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

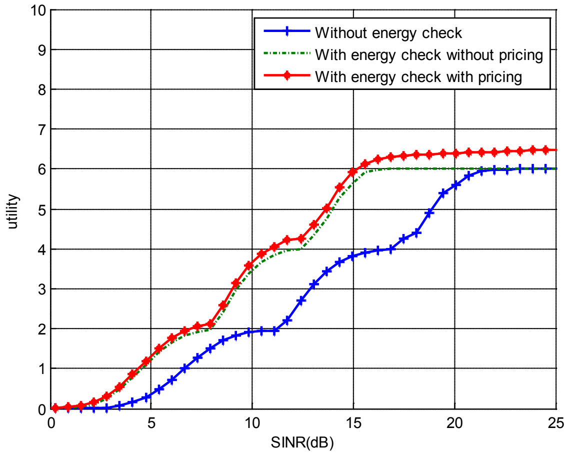

Fig.4 Utility of the game with and without energy check

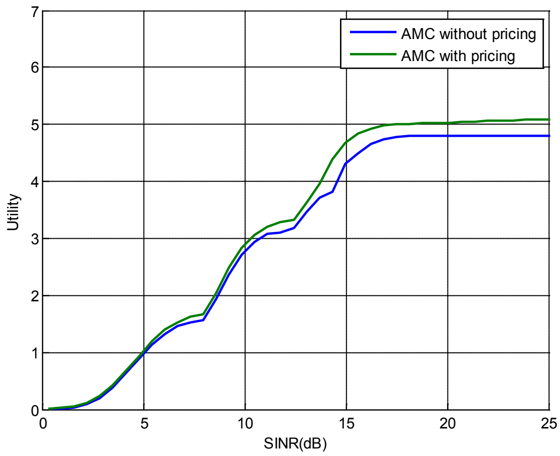

Fig.5 Utility of the game with and without energy check for coding efficiency of 4/5

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

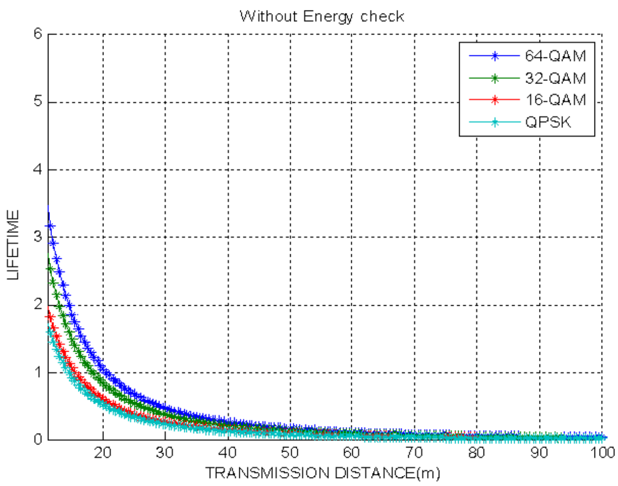

Fig.6 Lifetime analysis without energy check

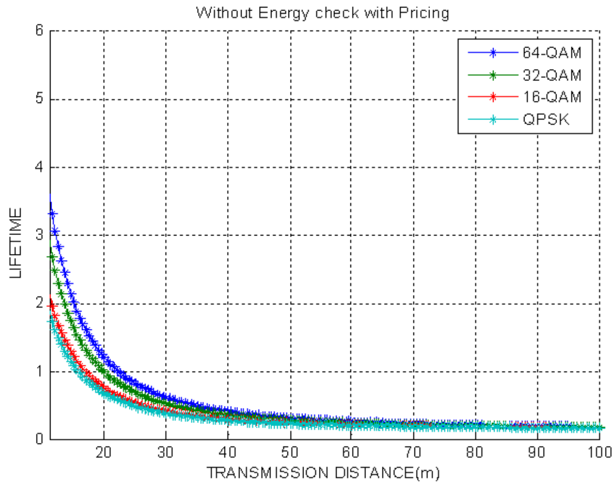

Fig.7 Lifetime analysis without energy check with pricing

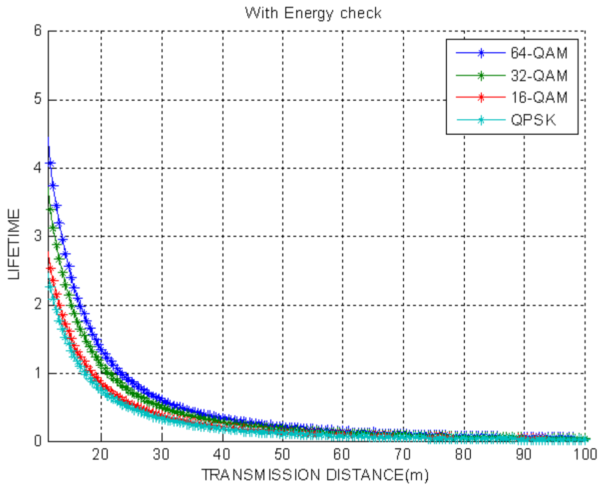

Fig. 8 Lifetime analysis with energy check and without pricing

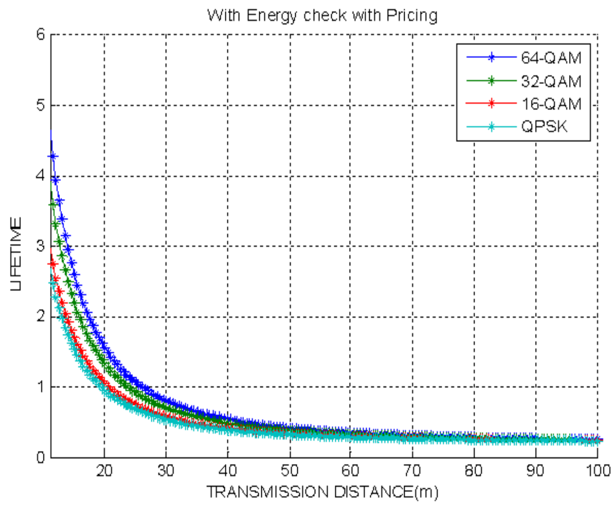

Fig. 9 Lifetime analysis with energy check and with pricing

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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