OPTIMIZING WIRELESS CHANNEL USING ADAPTIVE MODULATION TO IMPROVE QOS IN VANET

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ABSTRACT

Vehicular Ad Hoc Network (VANET) is a multi-hop wireless network which involves vehicles acting as nodes to communicate with each other without infrastructural support. With the increase in Quality of Service (QoS) needs in evolving applications and the widespread use of wireless and mobile devices, it is desirable to support QoS in VANETs. The resource limitations and variability further add to the need for QoS support in such networks. However, the characteristics of these networks make QoS support a complex process due to rapid topology changes caused by high mobility of communicating nodes. Modulation scheme implemented in wireless network affect the data rate hence the throughput of the communicating nodes, this in turn affect QoS. The paper focuses on adaptive modulation to improve the data throughput and efficiency of channel spectrum in VANET. Through theoretical and simulation results, it was shown that adaptive modulation performs well and improves throughput than other modulations schemes when used singularly in dynamic changing network topology like VANET.

Keywords: VANET, MANET, Quality of Service, Modulation, BER, SNR

1.0 INTRODUCTION

Vehicular Ad Hoc Network (VANET) is a form of Mobile Ad Hoc Network (MANET) which involves nodes moving at a high speed. It is an infrastructure less network involving two or more cars communicating with each other. The main data stream expected to be routed in VANET are those concerned with road safety (accident messages, weather condition, congestion in roads, warning messages, etc) as well as comfort applications. These applications require different level of Quality of Service (QoS) provision to them in order to meet user satisfaction. Providing of end-to-end QoS guarantee is essential for VANET to be successful and preferred by users. However, the characteristics of these networks make QoS support a very complex process. This is due to high mobility of the communicating nodes, hence, leading to rapidly changing network topology. QoS is the minimum service requirement that a network should meet to provide uninterrupted transportation of packet stream from source to its destination. QoS of the network is determined by three factors; (1) delay in packet delivery, (2) packet loss and (3) jitter; variation in delay. Another important parameter in the measure of QoS is bandwidth (throughput) or data rate. Understanding fundamental problems faced in providing of QoS in MANET helps to comprehend problems in VANET QoS. MANET generally provides low bandwidth throughput due to modulation scheme type in the radio channels [1]. The modulation schemes in wireless network may affect the data dissemination which offers different performance in terms of data throughput. Theoretically, Bit Error Rate (BER) is determined by Signal to Noise Ratio (SNR) and modulation scheme method [19]. The more complex the modulation scheme is, the higher the BER, however, higher SNR result in lower BER. Data rate is directly proportional to BER thus increase in data rate increase BER and inversely proportional to SNR implying increase in data rate decrease SNR. Traditional wireless communication systems built upon fixed modulation schemes does not scale well in channels that have coefficients randomly fluctuating. By adaptively altering the modulation schemes for transmission, a higher throughput, an acceptable BER, and a better quality of service can be achieved in dynamically changing channel conditions like that of VANET. Although rapid variations in channel conditions with respect to time pose challenges to the appropriate functioning of adaptive modulation based systems, researchers believe that they are at least a step above the traditional systems based on fixed modulation formats [2, 3, 6, 7, 8]. The channel of wireless communication systems tends to have random fluctuations in radio channels characterized from Doppler spread and multi-path fading [20]. These changes result due to rapid alterations in the signal strength over a small travel distance or time interval, time dispersion caused by multi-path propagation delays and random frequency modulation due to varying Doppler shifts on different multi-path signals. Thus, the system performance is highly dependent on the wireless channel which dynamically varies with respect to time [4]. Adaptive modulation is a technique to exploit the rapid fluctuations in wireless channels to maximize the data throughput in energy and spectral efficient ways. In adaptive modulation, many parameters can be adjusted according to the channel variations such as the transmit-power, modulation level, symbol rate, coding rate, etc.

The rest of the paper is organized as follows; the previous work on QoS in VANET and some techniques used to achieve improved performance is discussed in section 2. Section 3 introduces the concept of modulation which includes the analysis of BER versus SNR for different modulation schemes which are BSPK, QSPK, 16QAM and 64QAM. Section 4 discusses and presents simulation results and finally section 5 concludes the work.

2.0 RELATED WORK

Quality of service (QoS) can be achieved at different layers of network from data link layer which deals with QoS in media access layer to application layer. Due to dynamic topological changes in VANET, it is difficult to support QoS mechanism implemented in wired network such as integrated services (IntServ) or differential service (DiffServ) [5]. A general overview of QoS routing protocols in MANET is given in [9], the objective of the QoS routing protocol is to establish a path from source to destination with needed end-to-end QoS requirement. In [10] a routing protocol proposed improves QoS by disseminating packets among links with longer expiration time calculated by using relative velocity vector. By selecting and maintaining one routing path and one backup route, this reduces topology dynamic, and avoids flooding control messages over the whole network when discovering new routes, hence, improving bandwidth throughput. However, this can also lead to disrupt in communication if the backup route become obsolete because of rapidly changing topology in VANETs. Some of the important parameters for QoS metrics in VANET are highlighted in [11] which are connection duration, packet delivery ratio, end-to-end delay and jitter for unicast communication. They propose that delay and jitter are adequate for most unicast-based application in VANET as the metrics to consider, while packet delivery ratio and connection duration may not meet the requirements for most unicast based application in terms of QoS provision.

Quality of Service mechanism can also be implemented in other network layers to support end-to-end performance requirement of sensitive traffic in VANET. Such network layer include the media access layer, in [12] a QoS supported multi-channel MAC is proposed, it adaptively change the contention window for different services and dynamically adjusting intervals of control channels and service channels working in multi-rate. The scheme shows improvement in QoS supported delivery on service channels regarding throughput and delay. Another such scheme is proposed in [13], this is a mechanism to provide QoS in VANET based on IEEE802.11e for priority based service differentiation such as emergence messages, with repetitive transmission that provide proportional reliability differentiation, the scheme provides for high normalized throughput and low delay for prioritized message. In [15] QoS provision to vehicle based on Enhanced Distributed Channel Access (EDCA) is proposed. Other methods include incorporating routing protocols with media access protocols that supported differential service provision, for example in [14] a new QoS framework is proposed based on Proxy-based Vehicle to Internet (PVI) protocol with a Prediction-Based Routing (PBR) algorithm and IEEE802.11p EDCA to forward data to Internet without a gateway. The proxy-based vehicle is chosen and communicates with the road side unit in order to access the Internet. Through simulation, it was shown that the framework reduces the number of dropped packets and shortens end to end delay. With enhanced PBR and IEEE802.11p EDCA, PVI performs well for QoS enabled Internet connectivity. Modulation scheme implemented in any form of wireless network affect the data rate hence the throughput of the communicating devices, this in turn affect the QoS provision.

The modulation schemes available based on IEEE802.11p (the media access standard for VANET) include binary shift phase keying (BSPK), Quadrature Shift Phase Keying (QSPK), 16 Quadrature Amplitude Modulation (16QAM) and 64 Quadrature Amplitude Modulation (64QAM)[4]. When used in singularly, modulation schemes have limitations, for example 16QAM and 64QAM modulation performs better if the distance between the communicating nodes is short, thus when the SNR is high [7] and provide for higher bandwidth. On the other hand, BPSK and QPSK provide for low data rates but can cover a wider range with low SNR [6]. Research has shown that using adaptive modulation can increase the data rate of the network [2]. Through theoretical and numerical analysis it was shown that a MANET network when using adaptive modulation can reach data rate of up to 96 Mbps when using 64QAM within short distance between nodes, 64 Mbps under 16QAM with longer distance while reaching up to 32 Mbps under QPSK with even longer distance. Furthermore, adaptive modulation increase capacity to upper link layer in ad hoc network [3], to support the hypothesis, three basic approaches were used to investigate the performance of the network; (1) knowledge of current signal interference ratio (SIR), (2) knowledge of signal attenuation and (3) knowledge of only slowly varying component of signal attenuation. Knowledge of signal attenuation is more favorable and practical to implement because interference can be predicted. Knowledge of SIR on the other hand provide best improvement by doubling the average information efficiency of non-adaptive scheme, however, it is difficult to predict the interference in bursty packet radio network making it less preferred approach.

3.0 MODULATION TECHNIQUE

Modulation is the technique by which digital signals are carried by radio carrier waves. There are four kind of techniques by which signals can be carried [17]; first is Amplitude Shift Keying (ASK) which involves increasing the amplitude of the wave in step with digital signal for example low is represented by 0 and high by 1. The second technique is Frequency Shift Keying (FSK) in which digital information is transmitted through discrete frequency changes of a carrier wave. The third technique is Phase Shift Keying (PSK), unlike the other two techniques; PSK conveys data by changing the phase of a reference signal that is the carrier wave. Some of the modulation schemes based on PSK technique include Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK). In BPSK, each symbol indicate two different states allowing one bit per symbol, thus 0 degrees represent a digit 0 while 180 degrees digit 1. In QPSK two more phases are added, 90 and 270 degrees. Addition of these two degrees allows QPSK to transmit two symbols per transmission. Symbol's phases are compared relative to previous symbols, for example, if there is no phase shift denoted by 0 degree, the bits "00" are represented. When there is a shift of 180 degree, the bits "11" are represented and when there is a shift of 90 or 270 the bits "01" and "10" are represented respectively. The fourth technique is Quadrature Amplitude Modulation (QAM) which is the combination of ASK and PSK in which both the phase and amplitude are changed. Modulation schemes based on QAM include 16QAM and 64QAM. Better spectral efficiencies or higher throughput is achieved by different order modulation sending more bits per symbol. However, to maintain a certain BER, some modulation schemes like 64 QAM need higher SNR. Table 1 shows several parameters involved in four different types of modulation technique.

Table 1: Modulation Parameters

Modulation	Technique	Bit Per Symbol	Symbol Rate	Uncoded Block Size (bytes)	Coded Block Size (bytes)	Coding Rate (FEC)	Bandwidth Efficiency bits/second /Hz	Spectrum Frequency	Data Rate	SNR (dB)	Required BER
BPSK	PSK	1	1 bit	12	24	1/2	1	5.9 GHz	6 Mbps	<11dB	10^{-4}
QPSK	PSK	2	1/2 bit	24 - 36	48	1/2-3/4	2	5.9 GHz	6 Mbps	11dB-18dB	10^{-4}
16QAM	ASK/PSK	4	1/4 bit	48 - 72	96	1/2-3/4	4	5.9 GHz	6 Mbps	19dB-24dB	10^{-4}
64QAM	ASK/PSK	6	1/6 bit	96 - 108	144	2/3-3/4	6	5.9 GHz	6 Mbps	24dB-30dB	10^{-4}

3.1 Additive White Gaussian Noise (AWGN)

In wireless communication, one of the major problems is thermal noise which is caused by random motions of electrons due to thermal energy in transmitters. This thermal energy have additive effect which result in Additive White Gaussian Noise (AWGN) [21], the additive refers to information signal (digital signal) being combined with interfering signals by adding, while white refers to noise having constant power spectral density and finally Gaussian means the probability density function of samples of random process is Gaussian.

AWGN channel is a model in which there is a linear addition of wideband or white noise that has a constant spectral density and a Gaussian distribution of amplitude. The model does not account for the phenomena of fading, frequency selectivity, interference, non-linearity, or dispersion. AWGN has the effect on the received signal; we are interested in the power of the noise signal in relation to the power of the desired signal. The ratio of the two is known as the signal-to-noise-ratio (SNR).

3.2 BER Rate versus SNR Expressions

The mathematical expressions for the BER over the AWGN channel in relation to SNR and performance of different modulation schemes which are BPSK, QPSK, 16QAM, and 64QAM, assuming perfect clock and carrier recovery, in a Gaussian channel are as given below [16]:

$$P_{BPSK}(\gamma) = Q\left(\sqrt{2\gamma}\right) \quad 3.1$$

$$P_{QPSK}(\gamma) = Q\left(\sqrt{\gamma}\right) \quad 3.2$$

$$P_{16QAM}(\gamma) = 1/4\left[Q\left(\sqrt{\gamma/5}\right) + Q\left(\sqrt[3]{\gamma/5}\right)\right] + 1/2\, Q\left(\sqrt{\gamma/5}\right) \quad 3.3$$

$$P_{64QAM}(\gamma) = 7/21\, Q\left(\sqrt{\gamma/21}\right) + 1/2\, Q\left(\sqrt[3]{\gamma/21}\right) - 1/12\left(\sqrt[5]{\gamma/21}\right)$$

$$+ 1/6\, Q\left(\sqrt[9]{\gamma/21}\right) + 1/12\, Q\left(\sqrt[11]{\gamma/21}\right) - 1/12\, Q\left(\sqrt[13]{\gamma/21}\right) \quad 3.4$$

In the equations, (3.1), (3.2), (3.3) and (3.4) the γ is the SNR while Q (...) is the Q- function which is defined by the equation given below:

$$Q(x) = 1/\sqrt{2\pi} \int_x^{\infty} e^{-x^2}/2 \; dx \quad 3.5$$

3.3 Curve plot for BER against SNR

Using equation (3.1), (3.2), (3.3) and (3.4), the curves below show the correlation between BER and SNR theoretically. The curves shown are for modulation schemes BPSK, QPSK, 16QAM and 64QAM. In Fig. 1 [8], the curves are plotted between SNR 0 dB to 30 dB on the x-axis, from the graph, 64QAM require high SNR to achieve better and low BER while BPSK and QPSK require low SNR.

4.0 SIMULATION AND ANALYSIS

The experiments conducted were about simulating vehicular traffic on the road. Hence, the speeds considered were stationary vehicles (0m/s), 5m/s, 10m/s, 15m/s, 20m/s and 25 m/s with two vehicles randomly selected out of 10 communicating in the network topology. The experiments were run with configurations of IEEE 802.11Ext (NS-2.34) which has been extensively used in NS-2 to emulate vehicular network behaviors with the draft IEEE 802.11p, especially as far as the physical layer characteristics are concerned [18]. The four different modulation schemes BPSK, QPSK, 16QAM and 64QAM were used and the operating frequency was within the range of 5.9-GHz ITS band. Fig 2 shows the network topology considered in the experiments, while Fig 3 depicts the NS- NAM topology.

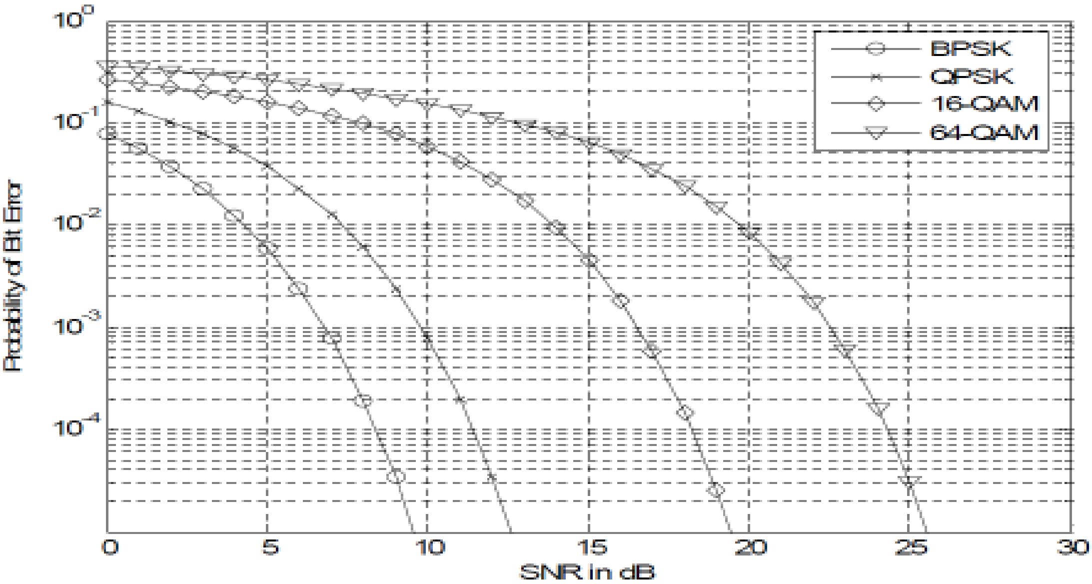

Fig 1: BER against SNR for BSPK, QPSK, 16QAM and 64QAM [8]

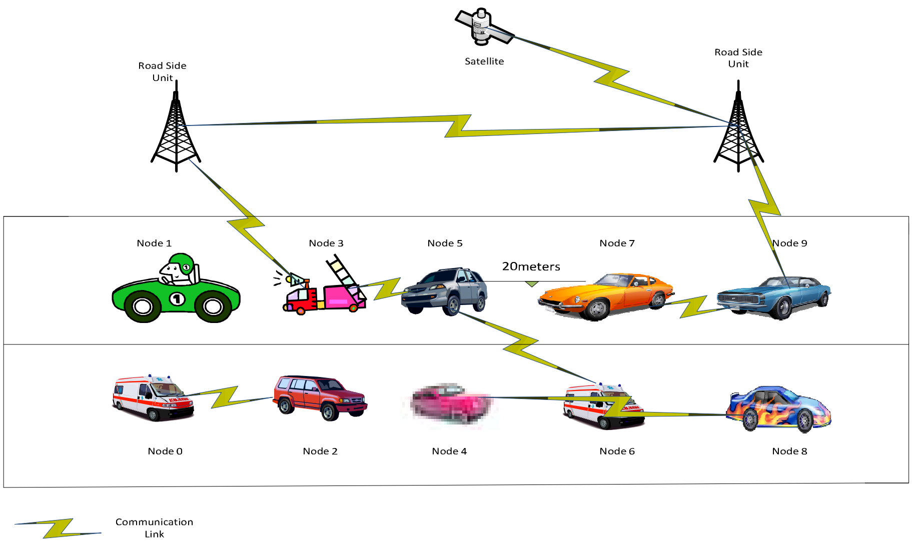

Fig 2: Highway Network Topology

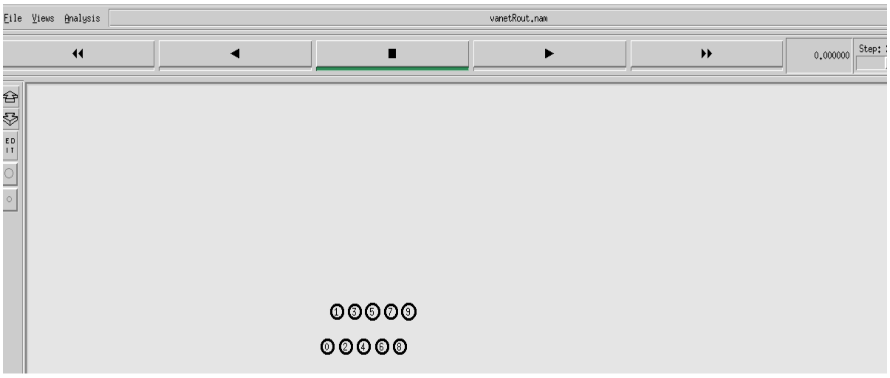

Fig 3: NS-NAM Simulated Network Topology

Table 2 presents the parameters used during the experiments.

Table 2: Simulation Parameters

Parameter	**Value**
MAC	802_11Ext (IEEE802.11p)
Routing Protocol	DSDV
Modulation Schemes	0, 1, 2, 3 (BPSK, QPSK, 16QAM, 64QAM)
Frequency	5.9GHZ
Traffic/PacketSize	UDP/512
Data Rate	6Mbps
Simulation Time	150 Seconds
Network Topology	500m x 500m
Number of Simulated Nodes	10

With adaptive modulation, particular modulation scheme can be chosen depending on the value of SNR. For example, when the required BER is 10^{-4} and below, to achieve better performance, adaptive modulation maintains the required BER with different modulation schemes for SNR in the range of 0dB to 30dB as follows; for SNR of less than 11dB, BPSK is the best modulation to be used, as for SNR between 11dB to 18dB, the best option is to use QPSK, while SNR between 19dB and 24dB, 16QAM is used and finally for SNR from 24dB to 30dB 64QAM is used which require high SNR. Fig. 4 shows the probability of bit error against signal to noise ratio derived from above ranges and the equations for different modulations presented in section 3.2.

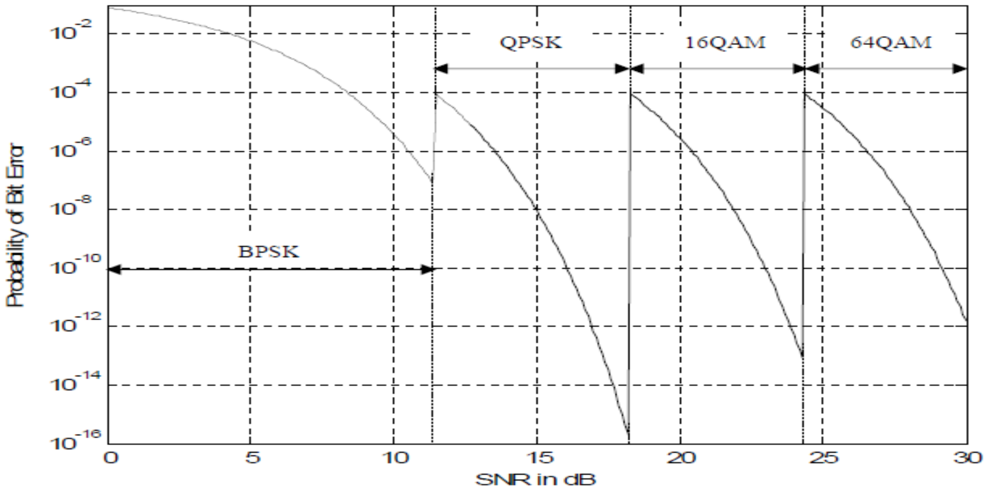

Fig 4: Adaptive Modulation for BPSK, QPSK, 16 QAM and 64 QAM

Fig. 5 shows throughput for different modulation simulated for different speed. For small distance between communicating nodes thus when the SNR is high, 64QAM performs better than any other modulation scheme, it reached the average throughput of 4.57 Mbps which consumed 76.15% of the total bandwidth. The transfer rate was set at 6 Mbps in the simulation parameters and simulation duration of 150 seconds was considered. On the other hand, modulation scheme such as BPSK, the average throughput was 4.46 Mbps which is 74.47% of the total bandwidth indicating the reduction in bandwidth utilization. However, when distance between communicating nodes increased, implying the SNR is low, 64QAM performance in terms of data rate was very low as compared to other modulation schemes. For example, when the nodes (vehicles) were moving at the speed of 5 m/s, the throughput for 64QAM reduced almost by half (i.e. 2.45 Mbps which represented 40.82% of total bandwidth) as compared to the previous value of 4.57 Mbps, on the other hand, QPSK modulation scheme performs better with an average throughput of 3.46 Mbps with the nodes moving at the same speed of 5 m/s.

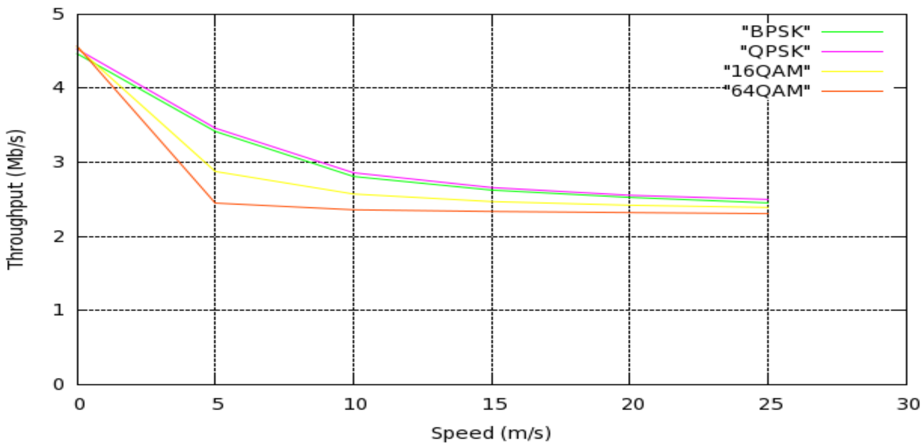

Fig. 5: Throughput for Different Modulations for Different Speeds

The conventional modulation schemes were fine tuned to accommodate the SNR range of values proposed above, Fig. 6 shows an improvement in performance for adaptive modulation as compared to singular modulation schemes. When the nodes are moving away from each other with the speed of 5m/s QPSK was adapted to give the output of 3.61Mps which is better when compared to the previous result of 2.45Mps when 64QAM is used singularly.

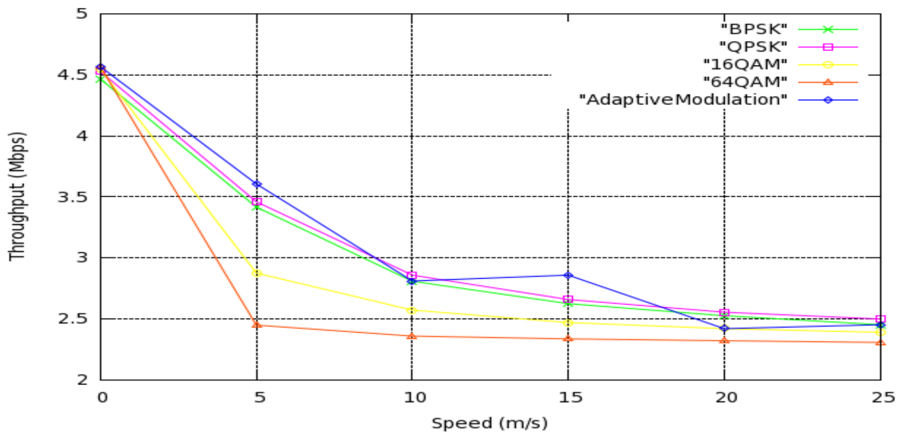

Fig. 6: Throughput for Adaptive Modulation in Comparison to other Modulation Schemes

5.0 CONCLUSION

VANET is one of the emerging technologies that will be very useful to road users once fully deployed, However, without guaranteed QoS or sufficient throughput to support these networks, it is difficult to fully exploit the benefits, thereafter, support critical mission packets such as emergence warnings, accident messages which require some QoS. VANET are dynamic by nature, hence, requires protocols that are able to converge fast to avoid any data loss. Through theoretical and simulation conducted, it was shown that throughput can be increased by adaptive modulation there by effectively and efficiently utilizing the channel spectrum. With the data rate set at 6Mbps in simulation, 64QAM gives better throughput of 4.57Mbps accounting for 76.15% of total bandwidth when the SNR is high as compare to other modulation schemes which give 4.47Mbps for BPSK, 4.53Mbps for QPSK and 4.55Mbps for 16QAM.

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