QoS Based Adhoc Probabilistic Routing Strategy for e-health Services

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Abstract— Fast growing area of remote monitoring has seen E-Health as a recent addition to its domain. The objective is to provide healthcare diagnosis and monitoring services at remote locations. Adhoc networks are being used to provide the communication link between the patient being monitored and medical expert. This paper presents a probabilistic routing strategy for Adhoc networks deployed to provide e-health services. The objective is to cope-up with performance related issues due to the randomness and diversity of the channel conditions prevailing at various participating nodes. More realistic channel conditions have been considered by modeling the effect of jamming and multipath fading. Bit error rare and packet size have been taken as decision making parameters for routing algorithm.

Index Terms— Adhoc networks, BER, channel model, e-health, PER, QoS, routing strategy.

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1   INTRODUCTION

IN the recent past, several wearable (on-body) and implantable body sensor have been developed to monitor and record the vital physiological parameters of the human body. These devices frame body area networks and are supported by mobile applications through which the recorded data can be utilized by healthcare professionals for remote diagnosis and monitoring services, together known as e-health [1] – [4]. The major bottleneck towards deployment of these systems is unavailability of a dedicated communication system for healthcare services and inability of the existing systems to perform as per the desired standards of healthcare industry. Another challenge faced is the diversity and randomness of the entire context in which these systems are to be deployed and used. One of the possible solutions to these requirements and challenges is the use of adhoc networks.

Efficient routing strategy has always been a major issue of concern for adhoc networks. The mission critical nature of e-health services demands for best possible availability of the network resources under all kind of geographic and environmental conditions. This paper concentrates on proposing an efficient probabilistic routing strategy for adhoc networks using Quality of Service (QoS) parameters for the areas strongly affected by fading and jamming effects. Due to the wide spread nature of Adhoc networks the participating nodes may be present in different channel conditions. Four such scenarios have been considered in this paper to analyze the fading and jamming effects encountered by Adhoc networks:

1. Additive White Gaussian Noise (AWGN)
2. AWGN with Jamming
3. Rayleigh faded channel
4. Rayleigh faded channel with Jamming

For any particular node having critical patient data to be transmitted, the neighbouring nodes may be present in different channel conditions. Bit error rate (BER) and packet error rate (PER) are calculated for links to all the neighboring nodes and a decision is made to select the best performing node. This paper considers two commonly used digital modulation techniques viz. QPSK and GMSK to obtain probabilistic model of BER for the four above mentioned conditions. The effect of packet size on PER is also analyzed.

2   PROBABILISTIC CHANNEL MODELS

Probabilistic models for BER analysis have been obtained for all the four scenarios mentioned in section 1 in the form of four cases.

Case 1: AWGN: We begin with a simple case of AWGN channel. BER for $(\pi/4)$QPSK can be given as [5]

$$p_{b,QPSK-AWGN}(E) = (1/2)erfc\sqrt{E_b/N_o} \qquad (1)$$

where E_b/N_o is the Bit Energy to Noise Ratio.
The probability of BER for GMSK (for 3db Bit Duration) over AWGN channel is given as [5]

$$p_{b,GMSK-AWGN}(E) = (1/2)erfc\sqrt{0.68E_b/N_o} \qquad (2)$$

Case 2: Rayleigh fading: A more practical situation in wireless propagation demands for multipath fading models e.g. Rayleigh Fading. There will be a large number of plane waves present in the received signal. Now the complex low pass signal of plane waves can be treated as a circular symmetric Gaussian random variable. BER of $(\pi/4)$QPSK over Rayleigh fading channel can be given as

$$P_{b,BFSK-Rayleigh}(E) = \frac{1}{2}\left[1-\sqrt{\frac{\bar{\gamma}}{\bar{\gamma}+1}}\right] \qquad (3)$$

where $\bar{\gamma}$ is average signal to noise ratio and can be given as [5]

$$\bar{\gamma} \triangleq \bar{\beta^2} E_b/N_0 \qquad (4)$$

$\overline{\beta^2}$ is mean square value of the Rayleigh multipath random variable.

BER of GMSK (for 3db bit duration) over Rayleigh fading channel can be given as [5]

$$P_{b,GMSK-Rayleigh}(E) = \frac{1}{2}\left[1 - \sqrt{\frac{0.68\overline{\gamma}}{0.68\overline{\gamma}+1}}\right] \qquad (5)$$

Case 3: AWGN with Jamming: Since the proposed routing strategy is for the mission critical application of e-health, it needs to be analyzed in the presence of jamming signals also. In such areas, the signal to noise ratio is given by

$$\gamma_{0J} \underline{\underline{\Delta}} \beta^2 E_b / (N_0 + J_0) \qquad (6)$$

Due to jamming average signal to noise ratio is given by

$$\overline{\gamma}_{0J} \underline{\underline{\Delta}} \overline{\beta^2} E_b / (N_0 + J_0) \qquad (7)$$

Now BER due to jamming signal for $\pi/4\ QPSK$ in AWGN channel can be given as [6]

$$P_{b,QPSK-Jamming}(E) = \frac{1}{2}erfc\left(\sqrt{\frac{E_b/N_0}{1+(E_b/N_0)(J/S)/G_P}}\right) \qquad (8)$$

Now BER due to jamming signal for GMSK over AWGN channel is given as [6]

$$P_{b,GMSK-Jamming}(E) = \frac{1}{2}erfc\left(\sqrt{\frac{0.68E_b/N_0}{1+0.68(E_b/N_0)(J/S)/G_P}}\right) \qquad (9)$$

Case 4: Rayleigh Fading with Jamming: When jamming signals are present in the areas affected by multipath fading, the combined probability density function (PDF) of Rayleigh fading is written as:

$$P(\gamma_{0J}) = \frac{1}{\overline{\gamma}_{0J}}\exp\left(\frac{-\gamma_{0J}}{\overline{\gamma}_{0J}}\right) \qquad (10)$$

So, BER for $\pi/4\ QPSK$ over Rayleigh multipath fading channel in presence of jamming signal can be calculated as

$$p_{J,QPSK}(E) = \int_0^\infty p(J;\gamma_{0J}).P(\gamma_{0J}).d\gamma_{0J} \qquad (11)$$

where $p(J;\gamma_{0J})$ is the conditional BER and can be given as

$$P(J;\gamma_{0J}) = \frac{1}{2}erfc(\sqrt{\gamma_{0J}}) \qquad (12)$$

Now evaluating the eq. (9), the average BER of $\pi/4\ QPSK$ over Rayleigh fading with jamming is given by [6]

$$P_{J,QPSK}(E) = \frac{1}{2}\left[1 - \sqrt{\frac{\overline{\gamma}_{0J}}{\overline{\gamma}_{0J}+1}}\right] \qquad (13)$$

In terms of jamming parameters, eq. (13) can be written as

$$P_{J,QPSK}(E) = \frac{1}{2}\left[1 - \sqrt{\frac{\overline{\beta^2}(E_b/N_0)G_P}{G_P+(J/S)(E_b/N_0)+\overline{\beta^2}(E_b/N_0)G_P}}\right]$$

$$(14)$$

where J/S is the system's jamming rejection capability and is known as the quality factor. G_P is the processing gain of the system.

Similarly the BER of GMSK (for 3db bit duration) over Rayleigh fading with jamming is given by

$$P_{J,GMSK}(E) = \frac{1}{2}\left[1 - \sqrt{\frac{0.68\overline{\gamma}_{0J}}{0.68\overline{\gamma}_{0J}+1}}\right] \qquad (15)$$

In terms of jamming parameters eq. (15) can also be written as

$$P_{J,GMSK}(E) = \frac{1}{2}\left[1 - \sqrt{\frac{\overline{\beta^2}(E_b/N_0)G_P(0.68)}{G_P+0.68(J/S)(E_b/N_0)+\overline{\beta^2}(E_b/N_0)G_P}}\right]$$

$$(16)$$

Higher BER may result in link outage and thus transmitting node sends data to several the neighbouring nodes which further follow the same process till the data reaches destination. Any pre-anticipation of the best performing link in terms of BER can act as an important decision rule for routing in case of critical applications.

3   BER BASED ROUTING STRATEGY

In wireless communication, various kind of routing algorithms are available but their typical limitations include high power consumption, low bandwidth, and high error rates. A probabilistic routing strategy based upon BER estimation is proposed here. Also the strategy is optimal in terms of energy conservation by reducing the number of transmission to more than one neighbouring nodes. Fig. 1 presents a network of randomly placed nodes which frame an Adhoc network amongst them. Node 1 acts as the source of data thus representing the patient being monitored. Node 8 is the destination or the healthcare professional in case of a network providing e-health service.
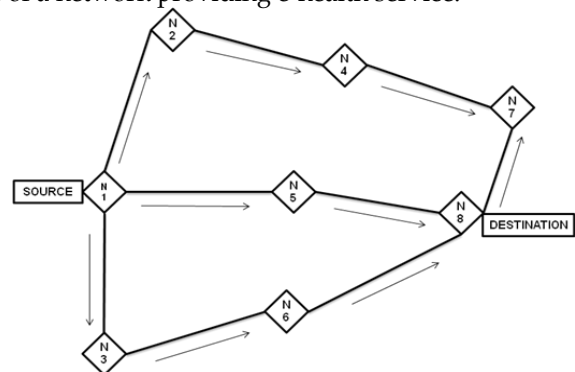

Fig. 1: Adhoc Network model

An algorithm for the proposed routing strategy is given below:

(1) START

(2) Identify neighbouring nodes for transmitting node say N1.
(3) Calculate BER and/or PER for all the neighbouring nodes.
(4) Identify channel conditions for links by comparing calculated values with those stored in lookup table or by following curve fitting approach.
(5) Select the optimum link as per the requirements of the application for which data is being transmitted.
(6) Repeat steps 2 – 5 for all the intermediate nodes till destination node is reached.
(7) STOP

The performance of proposed routing strategy has been analyzed in terms of BER, PER and energy or power requirements. In order to route the packets from N1➔ N8 a look up table is created and stored in every node. For example the look up table present at node N1 will contain the limiting values of BER, PER and power saving for four different cases of channel conditions discussed in section 2. Node N1 calculates BER and PER for its neighbouring nodes N2 and N3 i.e. N1➔N2 and N1➔N3. The results of these calculations are compared with the values present in the look up table. After comparing the two values, decision is made about the channel condition between the two nodes. Once we know the propagation characteristics of all the possible links, an optimum link for data transmission is selected based upon the requirements of the application. Details of the optimization process are out of the scope of this paper. This information can also be utilized for selecting a particular modulation technique or error coding scheme. The performance of modulation techniques and error coding schemes are affected by the propagation characteristics of the medium.

A structure of lookup table for BER and PER is shown in table 1. PER can be obtained for different values of Packet size N. The effect of Packet size on PER will be explained in the next section.

TABLE 1

STRUCTURE OF LOOKUP TABLE FOR BER AND PER

Eb/No	BER	PER N=8	PER N=16	PER N=32	Suitable Channel Model

4. RESULTS AND ANALYSIS

As far as QoS parameters are concerned, importance of BER and PER cannot be ignored. Since the proposed routing strategy is based on these two factors, analysis has been done using BER expressions derived in section 2 for two modulation techniques namely GMSK and π/4 QPSK. This analysis has been done on all the four practical scenarios introduced in section 2 in the form of four cases that might occur while deploying Adhoc networks. Once we obtain the BER for a particular link, then PER can be obtained by using the following formula.

$$PER = 1 - [1 - BER]^N \qquad (17)$$

Where N is packet size including error detection coding bits if any. Mathematical simulation has been used to obtain the results.

Impact of jamming: Since fading and jamming represent more practical situations, results have been plotted to analyze the jamming in presence and absence of Rayleigh fading.
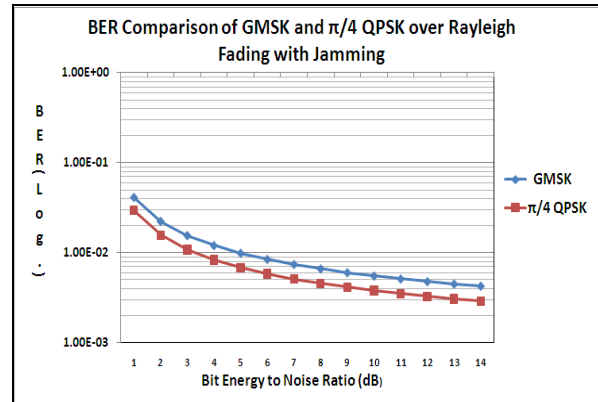

Fig. 3: BER Comparison of GMSK and π/4 QPSK over Rayleigh Fading with Jamming

Fig. 3, 4 and 5 show that performance degradation due to presence of jamming signal is more severe in case of Rayleigh faded channel since no significant reduction in BER is achieved even for higher values of bit energy to noise ratio. In other words, if any link with low or no fading effect is available, data transmission with quite low level of BER can be achieved even in presence of jamming signal by increasing signal power. For critical applications of e-health services this extra consumption of power is quite acceptable. However, links in faded regions must be avoided since jamming effect is more severe in such regions.
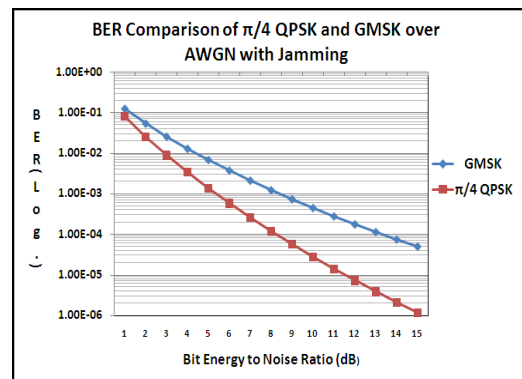

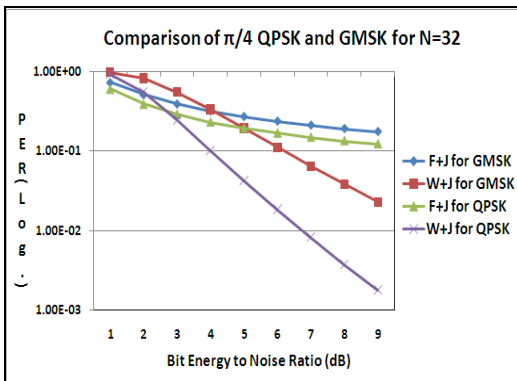Fig. 4: BER Comparison of π/4 QPSK and GMSK over AWGN with Jamming.

Fig. 5: Performance of π/4 QPSK and GMSK in AWGN channel and Rayleigh for N=32

Impact of packet size: In a wireless Adhoc network, packet size may vary as 4, 8, 16, 32, and so on. Therefore the impact of packet size on performance of the wireless link is another useful QoS parameter that is to be considered while deploying Adhoc networks. The impact of packet size on PER for GMSK is shown in Fig. 6.
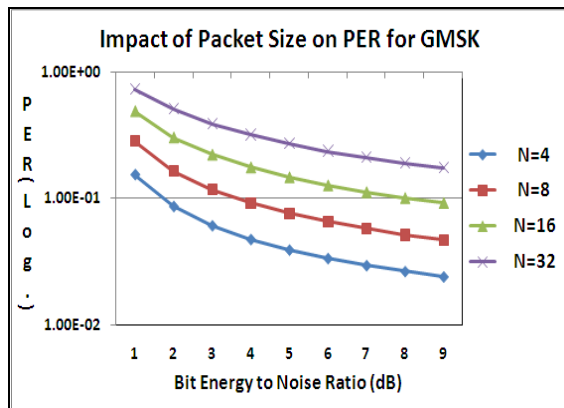

Fig. 6: Impact of Packet Size on PER for GMSK

Increase in packet size shows a uniform increase in PER for various values of bit energy to noise ratio. Therefore, it is advisable to transmit the data in small size packets for better reliability of the network. The increase in number of packets for a particular amount of data might result in more number of iterations for routing process in case of connectionless network. However, this increase will be compensated by reduction in number of retransmissions due to link failure since the transmission takes place by pre-anticipated packet size resulting in low PER.

Energy conservation: Power is a severely constrained resource in battery operated nodes in Adhoc networks. The proposed routing strategy discussed in the paper conserves energy by: (i) reducing retransmission selecting more reliable link/route and (ii) selecting an optimum value of signal power above which increased SNR doesn't prove useful in reducing the error rate. Therefore energy can be conserved.

5. CONCLUSION

E-health has recently evolved as a revolutionary service in healthcare sector and adhoc networks have been shown to provide a good communication background for this mission critical application. Routing strategy plays a vital role in performance of Adhoc networks. The routing strategy proposed in this paper presents an energy efficient way of transmitting data through more reliable links. More realistic channel conditions have been analyzed by considering the effect of jamming signal and multipath fading. The decision is made by comparing calculated values of BER and PER with those stored in lookup table to select better performing link along with optimum packet size and bit energy for transmission.

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