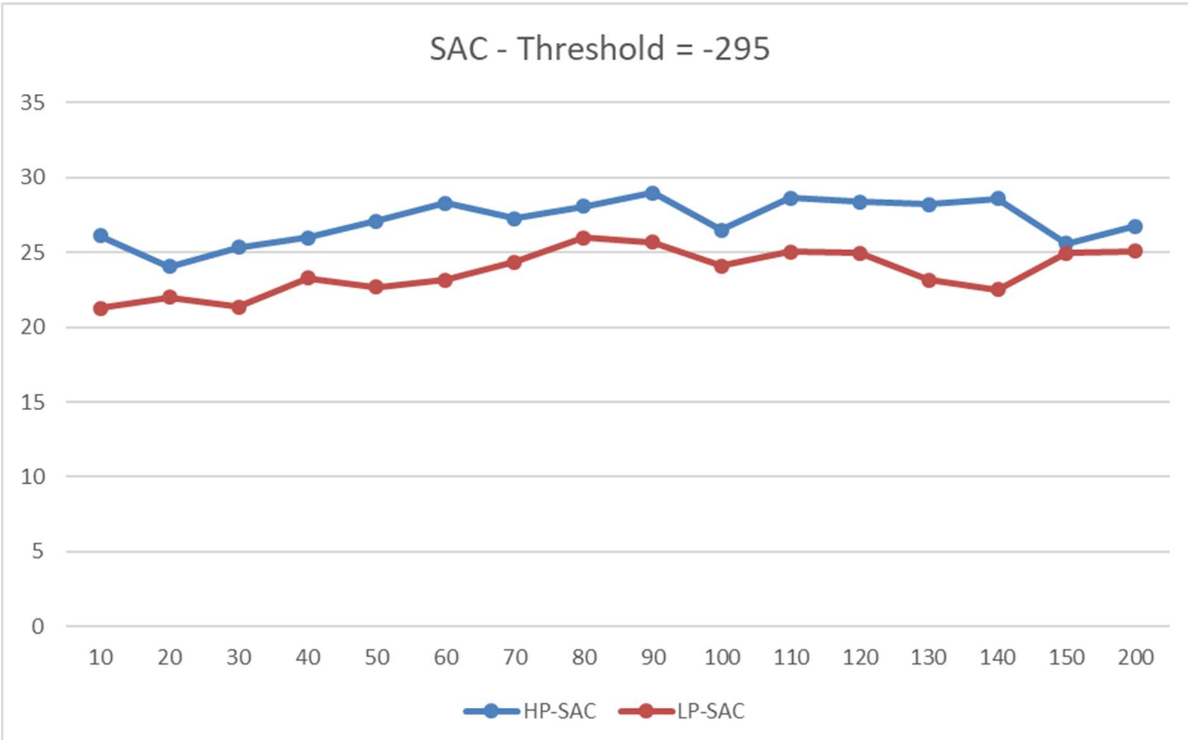
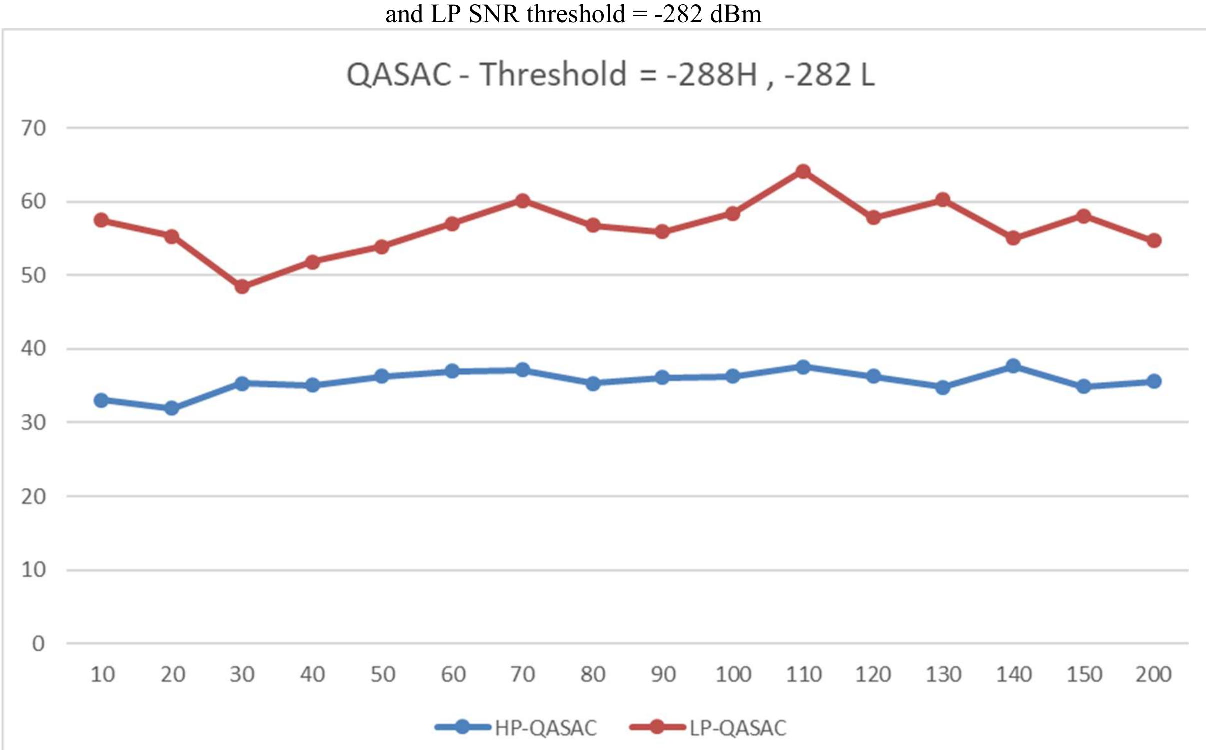
Appendix A3
Results of both High priority and low priority data drop ratio, SNR threshold = -295 dBm



Appendix A4
Results of both High priority and low priority data drop ratio for QASAC, HP SNR threshold = -288 dBm and LP SNR threshold = -282 dBm



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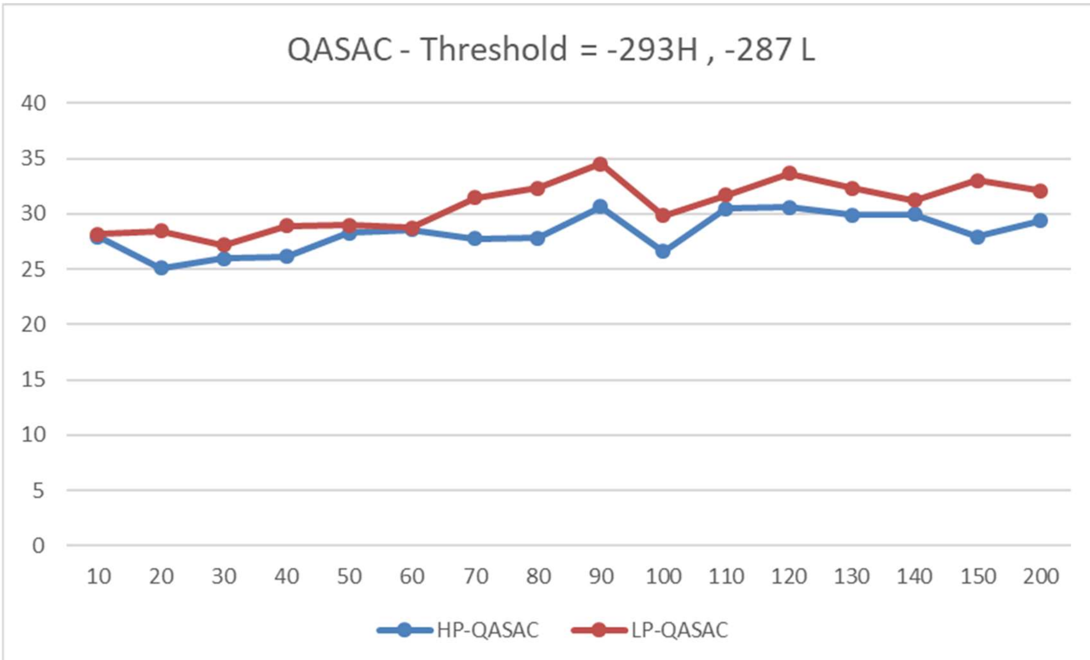
Appendix A 5
Results of both High priority and low priority data drop ratio for QASAC, HP SNR threshold = -293 dBm and LP SNR threshold = -287 dBm



Appendix A6
Results of both High priority and low priority data drop ratio for QASAC, HP SNR threshold = -298 dBm and LP SNR threshold = -292 dBm