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Analysis of BPSK, QPSK, 16-QAM and 64-QAM over Wireless Networks using NS-2

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Abstract— Modulation is the process of modifying parameters of a base communications signal for the purpose of encoding information into the signal that is suitable for transmission. Modulation is performed at the physical layer of the OSI Model. To enhance throughput in wireless communication systems, modulation and coding have been studied extensively and advocated at the physical layer, in order to match transmission rates to time-varying channel conditions. In this paper modulation scheme uses Binary Phase Shift Keying(BPSK), Quadrature Phase Shift Keying(QPSK) ,16-Quadrature Amplitude Modulation(16-QAM) And 64-Quadrature Amplitude Modulation(64-QAM) modulations with different coding rate and the performance of all these schemes are analyzed over wireless communication network by varying number of nodes and simulation time.

Key words: 16-QAM, 64-QAM, BPSK, modulation, QPSK

I. Introduction

Modulation is the process of modifying one or more parameters of a base communications signal such as amplitude, frequency, phase or angle of the signal, for the purpose of encoding information into the signal that is suitable for transmission. It involves translating a baseband message signal to a bandpass signal at frequencies that are very high when compared to the baseband frequency. Modulation is performed at the physical layer of the OSI Model. The carrier signal can be a radio or microwave frequency. The process of modulation of the data also requires demodulation at the receiving end. Demodulation is the process of extracting the baseband message signal from the carrier so that it may be processed and interpreted by the intended receiver. In this paper mainly focused on Phase Shift Keying (PSK) and Quadrature Amplitude Modulation (QAM) modulation techniques.

In wireless communication networks, there is a lot of demand for high data rates and quality of service (QoS). However, the performance of wireless links is degraded due to channel fading, which limits the overall system throughput. Modulation and coding [1][2][3]have been studied and advocated at the physical layer to enhance throughput in wireless communication networks, in order to match transmission rates to time-varying channel conditions. In order to achieve high reliability at the physical layer, one has to reduce the transmission rate using either small size constellations or low-rate error-control codes.

In order to improve the system performance, high data rate and coverage reliability, the transmitted signal is subject to variation of interfering base stations, path loss, fading and noise that affects the quality of received signal. On such situation, the transmitted signal is modified through a process commonly referred to as link adaptation. The fundamental idea is dynamically adapt the modulation and coding scheme to the channel state conditions to achieve the highest spectral efficiency at all times in accordance to link quality degradation. When a user is close to the base station (BS), a higher modulation order 64-QAM with higher code rate is assigned, while the modulation order QAM-16 is assigned when a user is far from the BS. Different order modulation can allow to the transmitter to send more bits per symbol and thus achieve higher throughputs or better spectral efficiencies. However, when using a modulation technique 64-QAM requires better signal-to-noise ratios (SNRs) in order to overcome from any interference and maintain a certain bit error ratio (BER). The different variants of modulation are used in various communication scenarios, in order to meet specific data rate performance as shown in Fig.1.

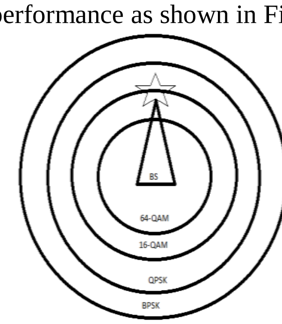

Fig. 1. Modulation order for different users of Base Station

In this paper modulation scheme uses BPSK, QPSK ,16-QAM and 64-QAM with different coding rate and the performance of all these schemes are analyzed over wireless communication network by varying number of nodes and simulation time.

II. MODULATION TECHNIQUES CONSIDERED

In this paper ,mainly concentrating on BPSK ,QPSK,16-QAM and 64-QAM modulations [4][5]over wireless network.

A. BPSK

BPSK is the simplest form of PSK. It uses two phases 0 and π which are separated by 180° and can also known as 2-PSK. It is only able to modulate at 1 bit/symbol and so it is

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unsuitable for high data-rate applications. It is equivalent to 2-QAM modulation. The probability of BER of BPSK can be calculated as

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \quad (1)$$

Since there is only one bit per symbol, this is also the symbol error rate.

B. *QPSK*

QPSK [6] is known as quadriphase-PSK, 4-PSK, or 4-QAM. With four phases, it can encode two bits per symbol and at the same BER, it transmits twice the data rate in a given bandwidth as compared to BPSK. It has in-phase component of the signal uses the even (or odd) bits for modulating signal and quadrature component of the signal uses odd (or even) bits for modulating signal. BPSK is used on both carriers and so they can be independently demodulated. Hence, the probability of BER for QPSK is the same as for BPSK.

C. *Quadrature Amplitude Modulation(QAM)*

QAM [7] is a method of combining two amplitude-modulated signals into a single channel, thereby doubling the effective bandwidth. It is a signal in which two carriers having the same frequency shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. It can be a combination of amplitude and phase modulation. Mathematically, one of the signals can be represented by a sine wave and the other by a cosine wave. At the source, the two modulated carriers are combined for transmission. At the destination, the carriers are separated, the data is extracted from each, and then the data is combined into the original modulating information.

The advantage of moving to the higher order modulation is that there are more points within the constellation and it is possible to transmit more bits per symbol. The downside is that the constellation points are closer together, the link is more susceptible to noise. As a result, higher order versions of QAM are only used when there is a sufficiently high signal to noise ratio. Table1. gives a summary of the bit rates of QAM and PSK.

Table 1. Bit rates of different forms of QAM and PSK

Modulation	Bits per symbol	Symbol Rate
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
16QAM	4	1/4 bit rate
64QAM	6	1/6 bit rate

III. IMPLEMENTATION

The packet and frame structures are as shown in Fig.2..The processing unit at the data link layer is a packet, which comprises multiple information bits. The processing unit at the physical layer is a frame, which is a collection of multiple transmitted symbols. At the physical layer, deals with frame by frame transmissions, where each frame contains a fixed N_f number of symbols. Each frame at the physical layer may contain multiple packets from the data link layer. Each packet contains N_p bits, which include serial number, payload, and cyclic redundancy check (CRC) bits to facilitate error detection. After modulation and coding with mode n of rate R_n bits/symbol, each packet is mapped to a symbol-block containing N_p/R_n symbols. Multiple such blocks, together with N_c pilot symbols and control parts, constitute one frame to be transmitted at the physical layer. If mode n is used, the number of symbols per frame is $N_f = N_c + N_b N_p/R_n$, where N_b is the number of packets per frame depends on the chosen modulation and coding pair.

Pilots	Control parts	1	2	3	4	--	N_b

PHY mode	Data Bits per OFDM Symbol N_{DBPS}	Coded Bits per OFDM Symbol N_{CBPS}	Coding rate R
0	24	48	1/2
1	36	48	3/4
2	48	96	1/2
3	72	96	3/4
4	96	192	1/2
5	144	192	3/4
6	192	288	2/3
7	216	288	3/4

Table 2. Rate-dependent parameters of IEEE 802.11 PHY layer

Modualtion and coding scheme as shown in Table 2. In this implementation, PHY mode 0(BPSK),2(QPSK),4(16-QAM) and 6(64-QAM) and its corresponding NDBPS 24,48,96 and 192 being considered for analysis purpose[8].

IV. RESULTS AND ANALYSIS

Comparison of different modulation techniques BPSK,QPSK[9],16-QAM and 64-QAM at physical layer is simulated over multi-hop network by considering default packet retransmission .Simulation is conducted in the Network Simulator(NS)-2.35[10] with User Datagram Protocol traffic(UDP) with constant bit rate(CBR) is implemented with a packet size of 1024Byte. In NS-2.35, the configuration

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specified for different number of nodes in a flat space with a size of 500 × 500 m. In tcl script, change the value of BasicModulationScheme_ variable into 0,1,2 and 3 corresponding to modulation BPSK, QPSK,16-QAM and 64-QAM. These modulations are defined in WirelessPhy-Extension header. Routing protocol AODV is being considered.

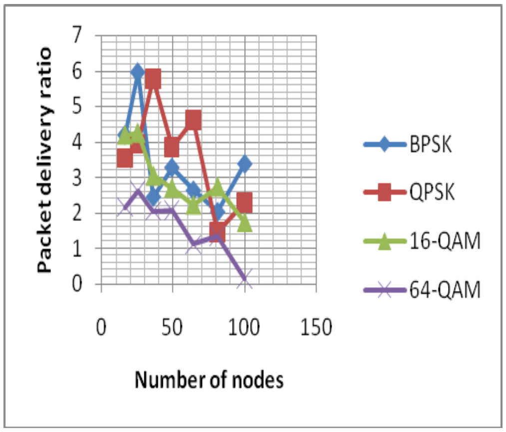

Fig. 2

A. *Performance Metrics*

Packet Delivery Ratio(PDR): It is the ratio of number of received packets and number of packets sent.

Throughput: It is the number of packets received within given time.

Average delay : It is the delay experienced by the number of received packets.

B. Simulation Methodologies

Scenario 1: For different number of nodes ,compared different modulations by considering fixed simulation time.

Scenario 2: For fixed number of nodes, compared different modulations by varying simulation time.

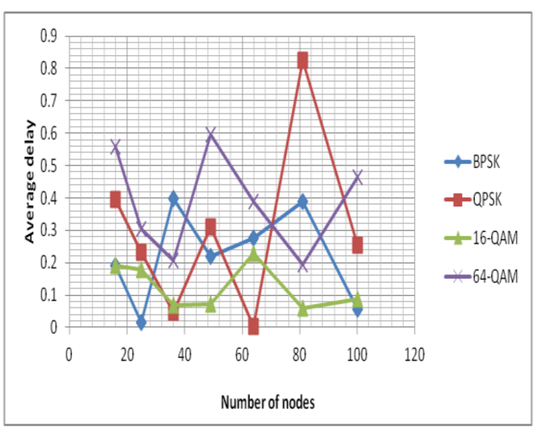

Fig. 3. PDR for different number of nodes

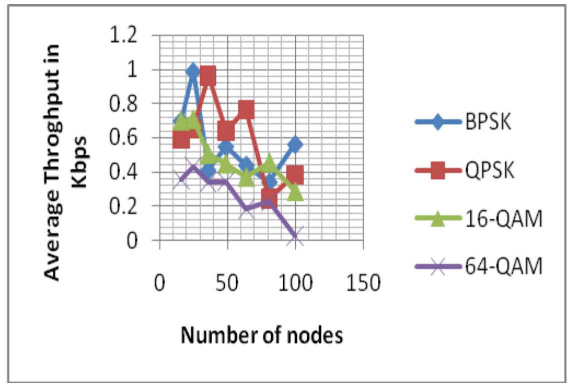

Fig.4 Average delay for different number of nodes

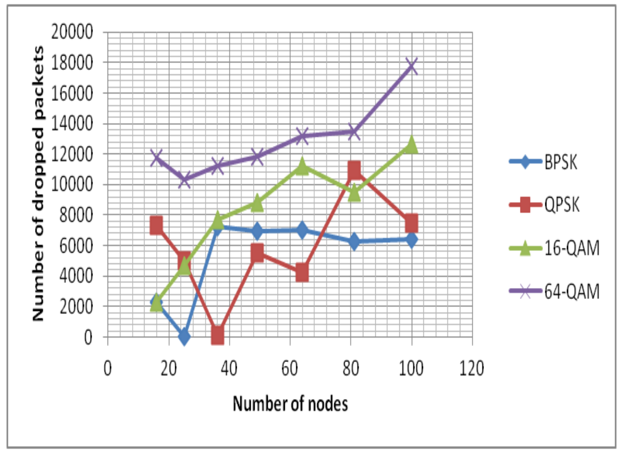

Fig. 5. Number of dropped packets for different number of nodes

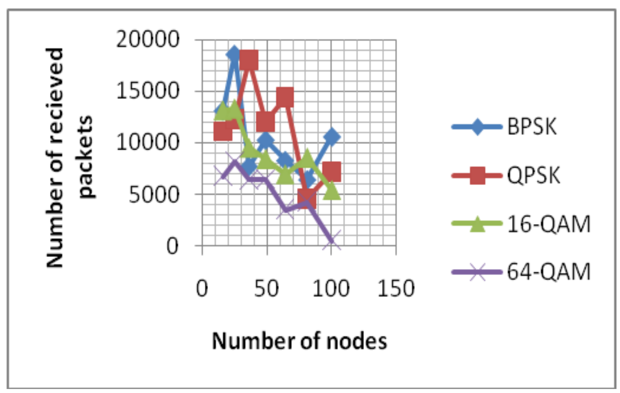

Fig. 6. PDR for different simulation time

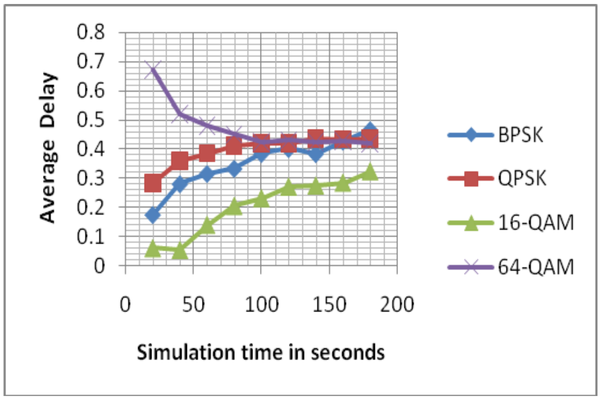

Fig. 7. Average delay for different simulation time

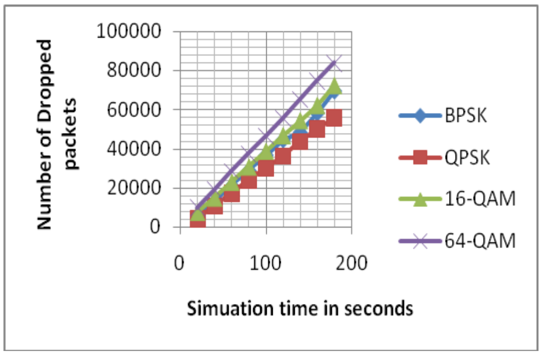

Fig. 8. Number of dropped packets for different simulation time.

In scenario 1, as number of nodes is increases for a fixed simulation time, QPSK modulation yields better performance in terms of throughput, PDR and average delay compared to other modulation methods.

In scenario 2, as simulation time is increases for a fixed number of nodes QPSK modulation yields better performance in terms of throughput, PDR and average delay compared to other modulation methods.

V.CONCLUSION

To enhance throughput in wireless communication networks, modulation and coding have been studied and advocated at the physical layer, in order to match transmission rates to time-varying channel conditions. Simulations are performed for BPSK, QPSK,16-QAM and 64-QAM modulations techniques is being implemented at the physical.

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