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Performance Analysis of MSK Modulation and Coding in QoS Enhanced Base Station Controlled Dynamic Clustering Protocol

[1]M. Sheik Dawood, [1]R. Aiswaryalakshmi and [2]G. Athisha
[1]Department of Electronics and Communication Engineering,
Sethu Institute of Technology, Pulloor, India
[2]PSNA College of Engineering and Technology, Dindigul, India

Abstract: A Wireless Sensor Network (WSN) consists of several physically separated sensors to monitor and control physical or environmental conditions. In this study the role of minimum shift keying modulation scheme along with channel coding is analyzed in QoS enhanced clustered sensor architecture. The performance comparison of MSK with other modulation also discussed in this research to increase the energy efficiency at their transceiver and improve the lifetime of sensor nodes. The simulation and mathematical results show the appropriate combination modulation and channel coding to improve the lifetime of energy efficient clustered WSN.

Key words: Sensor network, energy efficiency, lifetime, MSK, modulation, error control code, BCDCP (Base Station Controlled Dynamic Clustering Protocol)

INTRODUCTION

Over the few years sensor networks and its applications have become common as also has research in academic side and industry in sensor networking devices. Sensor network applications grew over the last decade to support various functions such as military surveillance, structural health monitoring, environmental monitoring, habitat monitoring and underwater sensing and disaster management (Abed *et al*., 2012).

A WSN can be defined as a network of nodes which can sense events in the environment and communicate the information gathered from sensing node to base station via cluster head. The nodes can be stationary or moving. It may be aware of their location or not. And they can be homogeneous or not.

Many efforts have been taken to increase the lifetime of sensor Networks by optimizing physical layer parameters and to develop an energy efficient communication protocol. In this study analyze the role of modulation and coding technique to improve the lifetime of sensor node by calculating energy required for transmitting an event sensed.

In a sensor network a unique power efficient modulation technique is used for all the sensor nodes in a cluster is not suitable for energy efficient operation of sensor nodes. Instead of using the same modulation for all sensors, depends on the position of sensor node different modulation techniques are used along with channel codes to reduce energy consumption. In this study, the performance of MSK with channel coding is analyzed and it is being compared with other modulation techniques.

EXISTING RESEARCH

Performance analysis of modulation techniques in fault tolerant sensor network is proposed by Dawood *et al*. (2012). Researchers analyzed the modulation schemes such as BPSK, MSK and QAM and transmission approaches to improve bandwidth and energy efficiency in fault tolerant WSNs for landslide area monitoring. The total energy consumption includes both the transmitted energy and the circuit energy consumption. The modulation schemes are compared based on their energy consumptions at their transceiver node. Researchers also analyzed the homogenous and heterogeneous modulation schemes to improve the energy efficiency and bandwidth efficiency in WSN. Yang and Yang (2012) introduced an adaptive modulation such as BPSK, QPSK, 16-QAM, 64-QAM and convolutional coding for all-participate amplify and forward relay network systems to achieve a better overall system performance where the two source nodes have chosen the appropriate modulation and coding scheme based on the information from the

Corresponding Author: M. Sheik Dawood, Department of Electronics and Communication Engineering, Sethu Institute of Technology, Pulloor, India

feedback channels to ensure that the Block Error Rate (BLER) of the relay system was under the system requirement. They furthermore derived mathematical expressions for the system performances over Rayleigh Channels including average spectral efficiency and average BLER.

Adaptive modulation and coding techniques for long distance wireless communication is analyzed for the WiMAX environment (Salih and Suliman, 2011). The research results show that choice of selecting modulation and coding techniques for yielding higher throughputs while also covering long distances. Researchers also implemented AMC features of the WiMAX and LTE access layer using SDR technologies in MATLAB and focused on the physical layer design. Modulation techniques such as BPSK, QPSK, 16-QAM, 64-QAM with RS codes applied for performance analysis.

Kumar and Gupta (2011) investigated the performance of Reed-Solomon code used to encode the data stream in digital communication. The performances were evaluated by applying to a binary PSK modulation scheme in symmetric Additive White Gaussian Noise (AWGN) channel. Researchers concluded that the Bit Error Rate (BER) performance is improved as the code rate is decreased and the simulations also showed that the BER performance is also improved for large block lengths.

The importance of designing low power transmitters and reduce energy consumption of sensor node is analyzed by many researchers. Sreedevi and Jenopaul (2011) designed CMOS integrated transmitters to reduce energy consumption at node level. Researchers furthermore analyzed CMOS transmitter technology with modulation techniques to improve the lifetime of WSN.

Islam (2010) developed an approach in finding appropriate error control codes for WSNs. Also, several simulations were taken considering both RS codes and Bose, Chaudhuri and Hocquenghem (BCH) codes and the result showed that the RS (31, 21) fits both in BER and power consumption criterion.

Performance study of different modulation types such as M-ary QAM (MQAM), MPSK and M-ary FSK (MFSK), frequently employed in wireless communication is analyzed. The relation between channel capacity and Signal to Noise Ratio (SNR) is studied with researchers to find the optimized parameters for minimizing the energy consumption per information bit in a point to point wireless link (Costa and Ochiai, 2010).

Padmavathy and Chitra (2010) analyzed the hop distance estimation which is used to find the minimum number of hops required to relay a packet from one node to another node in a random network by statistical method. The energy consumption and latency are calculated from the minimum number of hops.

Masud *et al*. (2010) considered the transmission from the base station to mobile or downlink transmission using M-ary QAM and QPSK modulation schemes in Wideb and Code Division Multiple Access (W-CDMA) System. The work further analyzed the performance of these modulation techniques when the system is subjected to AWGN and multipath Rayleigh fading in the channel.

Abouei *et al*. (2011) analyzed the energy efficiency of LT codes with Non-Coherent M-ary FSK (NC-MFSK), known as green modulation in a proactive WSN over Rayleigh flat-fading channels with path loss. In addition, although, uncoded NC-MFSK outperforms coded schemes for d<dT, the energy gap between LT coded and uncoded NC-MFSK is negligible for d<dT compared to the other coded schemes. They proved LT codes are beneficial in practical low-power WSNs with dynamic position sensor nodes.

Soltan *et al*. (2008a, b) focused on improvement of life time of each cluster of sensors in hierarchical WSN using optimization techniques at the physical layer and how the location-aware selection of the modulation schemes for sensors can affect their energy efficiency. Furthermore, the research analyzed how the energy in the network can be distributed more evenly by proper selection of the modulation schemes for different sensors. Soltan *et al*. (2008b) further analyzed on how certain physical layer attributes can affect both the lifetime and the end to end delay in a hierarchical WSN.

A heterogeneous modulation scheme has been presented and reported its impact on the spatial distribution of energy dissipation and the resulting network lifetime. Moreover, researchers discussed how this heterogeneous modulation scheme affects the end-to-end delay due to inherent trade-offs in power efficiency and bandwidth efficiency of the different modulation schemes.

Balakrishnan *et al*. (2007) focused the study on the performance analysis of various error control codes in terms of their BER performance and power consumption on different platforms by transmitting randomly generated data through a Gaussian channel. Based on the study and comparison of the three different error control codes such as BCH, RS and convolutional code, identified that binary-BCH codes with ASIC implementation were best suitable for WSNs.

Mukesh *et al*. (2007) evaluated the energy performances of uncoded MPSK, MQAM and MFSK modulations in both AWGN and Rayleigh fading channels are and compared for very short-range (<10 m) communication. Researchers concluded that MQAM was more energy more efficient than the other modulation schemes. Chen and Zhao (2005) derived a general formula for the lifetime of WSNs which holds the network model including network architecture and protocol, data collection initiation, lifetime definition, channel fading characteristics and energy consumption model. And referred to as the max-min approach, this protocol maximizes the minimum residual energy across the network in each data collection.

Yang *et al.* (2002) addressed the application of AMC for 3rd Generation (3G) wireless systems. Also, proposed a new method for selecting the appropriate Modulation and Coding Scheme (MCS) (16QAM, 8PSK, BPSK with turbo codes) according to the estimated channel condition and taken a statistical decision making approach to maximize the average throughput while maintaining an acceptable Frame Error Rate (FER).

ABOUT PROPOSED WORK

Energy is the scarcest resource in sensor network that must be utilized properly because it is impossible to recharge each sensor node so it must be energy efficient as possible as. This study extends the work of earlier research to improve the energy efficiency of clustered WSNs by analyzing performance study of adaptive modulation technique along with channel code.

This research studies the performance of MSK modulation with error control code in QoS enhanced base station controlled dynamic clustering protocol architecture to derive an energy minimization scheme for node communications in sensor network. The performance study reveals that among the several modulation and coding combination types, MSK is more energy efficient and bandwidth efficient in clustered sensor network when it is working with convolutional codes. Numerical analysis has been carried out to calculate the lifetime of sensor node by considering energy spent per information bit transmitted.

The main purpose is to derive a suitable energy efficient modulation and coding format and the optimum physical layer parameters in base station controlled clustering architecture that achieve minimum energy consumption for a given distance between nodes. In this study, QoS enhanced base station controlled dynamic clustering protocol architecture have chosen for clustering sensor nodes because it works energy efficient manner compare with traditional clustering protocols.

Base station controlled dynamic clustering protocol architecture: The example WSN Model is shown in Fig. 1. The network model considered in this study is as follows:

- The sensor network is considered that have sensor nodes in spreaded manner in an error prone sensor field. The operational situation is illustrated in Fig. 1, here the sensor field is a square area of side at a distance of alone fixed base station

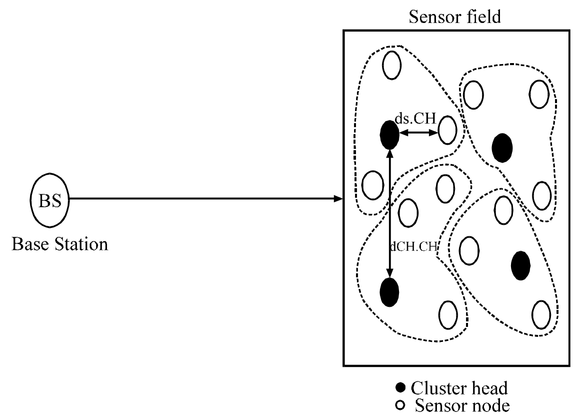

Fig. 1: Wireless Sensor Network Model

- The sensor nodes are provided with restrictions on battery power, processing power and memory space
- The sensor nodes are fixed and are grouped physically into clusters. The nodes in a cluster may possibly carry out any of the two functions: cluster head or sensing. Every cluster head carries out the intra cluster and inter cluster communications, data aggregation and data forwarding to the Base station with the help of multi-hop routing. On the other hand, a cluster head node cannot carry out the sensing process. The purpose of cluster head is rotated between the non-sensing nodes in a cluster. Alternatively, a sensing node will be dynamically sensing the event or in the inactive mode if it is not sensing. The nodes to be used for sensing events are decided by the base station
- The data sensed by the sensing nodes in a cluster are broadcasted straightly to their cluster head that afterwards aggregates and/or pass the data to another cluster head which will direct it to the base station. Different from the sensor nodes, the base station is not with the restricted resources. Thus, the communication from the base station to the sensor nodes can be performed straightforwardly
- The base station has information about the position of every node in the network that is situated within the sensor field

QoS enhanced base station controlled dynamic clustering protocol: QoS Enhanced Base Station Controlled Dynamic Clustering Protocol (QBCDCP) shown in Fig. 2, assume similarity in sensor node's ability and restrictions due to its uncomplicatedness of its deployment and analysis and for reliability with most of the offered work in routing for WSN. But there are several applications that would

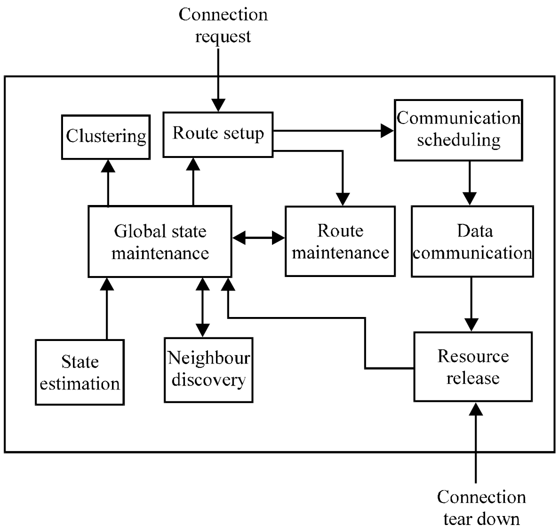

Fig. 2: QoS enhanced base station controlled dynamic clustering protocol

advantage from QoS routing for networks with homogeneous nodes and methods presented here to realize satisfactory QoS and lesser depletion of energy may also be suitable to the construction of protocol handling with heterogeneous networks. The theory of immobile nodes is based on the detail that for some applications, sensor nodes will be fixed at certain position after deployment because the energy necessary to offer mobility to such nodes is inordinate.

QBCDCP is an improved technique of BCDCP with the recently added functionality of QoS based route selection. QoS is maintained in QBCDCP by including delay and bandwidth detail in route selection. This research mainly focused on the energy necessary for transmission of sensor event. The functional components of QBCDCP and the associations among them are depicted in Fig. 2. Every data round, specified by a fixed time interval, the base station groups the sensor nodes into balanced clusters with the help of LEACH (Dawood *et al.*, 2011).

PROPOSED WORK

In WSN the cluster head node directly collects data from sensors and forwards the data towards the base station. Within a cluster, sensors communicate with the cluster head through TDMA channels, so there is no channel interference between sensors in one cluster. The network lifetime depends on the lifetime of each cluster. In this study, researchers try to poise the dissemination of energy consumption within each cluster. Assume that cluster head has access to larger energy source than the sensor nodes, so researchers focus on the energy consumption of the sensors due to data transmission to cluster head. To increase a cluster's lifetime, the energy consumption in each sensor should be reduced. Energy dissipation due to data transmission is a large percentage of the overall energy consumption within the sensors. To preserve the sensor node energy, researchers need to choose the appropriate transmission model and it should be implemented in the energy efficient clustering protocol. Hence, this research analyzes the performance of energy efficient modulation and coding in QoS enhanced base station controlled dynamic clustering protocol, to reduce energy consumption and increase the sensor node lifetime. The work divided into following components:

- The choice of selecting the energy efficient QoS enhanced clustering architecture
- Selection of the most adapted sensor energy model for calculating transmission energy and lifetime
- Finding out the optimal distance between cluster head and event detection node in energy efficient clustering architecture
- Optimal selection of adaptive modulation and coding technique with energy efficient error control codes
- Performance analysis of modulation and coding in AWGN channel conditions with respect to the QoS enhanced base station controlled dynamic clustering protocol

The choice of selecting the energy efficient QoS enhanced clustering architecture: The simulation result shows that QoS enhanced base station controlled dynamic protocol clustering technique results in more number of live nodes when compared to the existing cluster based routing technique for wireless sensor network. To achieve higher energy consumption in sensor nodes and cluster, researchers deploy the adaptive modulation and coding technique into this clustering architecture. It furthermore reduces the energy consumption and increase the cluster lifetime. The BSCDCP has been proven a veracious choice for WSNs over the traditional cluster based routing protocol LEACH.

Finding out the optimal distance between cluster head and sensing node: Consider a sensor field with several sensors; all sensor nodes are equipped with software enabled radio. An entire sensor field divided into several clusters. It consists of two types of nodes one is for event detection and another for a cluster head role. The information collected by cluster head transfers to base station. Here, base station controlled clustering protocol help the cluster head to identify the position of the event detection nodes in a cluster. According to information received from the base station, cluster heads transceiver works adaptively selects the modulation based on distance between nodes and transmit the information base station and other nodes.

Selection of modulation technique with energy efficient error control code: Modulation scheme is considered across the network and the levels adjusted to achieve lower required energy per bit. One common modulation scheme is considered and the target bit rate is adjusted to achieve lower energy per bit. This approach leaves lots of energy shortage in node lifetime. Hence, another approach is to consider a dissimilar position based modulation scheme where different nodes may use different modulation schemes under the desired BER value. In position-aware modulation scheme, energy consumption distribution within a cluster is balanced by using various modulation schemes for different nodes within a cluster. Modulation schemes such as PSK, OQPSK, PAM, QAM, DPSK, FSK and MSK along with convolutional and block codes are analyzed to improve the lifetime of the sensor nodes in a WSN. The codes convolutional and block codes are used with the several modulations to study the performance of WSN.

The scenario I (A unique power efficient modulation and coding technique are used for all the sensor nodes):

- Similar modulation techniques used for all deployed sensor nodes in QBCDCP
- Use a constant desired BER value
- Convolutional and block codes are applied with modulation techniques
- Performance of MSK modulation and coding technique is studied in an AWGN channel environment and its performance compared with other modulation techniques

In this scenario, MSK modulation has been used in all sensors within specified distance from their assigned cluster head node. MSK has the advantage of being very simple to generate, simple to demodulate and has a constant envelope. Regardless of simplicity, the use of the same modulation scheme over the entire network will adversely affect the energy efficiency of the network and subsequently the network lifetime will be reduced. The performance of MSK and coding is studied for different distance between nodes and it also compared with the performance of other modulation techniques. In this scenario, distance between nodes are considered as 5, 10, 40 and 60 m.

Scenario II (Disparate adaptive modulation and coding techniques for cluster heads and sensor nodes):

- Dissimilar modulation techniques used based on the position of the node for all deployed sensor nodes in QBCDCP
- Use a constant desired BER value
- Convolutional and block codes are applied with modulation techniques
- Performance of MSK modulation and coding technique is studied in an AWGN channel environment and its performance compared with other modulation techniques

There is also a trade-off between modulation power efficiency versus the receiver complexity and bandwidth efficiency. Therefore, using the most power efficient modulation for all sensors in the network may not be desirable. Hence, forward different modulation techniques with position based scheme are used for the event detection nodes. In this scenario, MSK modulation is used for centrally located sensors that are within 40 m from their assigned cluster head node. The rest of the sensors that are located >40 m from the cluster head node use other type of modulation techniques. This is an example implementation of the proposed energy efficient position reactive modulation selection. The performance of MSK and other modulation techniques applied for sensor nodes researchers prefer various modulation techniques with error control code for better performance of the WSN. The higher bandwidth efficiency is also achieved by using MSK with error control codes compared with other modulation and coding schemes.

Energy model of sensor node: This radio model shown in Fig. 3 shows a sensor energy model used for this research. This model used in this research has been widely adopted in several studies. Here, the energy spent by the transmitter is only considered, the circuit has three modes of operation: on, transient and sleep. The ‘on’ state is used for the transmission of information. The sleep state is used for saving energy and the short-term state is a temporary one between the two states. The sleep state has a very small power consumption compared to the other states, power is considered for sleep state almost be zero. The main aim of this study is precisely the minimization of the energy spent in the ‘on’ state (Liu *et al.*, 2009; Hussain and Martin, 2007; Macedo *et al.*, 2006).

Calculation of transmitting energy per bit: Calculation of Eb/No theoretically explained by Rappaport (1996) and

Proakis (2007) with the various digital modulation schemes its performance over different channel conditions (Yang *et al*., 2002). For any modulation scheme, the BER can be exemplified as a function of Eb/No which is the ratio of the energy per bit to the noise power spectral density. For a given Eb/No there can be a large difference between the required BER of different modulation schemes and vice versa.

The choice of digital modulation scheme will significantly affect the characteristics, performance and resulting physical realization of a communication system. An energy efficient modulation scheme for WSNs is chosen by the aid of BER vs. Eb/No plot using MATLAB. Here, BER is taken as 10^{-4} and the corresponding Eb value is found and its value used to calculate the transmission energy per bit. The performance comparison of modulation with and without coding for AWGN channel is shown in Table 1-3.

The transmission energy per bit is calculated by the equation of a log-distance path loss model, the required energy per transmitted bit in the ith sensor node may be written as:

$$e_{Tx}(i) = K_{Tx} \cdot E_b \cdot \left(\frac{4\pi d_{e(i),\, i}}{\lambda \omega} \right)^{\beta_{e(i),\, i}} \quad (1)$$

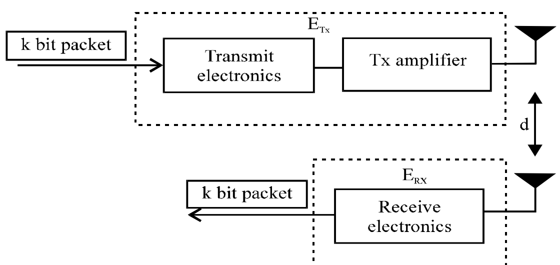

Fig. 3: Radio model for a sensor node

Where:

k_{Tx} = Constant coefficient
E_b = The needed energy per bit of the receiver
de (i), i and
βe (i), i = The distance and the path loss exponent between sensor i and its assigned cluster head node
βe (i), i = Depends on the environment
λ_ω = The signal wavelength

Calculation of network lifetime: Sensor node lifetime is calculated using the formula shown in Eq. 2. Bhardwaj and Chandrakasan (2002) defines the network lifetime as the time span from the sensor deployment to the first loss of coverage. Chen and Zhao (2005) define the network lifetime as the time span from the deployment to the instant when the network is considered non-functional for example the instant when the first sensor dies, a percentage of sensors die, the network partitions or the loss of coverage occurs. And they derived the average network lifetime as:

$$E[\iota] = \frac{\varepsilon_o - E[E_\omega]}{P_c + \lambda E[E_r]} \quad (2)$$

$$E[\iota] = \frac{S\varepsilon_o - E[E_\omega]}{E[E_r]} \quad (3)$$

Where:

S = The total number of sensors
ε_o = The initial energy
E [E_ω] = The expected wasted energy (i.e., the total unused energy in the network when it dies)
E [E_r] = The expected reporting energy consumed by all sensors in a randomly chosen data collection

Table 1: The average remaining energy and the network lifetime for both the standardized and mixed modulations without coding

Modulation scheme	Standardized modulation without coding for all nodes (MSK)	Mixed modulation without coding (MSK, QAM, OQPSK, PSK and DPSK)
Average remaining energy over the initial energy after 1500 days	59.73%	62.53%
Lifetime	896 days	938 days

Table 2: The average remaining energy and the network lifetime for both the homogeneous and heterogeneous modulations with block code

Modulation scheme	Standardized modulation with block code for all nodes (MSK)	Mixed modulation with block code (MSK, QAM, OQSK, PSK and DPSK)
Average remaining energy over the initial energy after 1500 days	64.13%	72.93%
Lifetime	962 days	1094 days

Table 3: The average remaining energy and the network lifetime for both the standardized and mixed modulations with convolutional code

Modulation scheme	Standardized modulation with convolutional code for all nodes (MSK)	Mixed modulation with convolutional code (MSK, QAM, OQSK, PSK and DPSK)
Average remaining energy over the initial energy after 1500 days	77.27%	90.6%
Lifetime	1159 days	1359 days

SIMULATION STUDY

In this study, 1500 sensors placed in a spread manner in a 100×100 m^2 field. The sensors are distributed and form clusters based on the base station controlled dynamic clustering algorithm. The packet size is set to 128 bytes. The initial battery energy level of each sensor is 2 kJ. The base station has information about the position of every node in the network that is situated within the sensor field. From this time, the position of the sensors and cluster head monitored and controlled by the base station. In according to the position of the event detection node an appropriate modulation is chosen along with error control code for transmitting the sensed information to other sensing nodes, cluster head and base station. The following assumptions are made in this simulation, a fixed BER is considered or entire simulation study, the path loss exponent is chosen depends on the channel in which sensor node transmitting the information.

By using the Eq. 2, the network lifetime is calculated for different modulation schemes with codes. Figure 4-8 show the lifetime of sensor node (days) at BER = 10^{-4} for MSK modulation alongside with convolutional and block codes at different distances 5, 10, 40 and 60 m. Figure 9-12 show the lifetime (days) at BER = 10^{-4} for different modulations along with convolutional and block codes at different distances 5, 10, 40 and 60 m.

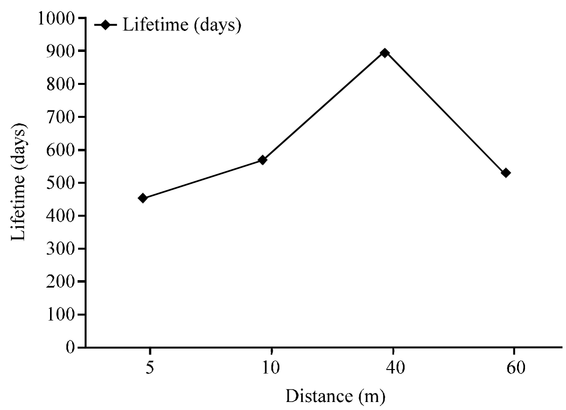

Fig. 4: Distance vs. lifetime for MSK without coding

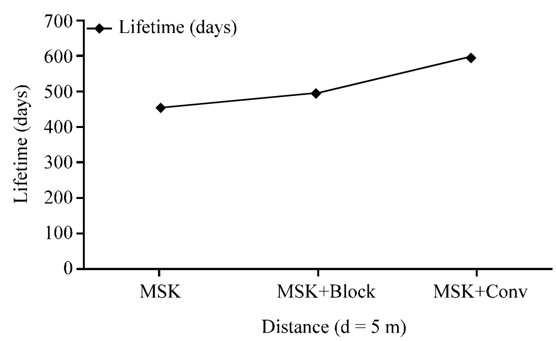

Fig. 5: Comparison of MSK modulation with and without coding at distance d = 5 m

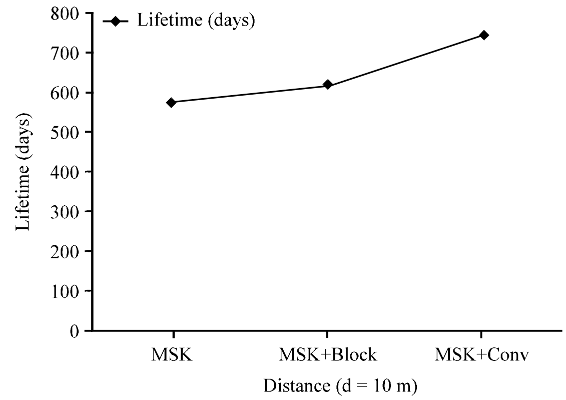

Fig. 6: Comparison of MSK modulation with and without coding at distance d = 10 m

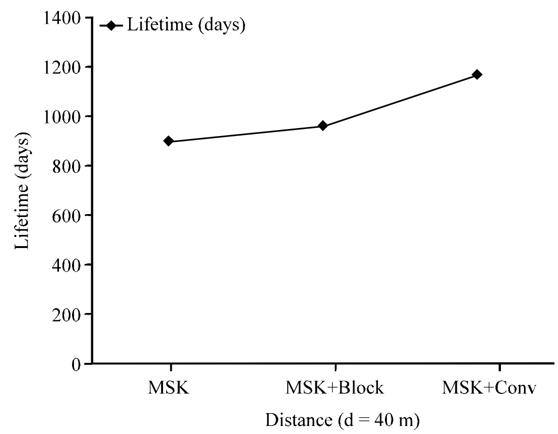

Fig. 7: Comparison of MSK modulation with and without coding at distance d = 40 m

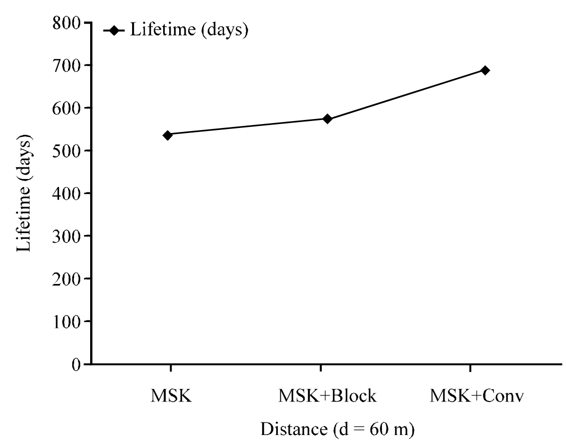

Fig. 8: Comparison of MSK modulation with and without coding at distance d = 60 m

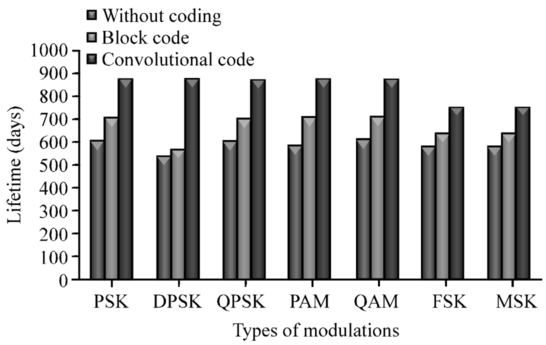

Fig. 9: Lifetime of WSN for different modulation and coding at d = 5 m

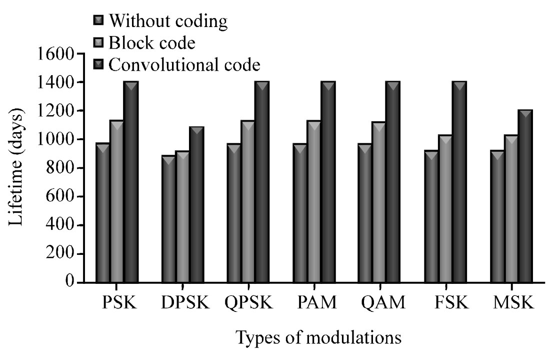

Fig. 10: Lifetime of WSN for different modulation and coding at d = 10 m

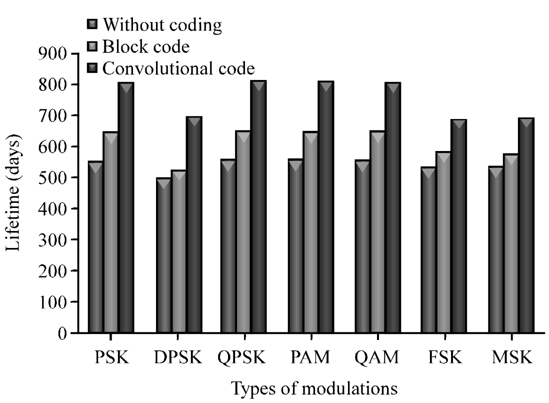

Fig. 11: Lifetime of WSN for different modulation and coding at d = 40 m

It is clear that the value of Eb/No (dB) are same for PSK, OQPSK, PAM and QAM value same for FSK and MSK. The results show that MSK with convolutional codes is more energy efficient than other combination of modulation schemes and convolutional code is more energy efficient than block code with modulation schemes.

Table 1 shows the average remaining energy and the network lifetime for both the standardized and mixed

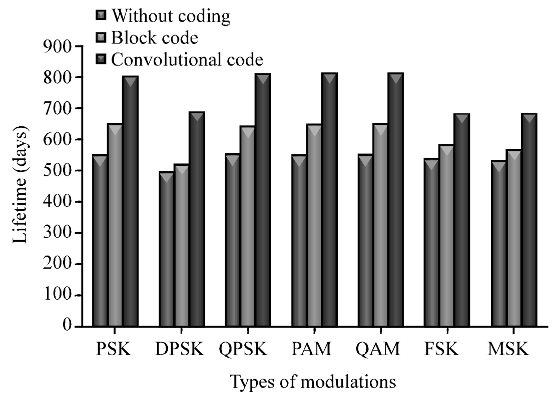

Fig. 12: Lifetime of WSN for different modulation and coding at d = 60 m

modulations without coding. Table 2 shows the average remaining energy and the network lifetime for both the standardized and mixed modulations with block code. Table 3 shows the average remaining energy and the network lifetime for both the standardized and mixed modulations with convolutional code.

CONCLUSION

This study analyzed the performance of MSK modulation with error control codes in base station controlled dynamic clustering protocol architecture of WSN. QoS enhanced base station controlled dynamic clustering protocol produce an enhanced energy consumption ratio comparable with conventional route based clustering protocols. Simulation and mathematical results show that if the distance between the nodes is high, MSK performed fighting fit without the addition of error control codes in AWGN channel condition. The results also disclose that when MSK is added with convolutional coding, researchers have attained higher energy consumption in sensor nodes; the distance between nodes is neither short nor long. It furthermore shows that the combination of MSK with block codes is comparatively consuming more power for sensor data transmission. The future research is to determine the strategies to further improvement in sensor node lifetime and to increase the overall performance of transmission schemes for fault tolerant energy efficient clustered WSN.

Distance based adaptive modulation scheme in various channels will be implemented in combination with other energy efficient techniques in order to improve the network lifetime.

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