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Lifetime Improvement using Adaptive Modulation in Wireless Sensor Network

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***Abstract*—The interest in Wireless Sensor Networks is increasing due to its advantages related to cost, coverage and network deployment. They are use in civil applications and in most scenarios depend upon the batteries, which are the main power source for the sensor nodes. Energy management is main issue of WSNs. To overcome this constraint at the physical layer node's energy consumption is optimized through the adaptive modulation scheme. The lifetime of the path depends upon the lifetime of lowest energy node. This lead to wastage of energy of all other nodes after the first node dead and decreased the lifetime of network. So main objective of the using proposed adaptive modulation is to save the energy of lowest residual energy's node by consuming the energy of other node that have high residual energy. The Simulation results showed that proposed adaptive modulation approach gives 44.44 % better result than the existing adaptive modulation approach.**

Keywords- Wireless sensor network; adaptive modulation; lifetime; M-ary NC-FSK.

I. INTRODUCTION

WSNs consist of large number of devices, which communicate with each other to collect the appropriate data. These devices are known as nodes, which contain sensing unit, processing unit, memory unit, power backup and transceiver unit. The data collected by each sensor communicates through the network to a single processing center that uses all report data to determine characteristics to detect an event. The life of the WSN depends only on energy system. To keep the cost and size of these sensors small, they are equipped with small batteries that can store at most 1 Joule. In large number of application, it is impossible to charge and replace the batteries to extend the lifetime of the wireless sensor network [1]; to increase the lifetime of network the sensing information communication process must be design to conserve the limited energy resources of the sensors, which affect the data rate of the information transmission.

At the physical layer, most of the energy is use for data modulation. For better performance of the WSN it should be chosen carefully. It is the main source of energy consumption in WSN. Selection of the good modulation can increase the lifetime of the whole sensor network [2]. Approximately 70 % of total energy is use for wireless transmission process. To minimize energy consumption of the network very efficient routing protocol are invented but less work has been done relating to the modulation schemes [3].

In this paper, we worked on the physical layer. To optimize the energy consumption of the WSN we proposed approach for adaptive modulation which objective is to improve lifetime of the WSN without affecting the system performance. Based on previous work, we selected efficient modulation technique and proposed adaptive modulation approach for it to further improve the lifetime of the network.

For simulation, WSN model is implemented to compare the result of proposed approach with the existing techniques.

Before explaining proposed adaptive modulation approach, we shall give first related worked on fix modulation and existing adaptive modulation approaches.

II. RELATED WORK

In [4], optimal strategies that minimize the energy per bit required for reliable transmission in the wide-band regime is discussed. The emphasis on minimizing transmission energy is reasonable in the traditional wireless link where the transmission distance is large ($\geq$ 100 m), so that the transmission energy is dominant in the total energy consumption. In order to find the optimal transmission scheme, the overall energy consumption including both transmission and circuit energy consumption to be considered. In, some insightful observations are drawn for choosing energy-efficient modulation schemes and multi-access protocols when both transmission energy and circuit energy consumption are considered. It is shown that M-ary modulation may enable energy savings over binary modulation for some short-range applications by decreasing the transmission time.

The authors In [5] worked on Energy-constrained modulation Optimization. Best modulation strategy to minimize the total energy consumption required to send a given number of bits is analyzed. The traditional belief that longer transmission duration lowers energy consumption may be misleading if the circuit energy consumption is included, especially for short-range application. For both MQAM and MFSK it shows that the transmission energy is completely dependent on the product of B and Ton. To minimize the total energy consumption the transmission time need to be optimized, where it show up to 80% energy saving is achievable via this optimization. It also shows that un-coded MQAM is not only more bandwidth efficient, but also more energy-efficient than the un-coded MFSK.

In [6], Modulation Aware Energy balancing in Hierarchical Wireless sensor Network is investigated. In this author focused on communication characteristics inside each cluster of a hierarchical WSN. A large number of simple low-power sensor devices are distribute in a field in order to collect sensing data and transmit it towards the assigned relay node. Author, investigated the effect of different modulation schemes on the energy consumption of the sensor nodes and demonstrates how proper selection of the modulation scheme can affect the overall distribution of energy consumption in the network and the lifetime of the network. Author proposed a location aware modulation scheme and showed how the modulation selection can flatten and balance the spatial distribution of energy dissipation over a coverage area in a wireless sensor network.

In [7], author proposed GREEN Modulation in Dense Wireless Sensor Networks. The objective of this paper was to analyze and compare the energy efficiency of various sinusoidal carrier based modulation scheme-using parameters in the IEEE 802.15.4 standard and state of the art technology to find the best scheme in a dense WSN over frequency- flat Rayleigh fading channel with path loss. The author analyzed and compared the energy efficiency of various sinusoidal carrier-based modulation schemes considering the effect of bandwidth and active mode duration to find the green modulation in a point-to-point WSN. The experimental result showed that MFSK is attractive for using in WSNs, in particular for short-range applications, since MFSK already has the advantage of less complexity and cost in implementation than MQAM and differential OQPSK, and has less total energy consumption.

In [8] authors proposed adaptive modulation approach to improve the lifetime of WSN. The approach is based on transmitting faster in those nodes that has more residual energy, and transmitting slowly in those nodes that has lower remaining energy. Transmit slowly means consume less energy with higher delay. To achieve latency constraint this delay is recovered by transmitting faster in other node that has higher residual energy. By this approach, node that has lower residual energy its lifetime is improved hence network lifetime, because network lifetime is depend directly upon the lifetime of the nodes who has lower energy. This approach is not optimal because in it energy saving is done only in one node who has lowest residual energy among all other nodes. But there is possibility that some other node has approximately equal energy to the lowest residual energy level. In this case the node that has second lowest residual energy its energy is not saving by this approach. Which lead to reduce the network lifetime.

III. PROBLEM FORMULATION

The solution adopted by Abdellah Chehri [8], which relied on minimizing the energy dissipation over all sensors along a path spending same energy in all the nodes, except only two nodes, which has lowest and highest residual energy is not optimal because there is a probability that another node also has approximately equal residual energy to the lowest energy node. Therefore, the node's consumption of energy inside a path can be different to the consumption of the other nodes because different nodes can have more traffic load than others can. Our approach tried to balance the difference in power consumption of the nodes. In a determined time, we achieved transmission and reception process in specified time duration. Therefore, our mechanism is based on transmitting faster in those nodes that has more residual energy, and transmitting slowly in those nodes that has less residual energy. Transmit faster means to have a lower delay and therefore consume more energy. The idea is to steal to the rich node transmission time in order to give it to the poor node. Thus, nodes with high energy will spend a little bit more energy and low energy nodes will save energy. This concept played important role to increase the lifetime in a path of nodes. Our methodology does not taken care about consuming the minimum energy along path. It centered all its efforts in maximizing the lifetime despite the fact that it consumed more energy than required. This over consuming in energy is justified with the following fact. The lifetime of a path is computed as the time from the beginning of the path until first node dead. Therefore, at this time, several nodes can still have energy in their batteries, energy that is wasted. Our approach tried to use that wasted energy by making over-spending of energy in high battery nodes in order to achieve savings in low battery ones.

Novelty of our approach, however, tries to balance the energy consumption of four nodes (two lower energy nodes and two higher energy nodes) in a determined time without introducing delay.

A. Fix modulation

Fix modulation scheme means use same modulation parameters in all nodes. Therefore, Fix modulation consumes same energy for all the nodes. It does not matter its initial energy is low or high, which lead to same energy consumption in all nodes. The node that has lowest initial energy its energy consumption is same as the other nodes that have high initial energy. With this strategy lowest energy node dead early as compare to other nodes and path connectivity break early. This shows that the lifetime of the path is depending upon the lifetime of lowest energy node. That lead to wastage of energy of all other node after the first node dead and decrease the lifetime of network.

B. Adaptive modulation

Adaptive modulation is the most common circuit technique to offer both low energy consumption and energy awareness in embedded real-time operating systems [9]. It is based on schedule voltage while maintain time and throughput constraints in order to achieve lower energy consumption. In adaptive modulation, the parameter plays the role of the voltage scaling and is schedule in order to achieve lower energy consumption. For a modulation scheme, the higher the modulation parameter, the higher the number of bits per symbol used in data transmission and therefore the lower the transmission time required. In addition, if the modulation parameter increases, the energy spent increase as well. The M-QAM provides better spectral efficiency while the M-FSK assures energy efficiency. The non-coherent M-FSK with small order of constellation size M has been considered the most energy-efficient modulation in wireless sensor networks over AWGN channel. Non-coherent M-FSK appears to be most attractive solution for sensor networks [10]. The modulation scheme requires the least circuit complexity. Apart from that increasing M-ary, result in small SNR and thus less required transmitted power needed for a given SER.

C. Algorithm Formulation

Step 1: Deploy Node randomly

Step 2: Select Path

Step 3: Check residual energy of Node

Step 4: If Node's residual Energy is less than threshold level and it is lowest or second lowest in the path then use M=2

I.e. NC-2-FSK

Step 5: If Node's residual Energy is greater than threshold level and it is highest or second highest in the path then use M=8

I.e. NC-8-FSK

Step 6: Else use M=4

D. Calculation of the nodes's Energy consumption

The energy consumption of the transmitter nodes is cause by two parts: one part is due to RF signal generation, which mostly depends on chosen modulation, and distance of the destination node. A second part of consumed energy (called Pc) is due to electronic components necessary for filters, frequency synthesis, frequency conversion, and soon. In this paper both type energy consumption are taken into account for calculating the energy consumption. The total energy consumption for a packet transmission over the i^{th} hop can be express as:

$$E_i = t * (P_{tx,i} + p_c) \quad (1)$$

In equation (1) E is Transmission Energy, P_{tx} is transmission Power and P_c is Circuit power Consumption. Transmission time for NC-MFSK is calculated by the equation (2)

$$t = Q/(2*B \log_2 M) \quad (2)$$

In equation (2) Q is number of bits, B is Bandwidth and M is Modulation Order used by nodes.

$$P_{tx,i} = 2 * n_s * g_1^{-1} * \log ((2 * (1- (1 - p_s))^{-1} \quad (3)$$

$P_{tx,\ i}$ is the transmission power for the i^{th} hop. It can be calculate by the equation 3. In equation (3) n_s is power spectral density, g_1 is Gain factor and P_s is probability of symbol error. Circuit's power consumption is calculated by equation (4).

$$Pc = P_{lo} + P_{filter} \quad (4)$$

In this equation P_{lo} is power Local oscillator .

$$\sum_{i=1}^{L} T_i \leq T_{max} \quad (5)$$

T_i is the individual transmission time of a node. The equation (5) ensures that the message should transmit through the path with minimum time Tmax.

IV. SIMULATION AND RESULTS

In this study, we randomly deployed sensor node using a two-dimensional uniform distribution in a 50x50 m^2. In the next step path selected, through which data is transmitted for different approaches. For the data transmission, Multi-hop data transmission topology has selected. Next step of the simulation setup is to design M-ary adaptive transceiver that can transmit and receive data up to NC-8FSK adaptively [9] as shown in figure 1.

The system simulated taking as a reference IEEE 802.15.4 standard in order to make a realistic choice of the simulation parameter values. For this purpose, we assume that all modulation schemes operate in B = 65.5 KHz and the 10 = 2.4 GHz Industrial Scientist and Medical (ISM) band has been utilized for WSNs.

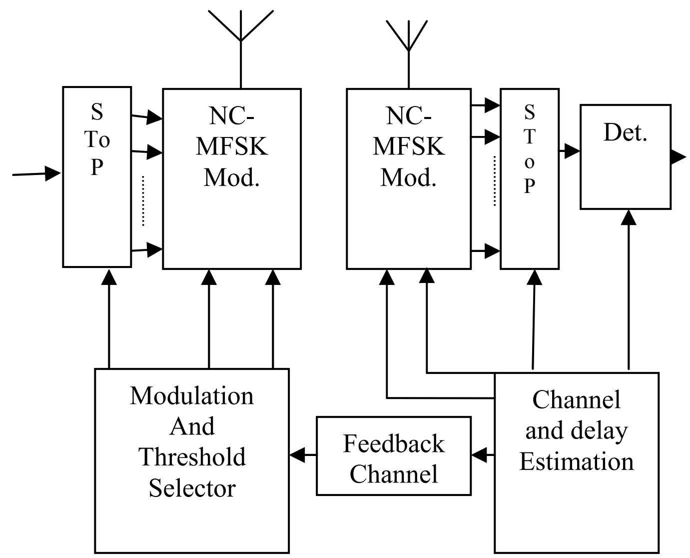

Fig. 1. Adaptive NC-MFSK transceiver

A. Waveforms for NC 8FSK Transceiver

Figure 2 is showing modulation and demodulation waveforms corresponding to the binary information. In 8FSK, signal is switches between eight frequencies. To represent a digital signal into the eight forms two three bits are used. Which represents the signal in 000 001 010 011 100 101 011 111 states. According to states, eight frequencies are use for modulation. Signal 000 001 010 011 100 101 011 111 represented by f1, f2, f3, f4, f5, f6, f7, f8 respectively. Modulated and received signal waveform according to its states.

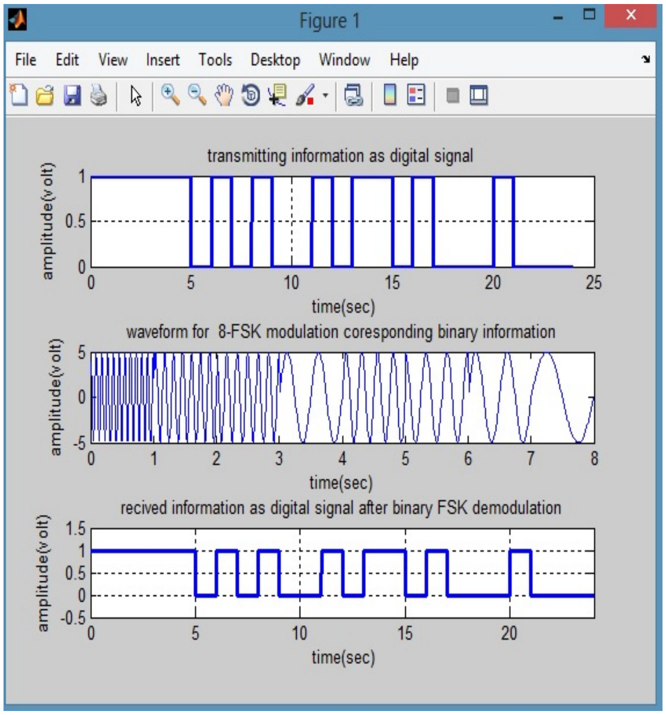

Fig. 2. Waveforms for NC 8FSK Transceiver

Table 1. Input parameters

Parameter	Value
Area	50*50 meters
Bandwidth(B)	10 KHz
Antenna Gain(G_1)	30db
Path loss(N_s)	-174
P_{filter}	2.5mw
P_{Lo}	1.8mW
Symbol Error Rate(P_s)	10^{-3}

Table 1 is showing the parameters that are taken account for simulation purposes.

A. Comparison of Energy Consumption for fix, existing adaptive and proposed Adaptive Modulation approaches:

The Figure 3 is showing comparison between fix, existing adaptive and proposed adaptive modulation approaches. It shows that for fix modulation energy consumption in all the nodes is same it does not matter its initial energy is lowest or highest. In the case of existing adaptive modulation approach, it cleared that the node 1 that has lowest energy its energy consumption is also lowest and node 10 that has highest initial energy its energy consumption is highest. The main objective of the proposed adaptive modulation approach is to use less energy of nodes which initial energy is lowest or equal to the lowest state. Figure 3 clearly shows that with this approach node number 1 and 2 which has lowest energy its energy consumption is also lowest and the node 9 and node 10 which has highest initial energy its energy consumption is also highest. Comparison of approaches show that, with proposed approach node 1's energy saved as well as node 2's energy that also has lowest energy its energy is also saved, which led to improvement the lifetime of the network as compared to fix and existing adaptive modulation approaches.

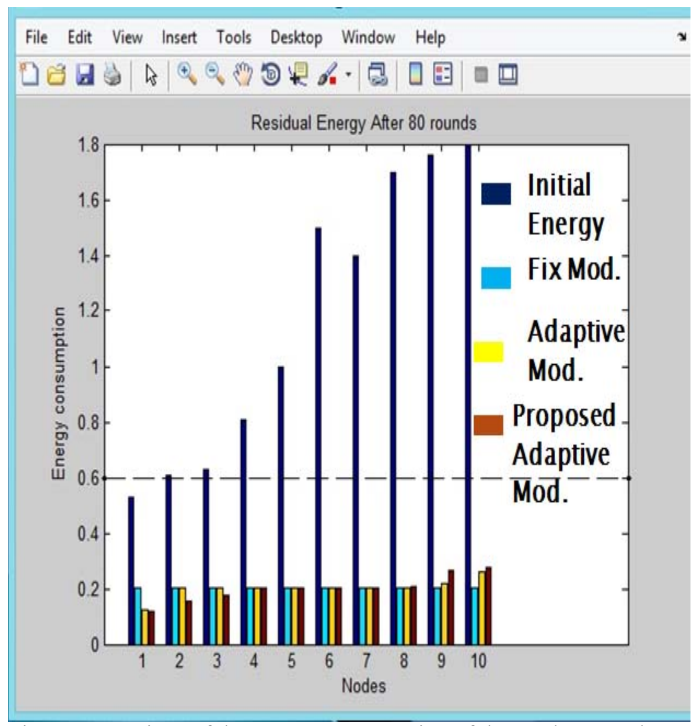

Fig.3. Comparison of the Energy consumption of the used approaches

B. Improved Lifetime

Figure 4 show the percentage-improved lifetime for wireless sensor network. In comparison, existing adaptive modulation gave 47% better result than fix modulation and proposed adaptive modulation approach gave 68% better result than fix modulation. Therefore, we can say that proposed adaptive modulation approach improved lifetime of the network as comparison with existing approaches and it gave 44.44% better result than the existing adaptive modulation approach. So we can say that it is efficient approach for improve lifetime of the WSN.

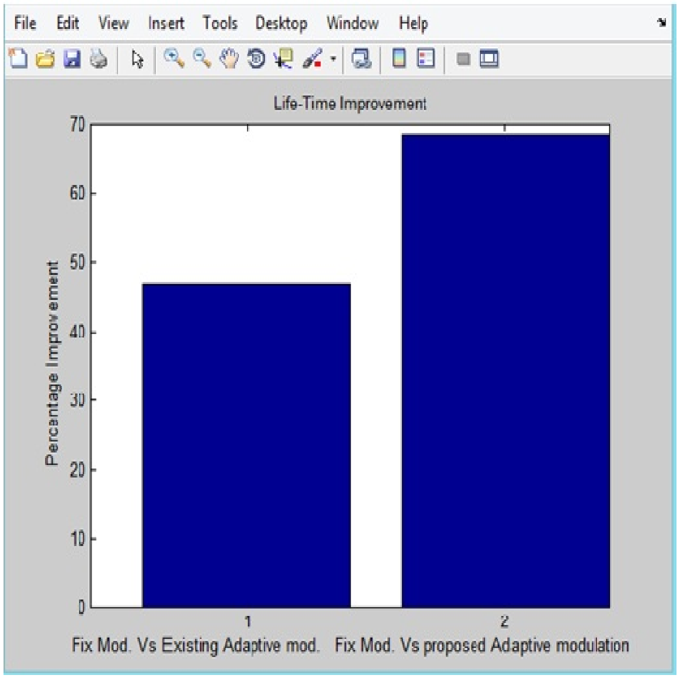

Fig.4. improved Lifetime

V. Conclusion

We considered the problem of Lifetime Improvement using Adaptive modulation. Initially, we developed WSN network model to compare the fix modulation versus existing adaptive modulation approach. For comparison, we selected NC-FSK modulation because it is efficient technique for data transmission in WSN and being use in practical. We adopt an Adaptive modulation approach to optimize transmission energy. The objective is to reduce node energy consumption of node with lower energy. We compared the both techniques to in terms of lifetime. The results showed that with adaptive modulation we minimized the energy consumption of node. In terms of lifetime improvement, existing adaptive modulation gives 50% better result than fix modulation whereas proposed approach gives 72% better result than fix modulation approach. In proposed approach, we optimized the energy consumption more number of nodes than in the existing approach. The Results showed that proposed adaptive modulation approach consumed less energy than the existing adaptive modulation approach and gave better result than other Adaptive modulation approach and improved 44.44 % lifetime of WSNs. Therefore, we can say that proposed approach decreased energy consumption and maximized the network lifetime.

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