Adaptive Modulation and Coding for Lifetime Enhancement of WSN using Game Theoretic Approach

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Abstract: - The fundamental component of resource management in Wireless Sensor Network (WSN) is transmitter power control since the sensors are miniature battery powered devices. Power control is an important research trend in WSNs for improving the efficiency of network communication and prolonging the life time of the network thereby supporting system quality and efficiency. This paper analyses a game theoretic model with pricing in which the game is formulated as a utility maximizing distributed power control game considering the residual energy of the nodes along with adaptive modulation. The game approach considered adapts to the changes in channel condition and selects the appropriate modulation and transmits using the optimal transmission power thereby enhancing the network lifetime. Simulation results show that the game with pricing provides maximum utility by consuming lesser power. The adaptive modulation strategy also minimizes the energy consumption and maximizes the network lifetime by selecting the optimal constellation size.

Key-Words: - game theory; power control; adaptive modulation and coding

1 Introduction

Wireless Sensor Network (WSN) is a group of sensor nodes that are capable of sensing, computation and communication. The sensor nodes are normally distributed over a certain area to give information on relevant physical parameters or events. WSNs are used to monitor ecosystems, wild and urban environments. They have been vital in predicting events that threaten species and environments, including gathering information from animal habitats, in volcanic activity monitoring, flash-flood alerts and environmental monitoring [1]. To cater all these needs WSN should operate as long as possible without replacement of the batteries. In such a circumstance, where recharging is typically not possible, radio power control is vital in order to increase the network lifetime. Transmission power is accountable for up to 70% of the total energy consumption for off-the-shelf sensor nodes [2]. Therefore energy conservation is very crucial for WSNs, both for each sensor node and the entire network to escalate the network lifetime.

In a WSN, each node transmits its information over the air and is prone to fading and other impairments. The data transmitted from the sensor nodes is highly susceptible to error in a wireless environment which leads to higher packet loss and thereby increases the transmit power. Error Control Coding (ECC) is used to improve the system performance and is shown that ECC saves energy as compared to uncoded data transmission [3]. To mitigate the fading effects in wireless channel, diversity techniques can also be used. Multi-Input Multi-Output (MIMO) scheme technology has the potential to enhance channel capacity and reduce transmission energy consumption particularly in fading channels [4]. Another way to combat fading is the use of adaptive modulation which allows a wireless system to choose the highest order modulation depending on the channel conditions while ensuring that no harmful interference is caused to other nodes [5]. Compared with non-adaptive methods which require a fixed margin to maintain acceptable performance when the channel quality is poor; adaptive approaches result in better efficiency by taking advantage of the favourable channel conditions. Since communication signals are modulated, varying the modulation also varies the amount of bits that are transferred per signal, thereby enabling higher throughputs and better spectral efficiencies. As a higher modulation technique is used, a better Signal-to-Noise Ratio

(SNRs) is needed to overcome interference and maintain a tolerable Bit Error Rate (BER) level.

After the physical layer set the optimal modulation level, it will adjust the transmission power to stabilize at the implicit optimal transmission power by the feedback based power control scheme. So actually the optimization of modulation level and transmission power is jointly considered.

In this paper, a non-cooperative power control game for adaptive modulation and coding considering the residual energy of the nodes is analysed. The rest of the paper is organized as follows. Contents pertaining to related work are summarised in section 2. Section 3 gives an overview of adaptive modulation and coding. Section 4 deals with the system model. The power control game for adaptive modulation is formulated section 5. Simulation results are given and discussed in section 6. Finally, conclusions are drawn in Section 7.

2 Related Work

As the demand for wireless services increases, efficient use of resources is significant. Though, reducing node energy consumption is important in ad hoc networks, it becomes very vital in WSN. In fact, the available energy is very limited in WSN due to low capacity battery. It is because of the reduced size of the sensor nodes. Despite this scarcity of energy, the network is expected to operate for a relatively longer time. As the replacing/refilling batteries are usually impossible, one of the primary design goals is to use this limited amount of energy as efficiently as possible.

Data transmission consumes the most energy among the various tasks of sensors such as sensing, computing and communication. Therefore, transmission at the optimal transmit power level is very crucial. It is due to the fact that a node will always try to transmit at high power levels just to make sure that the packets are delivered with a high success probability. Though, this increases the successful packet delivery, it proves to be counterproductive as energy is depleted faster. Also, transmitting at higher power levels increases the interference to other nodes, which in turn, will increase their power levels to combat the interference. This creates a cascade effect, where the nodes will continue to increase their power levels in response to the increased interference. Moreover, transmission at lower power levels will compromise the quality of communication. Hence, smart power control algorithms must be employed that find the optimal transmit power level for a node for a given set of local conditions. The problem of adjusting the transmission power of the nodes in a sensor network can be solved by using game theoretic framework.

An approach to adjust the transmission power of a node in WSN is based on the economic model [6] termed as game theory and there has been a growing interest in applying game theory to study wireless systems [7- 9]. Game theory is the theory of decision making under conditions of uncertainty and interdependence. The appropriateness of using game theory to study the energy efficiency problems and power management in WSN stems from the nature of strategic interactions between nodes. Though there are several centralised game theoretic power control approaches for cellular networks, these centralised algorithms suffer from major drawbacks. Typically, centralization requires substantial communication overhead within a hierarchical architecture. Hence these centralized algorithms for power control cannot be applied for sensor networks. Recently, a number of decentralized schemes for efficient power management in sensor networks have been proposed. These solutions have an ad hoc flavour as they are often inspired by heuristic arguments that typically work well for very specific scenarios but lack more general theoretical support for their performance. Another approach is to provide energy efficient power management by finding the optimal transmission power level with which a sensor node can transmit. The problem here arises due to the difficulty in characterizing the information that each sensor node has about the others. Hence, it is essential to arrive at the desired operating point in the incomplete-information scenario to enhance the lifespan of WSN.

Approaches from game theory can be used to optimize node-level as well as network-wide performance and pricing has been studied in decentralized networks as a control variable [10]. Chang and Tassiulas [11] investigated the energy efficiency in wireless sensor networks as the maximum network lifetime routing problem. They proposed to adjust the transmit power levels to just reach the intended next hop receiver so that the energy consumption rate per unit information transmission can be reduced. The research article [12] proposes a power control solution for WSN considering ECC in the analytical setting of a game theoretic approach. It has been well proved that incorporating pricing schemes can stimulate a cooperative environment, which benefits both the nodes and the network. A game theoretic approach to regulate the transmit power level of the nodes in a MIMO-WSN [13] is considered and investigated.

Gao Peng *et al.*, have proposed a non-cooperative power control game for Adaptive Modulation and Coding (AMC) and analysed [14]. But here the energy of the nodes has not been taken into consideration while designing the game.

3 Adaptive Modulation and Coding

Spectrally efficient communication techniques are of great importance in wireless communications. To improve the spectral efficiency particularly over wireless fading channels, adaptive modulation or link adaptation is used. Adaptive modulation offers parameters such as data rate, transmit power, instantaneous BER, symbol rate, and channel code rate to be adjusted relative to the channel fading, by exploiting the channel information that is present at the transmitter.

A simple block diagram, of an adaptive modulation scheme, is shown in Fig.1.

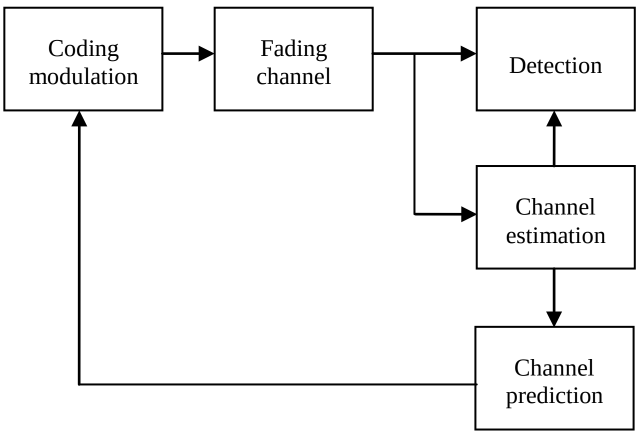

Fig.1. Block diagram of adaptive modulation scheme

Adaptive modulation systems invariably require some Channel State Information (CSI) at the transmitter. This could be acquired by estimating and predicting the channel conditions at the receiver and fed back to the transmitter, so that the transmission scheme can be adapted relative to the channel characteristics.

During each transmission, the modulation scheme is adjusted to maximize the spectral efficiency, under BER and average power constraints, based on the instantaneous predicted SINR. The various modulation techniques such as QPSK and M-ary Quadrature Amplitude Modulation (M-QAM) schemes with different constellation sizes are provided at the transmitter. The link adaptation can employ QPSK for noisy channels, which are more robust and can tolerate higher levels of interference but has lower transmission bit rate. M-QAM is adapted for clearer channels, and has twice higher bit rate but is more prone to errors due to interference and noise. Hence it requires stronger FEC coding which in turn means more redundant bits and lower information bit rate. To improve the quality of the wireless link the transmitter uses some form of channel coding. The coding can either be in the traditional form of coding followed by modulation (each done independent of the other) or joint coding and modulation. Coding (more specifically, FEC) adds redundant bits to the data bits which can correct errors in the received bits. The degree of coding is determined by its rate, which is the proportion of data bits to coded bits. This typically varies from 1/8 to 4/5. In short when the channel changes the CSI is estimated at the transmitter and the transmitter decides the modulation and coding parameters to be used.

4 System Model

A two dimensional plane is considered and is assumed to have *N* nodes in the network area A. All nodes remain stationary after deployment. The energy of the all nodes is limited and own same initial energy except the sink node. The maximum energy of a node is given as E_m. Energy consumed in the transmission is proportional of bytes transferred and distance. The sensor node has power control capability and are capable of transmitting at variable power levels depending on the distance to the receiver. Assuming that the node power control range is [s_{min}, s_{max}], s_{max} is the maximum transmission power. Nodes are location unaware i.e. they are not equipped with any Global Positioning System (GPS) device. Modulation schemes can be adjusted for the wireless module of the node. In WSNs since depletion of battery resource has a direct impact on the network lifetime, the power control should take into account the residual energy of the nodes. By considering the nodes residual energy, those nodes with minimum residual energy can be used less frequently, thus prolonging lifetime of the node and hence the network. The Signal to Interference Noise Ratio (SINR) of the ith node is given as,

$$SINR_i = \gamma_i(\cdot) = \frac{h_i s_i \frac{E_m}{E_i}}{\sum_{j=1, j \neq i}^{N} h_j s_j \frac{E_m}{E_j} + N_0^2} \qquad (1)$$

where
$G=W/R$ is the processing gain
W is channel bandwidth,
R is the data rate
E_i is residual energy of the i[th] node
E_j is residual energy of the j[th] interfering node
s_i is the transmission power of i[th] node
s_j is the transmission power of j[th] interfering node
E_m is maximum energy of i[th] node
h is the path gain
N_0 is the noise spectral density

5 Game Theoretic Modelling

Nowadays use of game theory in the vast majority of science and applications has increased considerably [6].
The game is defined as a triple $G1 =[N,\{S_i, M_i\},U_i]$ where
N is the set of players, which may be a group of nodes or an individual node in wireless sensor networks. They are the main decision makers of the game.

$\{S_i, M_i\}$ is the set of actions, available for the player i to make a decision. Here each node selects modulation type $m_i \in M_i$ and the corresponding $s_i \in S_i$

The payoff {u1, u2 ,.., ui}resulted from the strategy profile. Payoff function expresses the level of income or utility that can be got from the game by the players and is a function of the strategy of all the players.

The node or the entities (decision makers) that play the game are called the players. The players take part in the game by performing particular actions or moves. Suppose that $s \in S$ is a strategy profile and $i \in N$ is a player; then $s_i \in S_i$ denote player i's action in s and s_{-i} denote actions of other players except i. Each player has preferences for the action profiles. A player is affected not only by its own actions, but also by the actions of the other players as well. A utility function ui assigns a real value to each action profile of the game. At the beginning of the game, it is assumed that the nodes transmit with maximum power level to gather neighbour information [15]. Each node selects modulation and coding $m_i \in M_i$ and the corresponding power level $s_i \in S_i$ from the set of actions. The various modulation types considered are QPSK, 16QAM, 32QAM, 64QAM with code rates 1/8, 1/5, 1/4, 1/3, 1/2, 2/3, 4/5. The power levels available vary from minimum transmission power level s_{min} to maximum transmission power level s_{max} and are chosen to be continuous.

Since the game is an iterative process, the players are allowed to select the strategy (power level, modulation type with coding) that maximizes their utility function for each iterative process. At the receiving end channel SINR is estimated and predicted and then fedback to the transmitter to select the suitable Modulation and Coding Scheme (MCS) from the strategy set to maximize utility at that SINR.

5.1 Utility

Utility refers to the level of satisfaction that the decision maker (node) receives as a result of its actions. The utility function reveals the node preferences while considering reliability, and power consumption. The problem is viewed as an incomplete information non cooperative power control game, where the sensor node only has information about its own power level, neighbour number, SINR perceived from the environment and its own channel condition.

The utility function [14] considered is given as

$$u_i(s_i, \gamma_i) = \eta_{eff,MCH} = M_{sym} R_{coding} f(\gamma_i) \quad (2)$$

where M_{sym} is the number of bits of each symbol that can be modulated in the n^{th} type scheme of MCS, R_{coding} is the coding efficiency. $f(\gamma_i)$ is the efficiency function which increases with expected SINR.

The efficiency function which is the function of SINR, is given as

$$f(\gamma_i) = (1 - 2p_e)^F \quad (3)$$

where
p_e is the bit error rate (BER)
F is the size of the packet

The AMC selects appropriate MCS according to the change of SINR in order to maximize the effective modulation and efficiency. The nodes iteratively decide its transmission power level by maximizing its utility function.
The ideal AMC is given by

$$\eta_{eff,AMC} = \max\left(\eta_{eff,MC1}, \eta_{eff,MC2} \ldots \eta_{eff,MCn}\right) \quad (4)$$

The nodes iteratively decide its transmission power level by maximizing its utility function.

5.2 Pricing

The non cooperative nature of the game means that, an attempt to maximize the utility consumes maximum power, since utility monotonically increases with power. This will also create excessive interference, leading to performance degradation. The solution to this problem is to introduce pricing, which induces a degree of cooperation among players, brings an improvement in system performance by penalizing the selfish nodes and enables the nodes to communicate with a relatively low and stable transmission power.

The pricing accounts for the energy consumed/drained by the sensor nodes with usage of resources. If the strategy of the i^{th} node is to transmit at signal power $s_i \in S_i$ the pricing incurred is a function of s_i. The class of pricing functions considered is linear and is a monotonically increasing function of transmit power.

The pricing function is given by,

$$K = zhs_i \frac{E_m}{E_i} \tag{5}$$

where z is the pricing constant.

The utility with pricing is given by

$$u_i^c(s_i, s_{-i}) = u_i(s_i, s_{-i}) - K \tag{6}$$

5.3 Power control game based on energy

Consider node *i* is transmitting data to the sink node. Node *i* receives the sum of interference power from sink node. The non-cooperative game is an iterative procedure, where at each iteration, the players select the strategy that maximizes their utility function. In other words, a system adapts the most appropriate Modulation and Coding Schemes (MCS) according to the state of channel condition. This utility function is very important in non-cooperative power control game.

The first step in the game is to determine the threshold SINR. The SINR target requirement is determined based on the modulation type when employing an adaptive modulation scheme. Each node selects modulation type $m_i \in M_i$ according to the change of SINR in order to maximize the power efficiency and network lifetime [16]. The flowchart of the proposed game is given in Fig.2. The main objective of this game is that each transmitting node adjusts its modulation type and power level in order to maintain certain QoS under the constraint of target BER and SINR requirement. It is assumed that source node ‘i’ has data to transmit to the sink node.

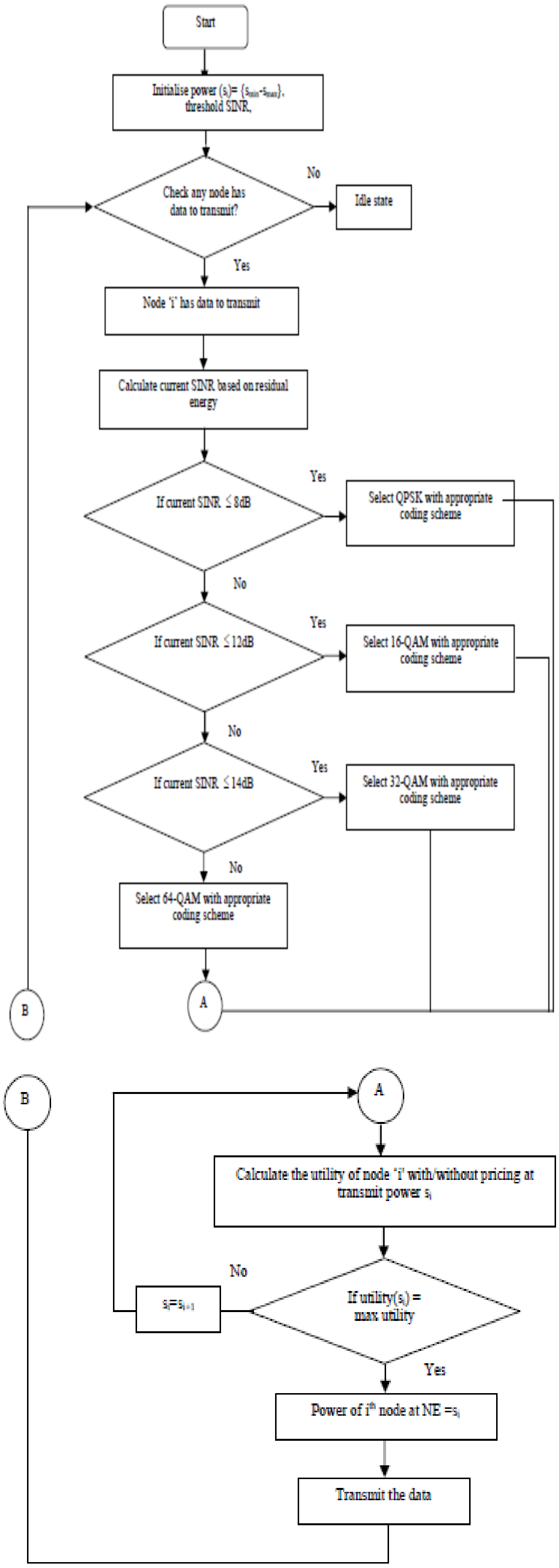

Fig.2. Flowchart of the proposed game

Based on the residual energy of the node, current SINR of the channel is calculated and compared with threshold SINR value. If the current SINR is less than or equal to 8dB, QPSK modulation with appropriate coding scheme that maximizes the utility is selected. On the other hand if the current SINR is greater than 8dB and less than or equal to 12dB, 16-QAM modulation with suitable coding scheme is adopted. 32-QAM with coding is selected if the SINR range falls within 12dB and 14dB. Otherwise if the current SINR is greater than 14dB, 64-QAM with proper coding scheme is chosen. Subsequently the node calculates the utility with/without pricing for the MCS selected. If this utility is not equal to the maximum utility, then the power is incremented and new utility is calculated. This step is repeated until to obtain maximum utility, where the NE point exists.

The power at this point is the optimal power and is given by

$$s_i = \arg\max_{s_i \in S_i} \left\{ u_i \left(s_i , \gamma_i \right) \right\}$$

5.4 Power efficiency

The performance of a modulation scheme is often measured in terms of its power efficiency. A scenario where a node is allowed to retransmit a packet if a transmission is unsuccessful, and it continues to retransmit until the transmission is successful is considered.

The probability of successful transmission of a packet containing F bits from node i to node j can be given by

$$p_s = \left(1 - p_e\right)^F \tag{7}$$

With increased SINR perceived by node j $\left(\gamma_j\right)$, the bit error probability decreases, which in turn increases the probability of successful transmission and vice versa.

The expected power consumption by the transmitter node can be given by

$$s_{exp} = \sum_{m=1}^{\mu} m\left(1 - p_s\right)^{m-1} \times p_s \times s_i$$
$$= \frac{s_i}{p_s} \tag{8}$$

where

p_s is the probability of successful transmission for node i.

With the power consumption given in eqn. (7), the power efficiency for power level s_i is defined as an inverse function of the expected power consumption.

$$power\ efficiency = \frac{\left(1 - p_e\right)^F}{s_i} \tag{9}$$

Then, the optimal transmit power is the power level, which will maximize the power efficiency(η).

5.5 Energy consumption

The total power consumption of a Radio Frequency (RF) transmission system consists of two components: the transmission power S_{PA} of the power amplifier and the circuit power S_{ckt} of all RF circuit blocks. S_{PA} is dependent on transmit power s_i.

$$s_i = \frac{\left(4\pi\right)^2 d^n M_l N_f}{G_t G_r \lambda^2} E_b R \tag{10}$$

where

d	is the distance between the transmitter and receiver
n	is the path loss component
M_l	is the link margin
N_f	is the noise margin
G_t	is the gain of the transmitting antenna
G_r	is the gain of the receiving antenna
λ	is the carrier wavelength
E_b	is the energy per bit

For M-ary Quadrature Amplitiude Modulation (QAM) in MIMO system, $\frac{E_b}{N_0}$ is given by

$$\frac{E_b}{N_0} = \frac{2}{3}\left[\frac{p_e}{\frac{4}{b}\left(1 - 2^{-\frac{b}{2}}\right)}\right]^{-\frac{1}{M_t M_r}} \left(\frac{2^b - 1}{b}\right) \tag{11}$$

where

M_t	is the number of transmitting antennas
M_r	is the number of receiving antennas
p_e	is the bit error probability
b	is the constellation size
N_0	is the noise power spectral density

The transmission power of the power amplifier S_{PA} is approximated as

$$S_{PA} = \left(1 + \alpha\right) s_i \tag{12}$$

where

$$\alpha = \frac{\zeta}{\eta_d} - 1 \tag{13}$$

ξ is the peak to average ratio

η_d is the drain efficiency of RF power amplifier

The circuit power consumption is given by

$$S_{ckt} = S_{DAC} + S_{mix} + S_{filt} + 2S_{syn} + S_{LNA} + S_{mix} + S_{IFA} + S_{filr} + S_{ADC} \quad (14)$$

where S_{DAC}, S_{mix}, S_{filt}, S_{syn}, S_{LNA}, S_{IFA}, S_{filr}, S_{ADC} are the power consumption values of the digital to analog converter, mixer, filter at the transmitter side, frequency synthesizer, low noise amplifier, intermediate frequency amplifier, filter at the receiver side and analog to digital converter respectively.

Energy consumption incurred in the transmission of data packets from node 'i' to node 'j' is

$$E_t = \frac{S_{PA} + S_{ckt}}{R} \quad (15)$$

5.6 Lifetime

The maximum energy of the node is assumed to be 5J. The remaining energy of the node after every transmission is known as the residual energy. After every round of data transfer the residual energy of the node is calculated. The inclusion of residual energy check scheme reduces the achievable transmission range of the node which is directly proportional to the transmission power. Hence the lifetime of the network is considerably improved. The optimal transmit power is estimated and the data is transmitted with estimated optimal power. For this, i^{th} nodes residual energy is determined.

The residual energy (E_0) of the i^{th} node is given

$$E_0 = E_{ini} - E_t \quad (16)$$

where

E_{ini} is the initial energy of the node

E_t is the energy consumption of the node in the previous round

The lifetime of the sensor node is given by

$$T = \frac{E_0}{s_i} \quad (17)$$

6 Simulation Results and Discussion

MATLAB acts as a simulation platform in this work. In the area of 100m × 100m, random spread of 100 sensor nodes with maximum energy of 5J is considered. The simulation parameters considered are given in Table.1

Table 1. Simulation parameters

Simulation parameters	Description
Network area	$100\times100m^2$
Transmitpower $\{s_{min}:s_{max}\}$	1-100mw
Channel Bandwidth	1MHz
Noise spectral density	5×10^{-15}
Path loss component	2
Modulation techniques	QPSK, 16-QAM, 32-QAM, 64-QAM
Code rates	1/8, 1/5,1/4, 1/3, 1/2, 2/3, 4/5

Power efficiency considering the QPSK, 16QAM, 32QAM and 64QAM schemes is shown in Fig.3. Periods of low fade, or high gain, will improve our instantaneous SINR, allowing higher rate modulation schemes to be employed with low probability of error. Periods of high fade will lower the effective SINR and force us to use low rate modulation in order to make transmission more robust.

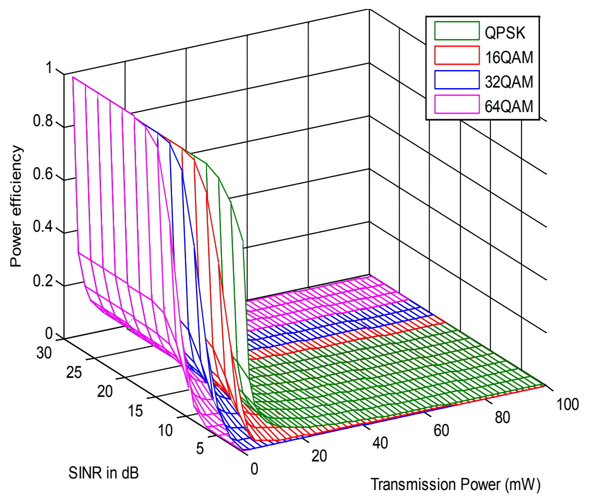

Fig.3 Power efficiency

It is inferred from the figure that at high SNR increasing the transmitting power unnecessarily decreases the power efficiency below the maximum. Hence at high SINR, a node should transmit at low power to maximise its power efficiency. At low SINR the power efficiency is very low for all power levels and hence the node should not transmit under such worse channel conditions. When the channel condition is poor, the system adapts to QPSK modulation and shifts to higher order modulation with improvement in channel condition.

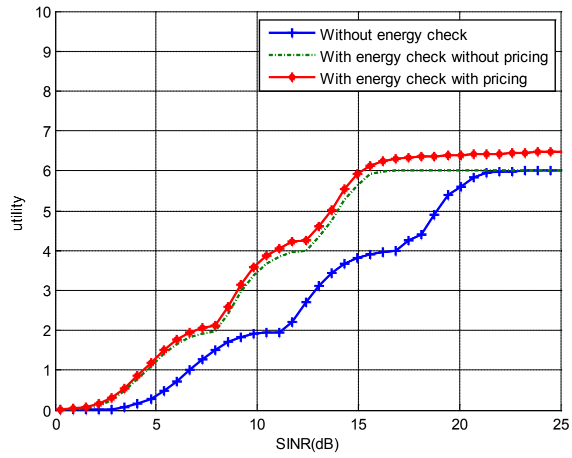

Fig.4 Utility of the game with and without energy check

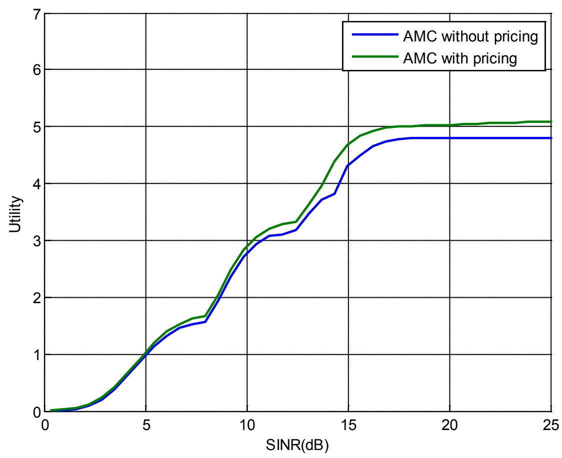

Fig.5 Utility of the game with and without energy check for coding efficiency of 4/5

The modulation and coding scheme with higher utility needs a higher SINR to operate. Fig.5 shows the utility of the game with and without energy check for coding efficiency of 4/5. AMC works by measuring and feeding back the channel SINR to the transmitting node, which then chooses a suitable MCS from the strategy set to maximize the utility. QPSK modulation is adapted during worse channel conditions. It is manifested from figure 3 that, the game without pricing provides an utility of 1.5 bits/s, whereas with pricing an utility of 1.6bits/s is achieved, thereby providing 6% increase in utility for a SINR of 7dB and coding efficiency of 4/5. Higher order modulations with higher coding rates are adapted when the channel condition improves. If the current SINR is greater than 8dB and less than 12dB 16-QAM is adapted. It is obvious from the figure that at a SINR of 11dB, the game with pricing provides an increase in utility by 13% compared to that without pricing. At a SINR of 14dB, the game without pricing gives an utility of 3.7 bits/s. The game with pricing provides an increase in utility by 8% compared to that without pricing. Considering 64-QAM, it is apparent that at a SINR of 17dB and a coding efficiency of 4/5, game without pricing provides a utility of 4.5bits/s. The game with pricing offers an incentive in utility by 13% compared to that without pricing.

Table.2 gives the energy consumption of node for communication and is obtained from eqn. (15). From this table it is evident that as the SINR increases the energy consumption of the node gradually increases. Under worst channel condition QPSK is adopted and is more energy efficient by 21%, 35% and 44% compared to 16-QAM, 32-QAM and 64-QAM respectively. Similarly with the change in channel condition appropriate modulation scheme is adopted to provide energy efficient communication. For the SINR of 16dB, 64 QAM is adapted and the energy consumption is reduced by 7%, 14% and 20% compared to 32-QAM, 16-QAM and QPSK respectively.

Table 2. Energy Consumption at a distance of 50m for various modulation schemes

SINR (dB)	Energy Consumption(J)			
	QPSK	16 QAM	32 QAM	64 QAM
8	0.01395	0.01769	0.02144	0.02519
11	0.04985	0.03124	0.03683	0.04231
13	0.06479	0.06126	0.05121	0.05789
16	0.07805	0.07284	0.06764	0.06244

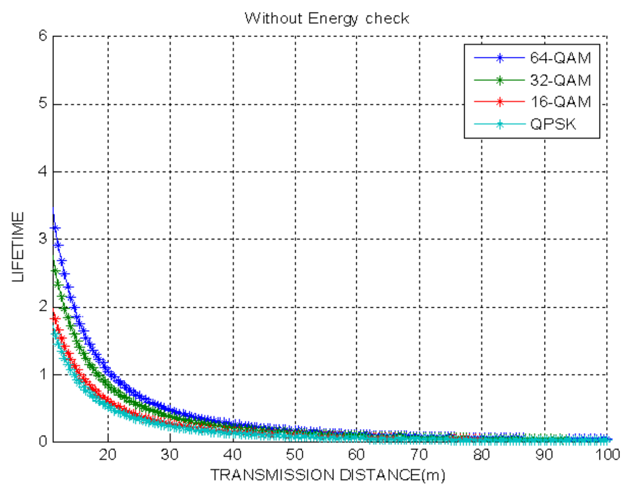

Fig.6 Lifetime analysis without energy check

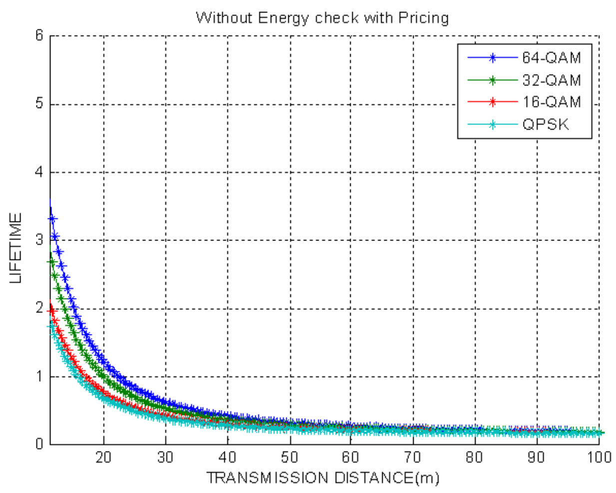

Fig.7 Lifetime analysis without energy check with pricing

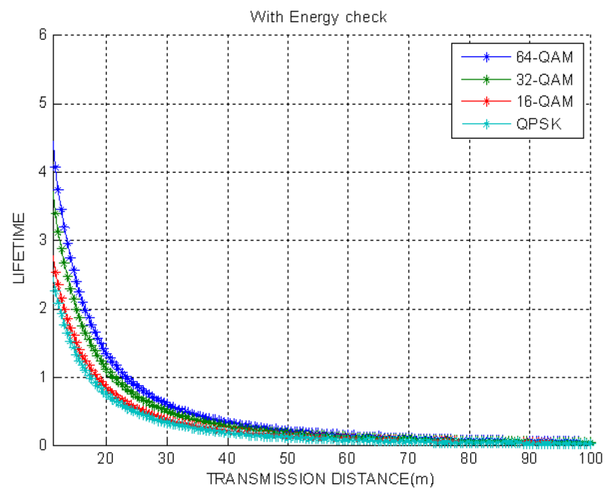

Fig. 8 Lifetime analysis with energy check and without pricing

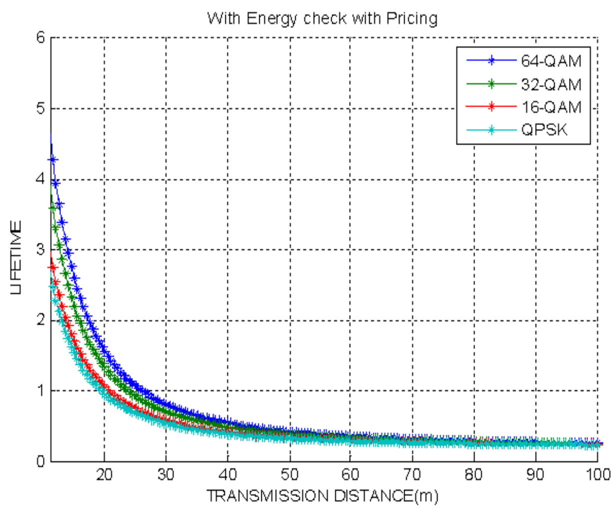

Fig. 9 Lifetime analysis with energy check and with pricing

Figs.6 and 7 demonstrate the lifetime analysis of WSN without energy check, with and without pricing. Figs.8 and 9 show the lifetime analysis of WSN using energy check with and without pricing. From Figs. 6-9, it is evident that considering, with and without energy check an increase in lifetime by 28% is achieved. The lifetime is enhanced by 20%, 23% when considering without energy check and with energy check for with and without pricing respectively.

7 Conclusion

An energy efficient adaptive modulation and coding for power control and lifetime enhancement in WSN using game theoretic approach taking into account the residual energy of the nodes has been analysed. The game is designed such that, appropriate modulation and coding is selected based on the current channel condition. The utility and lifetime of the nodes without residual energy check and with residual energy check are compared. The maximum utility is obtained when energy check is considered. With the inclusion of pricing the interference among the nodes due to the optimizing behaviour of a particular node is suppressed. Further the outcome shows that employing residual energy check with pricing achieves the best response for the sensor nodes.

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