Impact Of Fading On Quality Of Services in Wireless Sensor Network

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***Abstract*— In wireless sensor network, information has been sensed by the sensor node and transmitted to the destination sensor node by relaying through the various sensor nodes. These nodes are called relay node or intermediate nodes. As the transmitting channel in Ad-Hoc or sensor network is wireless channel. Hence, the original message signal gets affected by the physical impacts or parameters affecting the channel. Hence the original message signal becomes noisy and ultimately affected the quality of services. So due to the wireless transmission, fading, scattering, shadowing and multipath reduces the signal as well as quality of services.**

Keywords—Bit Error Rate; Successful data received; Rayleigh Fading Environment; Sensor Node Coverage Area; Square Grid sensor network.

I. INTRODUCTION

As in the wireless sensor network, the transmission medium is wireless air channel and wireless channel is error prone due to unguided transmission and unknown noise level introduced by the environment.

Hence, it is very important to evaluate the performance of data transmission in noisy environment, because this analysis gives us the realistic results of data transmission, QoS, and other performance parameters. The main objective of this paper is to compare and analyze the impact on the communication parameters of square grid network in presence of Rayleigh fading.

In this paper, every aspects of the Ad-hoc communication in wireless sensor network have been compared such as Bit Error Rate of route, Average number of hopes, Successful data received at base station of sensor network etc. Due to signal fading the route bit error rate gets degraded and hence it is necessary to evaluate the response of this signal parameter.

This paper deals with wireless sensor network for square grid topology [1]. The main parameters for the checking of signal quality are Bit Error Rates and Successful Data Received at base station. As we know that the data has been transmitted form of packets and data packets are the arrangement of a lot of bits. Hence, in wireless transmission the data bits of original message signal gets corrupted. As a result of which the data packet has been also corrupt. So that the calculation of total number of corrupt bit received at the destination or the base station, is very important. The total number of corrupt bits over the total number of transmitted bit is called Bit Error Rate. It is also a measure of the network connectivity.

If the data or information transmitted from the source node to destination gets corrupted above a threshold value (it means a lot of bits are received at the base station with error), then it is not called communication. In this case it is only called as data transmission.

Another performance parameter, which decides the quality of services in term of network connectivity, is called as Successful Data Receive. This parameter is defined as the total number of bits received successfully at the receiver over total number of transmitted bits. These transmission parameters have been compared in AWGN and Fading channel.

In this paper, we have analyzed the quality of services in term of Bit Error Rate and Successful Data Received in AWGN and Fading channel. We validate our analysis using MATLAB simulation. The rest of this paper is as following: In Section II presents Sensor Network Model. In Section III defines Quality of Services. Comparative results are presented in the Section IV. Finally section V concludes the paper.

II. SENSOR NETWORK MODEL

In wireless sensor networks, there are various topologies in which the wireless sensor nodes have been arranged for the data communication purpose. In this paper, the parameters of communication have been compared for square grid network topology in fading and in AWGN channel. In this paper, we have taken a network in, which sensor nodes are arranged in a regular manner and form a square grid.

The sensor nodes are arranged in such a way so that a small rectangular area covers sensor nodes at each vertex, now a lot of such rectangular areas make a large network of total area S. Hence, the total network has been covered the total number of sensor nodes (N) in total area (S). Then,

$$N\ (r_{link}^2) = S \qquad (1)$$

So, the distance between the two successive sensor nodes has been denoted by

$$r_{link} = \sqrt{\left[\frac{S}{N}\right]} = \sqrt{\frac{1}{nsd}} \qquad (2)$$

Hence, the wireless sensor network is shown in Figure 1. In this model sensor nodes are arranged in regular manner. Sensor Nodes have been managed in Tiers with a center node called Base Station or Destination Node. In this sensor network, there may be any number of tiers. Sensor Nodes are place in regular manner hence the straight flow of data has been considered. Sensor node can only transmit its data to the node, which placed at the Right, Left, Top or Bottom position of this node [1]. This sensor node cannot transmit the data to those nodes, which have diagonally placed from its position.

In this paper, route Bit Error Rate has been calculated for the insurance of sensor network connectivity. A sensor network is said to be connected if there is any multihop path or route connecting any wireless sensor node to the base station or destination node in the sensor network [1],[2],[3],[17],[18]. However, network connectivity can be affected because the wireless channel is error-prone.

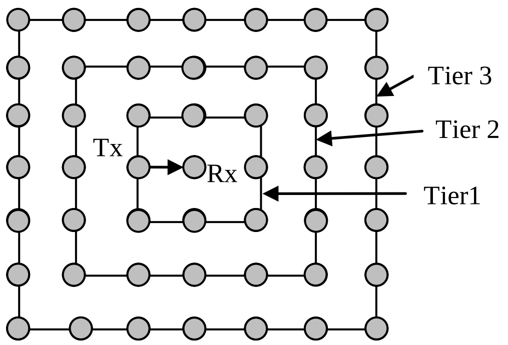

Fig. 1: Square Grid Wireless Sensor Network

Sensor node hops are susceptible to noise (in the form of signal interference), the QoS in terms of total route Bit Error Rate decline as the number of hops in a communicating path increases. Consequently, the network performance may be inadmissible, although there is a sequence of hops from source node to the base station.

III. QUALITY OF SERVICESS

In any wireless communication system, the Quality of Services is the measure of successful communication. The connectivity between any two sensor nodes has been also decided by the Total Bit Error Rate and Successful Data Received at the receiving sensor nodes [2].

In this paper, these two parameters have been evaluated for Square grid wireless sensor network and also compared for the AWGN channel and Rayleigh fading channel.

The total bit error rate for a wireless sensor network has been evaluated that the ratio of total number of bits received with error, at the destination to the total number of bits transmitted from the transmitter.

In any type of communication system, the quality of received signal has been decided by the term Quality of Services (QoS). Ideally the transmit signal must be received identical at the receiver, but due to practical response of communication system the received signal is differ from the original transmit signal.

Sometimes it is far away from the original message signal due to unpredictable system noise and channel environment. But the successful transmission of signal is called communication, hence for a good communication the variations in received signal must be in acceptable range [4],[5],[15],[16].

A. Bit Error Rate

In Digital Communication, if we consider BPSK, the message is in the form of bits i.e. in the form of “Zero (0)” and “One (1)”. When such data packet is transmitted from the transmitter, this gets corrupted means many of the “Ones” change into “Zeros” and many of the “Zeros” change into “Ones”. The amount of these corrupt bits decided the received signal quality; hence the measure of these corrupt bits over total number of transmitted bit is called Bit Error Rate.

$$\text{Bit Error Rate} = \frac{\text{Total number of received bits with error}}{\text{Total number of Transmitted Bits}} \quad (3)$$

B. Route Bit Error Rate

Now assuming that the original message signal is attenuated with a spatial distance raised to the power γ, where γ is denoted as pathloss exponent, the power of the original message signal from the transmitting node as observed at the base station or at receiving sensor node can be written as (4).

$$P_{rx} = \left(\frac{\alpha\, P_{tx}}{r_{link}^{\gamma}}\right) \quad (4)$$

Where

$$\alpha \triangleq \frac{G_{tx} G_{rx} c^2}{(4\pi)^2 f_c^2}$$

and P_{tx} is the uniform transmit power for all nodes [6],[7],[8], G_{tx} and G_{rx} are the transmitting and receiving antenna gain, f_c is the carrier frequency, and c is the speed of light.

Here it is assume that the omnidirectional antennas are used at the sensor nodes (hence G_{tx} = 1= G_{rx}), and f_c = 2.4 GHz i.e. ISM Band (unlicensed frequency band).

In addition, assuming binary phase shift keying modulation (BPSK), according to BPSK there can be two values for the amplitude of the received signal (S_r). Which are as written following:

1) $S_{signal} = \sqrt{P_{rx}/R_{bit}} \triangleq \sqrt{E_{bit}}$ if “ +1 ” is transmitted

2) $S_{signal} = -\sqrt{P_{rx}/R_{bit}} \triangleq -\sqrt{E_{bit}}$ if “ -1 ” is transmitted, remember that $\sqrt{E_{bit}}$ is the signal bit energy.

The noise power due to semiconductor thermal heating can be written as

$$P_{Thermal\ NOISE} = F\ k\ To\ B \quad (5)$$

Due to spatial invariance, one could calculate total interference experienced by the base station or by the final destination node. Now, consider a node k at a distance k r_{link} from the base station or destination node, produces interference, where k is a multiplicative factor depends on the tier number of k_{th} sensor node. For example, a wireless sensor node at the third tier would have k=3 because it is placed at the distance $3r_{link}$ from the base station. The interference signal power from k_{th} node can be written as following

$$P_{\text{int}\,k} = \frac{\alpha\, P_{tx}}{(k\, r_{link})^{\gamma}} = \frac{P_{rx}}{k^{\gamma}} \quad (6)$$

For each interfering node k, the interfering signal amplitude can be classified into any one of the following:

1) $S_k = \sqrt{P_{\text{int k}}/R_{bit}} \triangleq \sqrt{E_{bit}/(k\, r_{link})^{\gamma}}$ if a +1 is transmitted,

2) $S_k = -\sqrt{P_{\text{int}\,k}/R_{bit}} \triangleq -\sqrt{E_{bit}/(k\, r_{link})^{\gamma}}$ if a “ -1 ” is transmitted, and

3) $S_k = 0$, if “NO” transmission from k_{th} sensor node .

Now, the probability of transmission for an interfering sensor node can be calculated. This interfering sensor node cause interference depends on the MAC protocol [9],[10],[14]. In this paper, the Reserve and Go MAC protocol have been considered and also assumed that each wireless sensor node transmit signal in the form of packets.

Transmitting packets have L bits per packet. Hence the packets are transmitted with length L, which is also fixed. It can be shown that the probability of transmission for an interfering sensor node, is equal to that an interfering sensor node transmits during L=R_{bit} (permeable interval)

[11],[12],[13]. Now the probability of transmission for an interfering sensor node can be written as:

$$P_{trans} = 1 - e^{-\left(\frac{\lambda_t L}{R_{bit}}\right)} \quad (7)$$

Now the hop BER can be calculate in the following way. Since we are considering a binary phase shift modulation, it can be assume that when the transmitter transmits "+1", then $S_{signal} = \sqrt{E_{bit}}$ and when the transmitter transmits "-1", then $S_{signal} = -\sqrt{E_{bit}}$. Let us consider a random interfering vector $\overrightarrow{S_{int}} = \{S_1, S_2, S_3, S_4, \ldots\ldots S_{N-2}\}$, where S_k is the amplitude of the interfering signal received at the receiving sensor node, from an interfering sensor node k.

Remember that $\overrightarrow{S_{int}}$ is a random interfering vector because each component of this random vector can take anyone of the following different values. These values of S_k can take these values with the corresponding probability, which are given below:

$$S_k = \begin{cases} \sqrt{E_{bit}/(k\, r_{link})^{\gamma}} & \text{with probability } \frac{1}{2}P_{trans} \\ -\sqrt{E_{bit}/(k\, r_{link})^{\gamma}} & \text{with probability } \frac{1}{2}P_{trans} \\ 0 & \text{with probability } 1 - P_{trans} \end{cases} \quad (8)$$

Assuming that threshold for the detection of a receiving bit is placed at 0, hence the probability of bit with error can be written as following

$$P\{bit\ error\} = BER_{hop} = \sum_{\overrightarrow{S_{int}}} P\{r < 0 | \overrightarrow{S_{int}}\}\ P\{\overrightarrow{S_{int}}\} \quad (9)$$

Now for a known random interfering vector $\vec{S}_{int}$, the probability of error can be expressed as following

$$P\{r < 0 | \vec{S}_{int}\} = \mathrm{Q}\left(\frac{\sqrt{\mathrm{E_{bit}}} + \sum_{k=1}^{N-2} \mathrm{S_k}}{\sigma}\right) \quad (10)$$

Where, σ is equal to the $\sqrt{FkT_0/2}$. Assuming that an bit detected with error at the end of a hop is not corrected in next comming hops, the total Bit Error Rate at the end of a route with $\bar{n}_{hop}$ hops, denoted as $\mathrm{BER}_{\mathrm{route}}^{\mathrm{Total}}$, can be written as

$$\mathrm{BER}_{\mathrm{route}}^{\mathrm{Total}} = 1 - \left(1 - BER_{hop}\right)^{\bar{n}_{hop}} \quad (11)$$

Where, $\bar{n}_{hop}$ is the average number of hopes and denoted by

$$\bar{n}_{hop} = \frac{\sqrt{N}}{2}$$

As it is assumed that each relay sensor node computes the bit error rate of the signal before forwarding to the next sensor node in a multihop path from source node to the destination node.

C. Successful Data Received

In WSN, as the data is wirelessly transmitted. In BPSK, the message is in the form of bits. When these bits have been transmitted to the receiver then due to environmental effect, some of these bits gets changes and received at receiver 'With error'. But except of these bits other bits are received at the receiver 'Without Error'. The amount of these bits, which have been received correctly, called as successful data.

The successful data received at base station means the total amount of correctly received bits at the destination or base station after relaying through several intermediate nodes [1], [2]. Correctly received bits means identical to the transmit bits. The successful data received at the base station or destination node

$$\mathrm{SDR}_{\mathrm{route}}^{\mathrm{Total}} = \left(SDR_{hop}\right)^{\bar{n}_{hop}} \quad (12)$$

IV. Comparative Results

In this section, the simulation results of proposed idea have been discussed and compared with existing wireless sensor network environment. Moreover, MATLAB is used as a simulation tool.

A. Route Bit Error Rate for different values of Sensor Node Spatial Coverage Area in Fading Environment

In Fig. 2, the curve shown in Green color represents the BER_{route} for R_b= 100Kbps in fading environment, for the same data rate but in AWGN channel, the BER_{route} is represented by Red color for various sensor node coverage area.

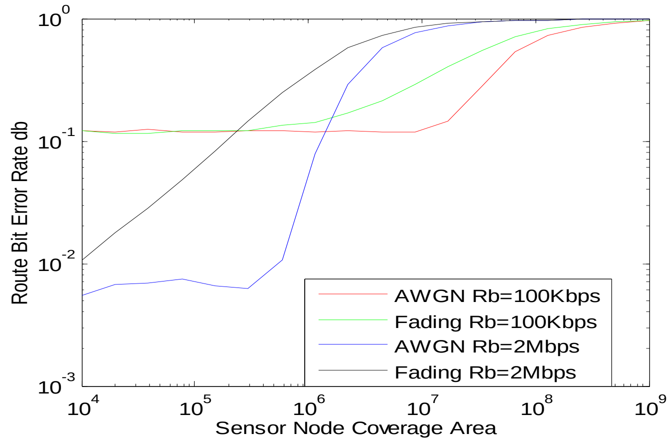

Fig. 2: Route Bit Error Rate as a function of Sensor node coverage area for two data transmission rates in AWGN channel and in Fading Environment.

Blue and Black color curve represents the BER_{route} for AWGN channel and Fading Environment respectively with R_b=2Mbps. It is very clear that in the wireless sensor network considering Fading Environment the QoS degrades.

B. Successful Data Received at base station as a function of Sensor Node Spatial Coverage Area in AWGN Channel and in Fading Environment

Here in Fig.3 a response of successful data received at base station is shown for AWGN channel and Fading Environment. It is simulated by two data rates i.e. 100Kbps and 2Mbps.

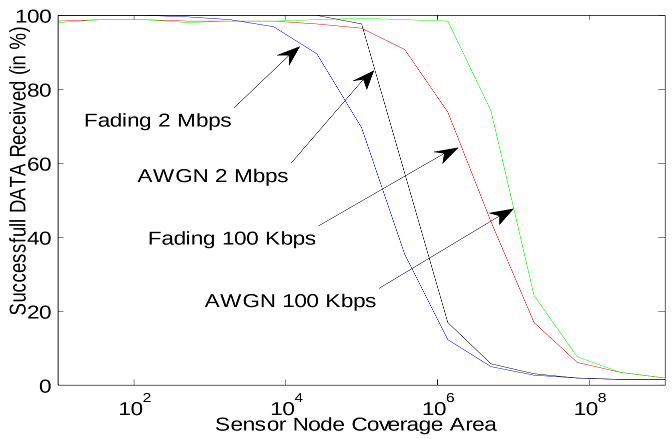

Fig.4: Successful Data received as a function of Sensor node coverage area for various data rates in Fading Environment.

It is very clear from this simulation that if we increase the coverage area of sensor node then the successful data arrival at base station gets degraded early in case of high data transmission rate than low data transmission rate. In Fig.3, Successful data received at base station shows same response for almost all data transmission rates before a certain value of sensor node coverage area and for higher values of node coverage area, shows better response for low data rates as comparison.

In Fig.3, parameter has been simulated for AWGN channel by Black and Green color for 2Mbps and 100Kbps respectively and for fading environment, parameter has been simulated by Blue and Red color for 2Mbps and 100Kbps respectively.

V. Conclusions

The comparative analysis of wireless sensor network in fading environment and in AWGN channel environment provides the exact information about the data flow, impact on original data, behavior of bit error rate and successful data received at the base station or destination. This also provides the information that the signal response or data quality degrades in Rayleigh fading channel as compared to the AWGN channel.

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