Various Methods of Link Design for Transferring Data in Wireless Sensor Networks for different Applications

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Abstract. This paper offers the different type transmission schemes used in wireless sensor networks. The wireless sensor network used in a number of applications such as Agriculture, Military, Medical, Multimedia etc. According to the applications there are different quality of service parameters and designing requirements for different layers in network design. While designing any ad hoc network or sensor network many designing principals and challenges are taken into consideration. For the designing of protocols layering in ad hoc sensor network basically a five layer model is taken into consideration. These layers are application, transport, network, Medium access control and physical layer. In this paper different types of designing constraints associated with physical and medium access layer has been introduced for different applications in sensor networks. In that manner this paper helps us to select the designing of a link for particular application.

Keywords: bit error rate (BER);Quality of service(QoS);wireless sensor networks(WSNs);error control schemes(ECS); packet error rate (PER); forward error correction (FEC); Amplitude shift keying(ASK) modulation, Binary Phase shift keying(BPSK);signal to interference plus noise ratio(SINR);orthogonal space time block code(OSTBC)

1. Introduction

Wireless Sensor Networks (WSNs) is a combination of tiny nodes with sensing, computational and short distance transmission capability. These networks have wide range of applications in target tracking or gathering intelligent information. Now a day’s biological sensors are also very popular in medical fields. Home based applications for monitoring electricity, gas and water remotely via sensor network are also very popular in market. The link design more or less related to the application for which sensor network is going to be installed in particular area. In this paper the main focus is on the designing of physical layer and MAC layer protocols. Most of sensors are deployed with non- rechargeable battery so Energy optimizations are the challenging task in wireless sensor network design. There are many factors that are taken into consideration while calculating the life time of any ad hoc sensor network, Nodes have fixed transmit power, the link signal to noise ratio between two communicating nodes will typically decrease as the distance between them increases. Link signal to noise ratio or interference ratio determines the communication performance of any link. The energy consumption shall achieved at all layers of network design, mainly the power control depends on two layers, the physical layer and the MAC layer in addition of that it is also a part of network layer when we talk about resource allocation .The physical layer of wireless sensor network deals with transmission of bits or packets over wireless link. The Quality of service parameter that governs the quality of that link is data rate and bits or packet error rate that is supported by that layer. The designing parameters that are taken into consideration while designing the physical layer are the
modulation, coding, diversity, spread spectrum etc. There are many ways to improve the bit error rate performance of any network such as multiplexing, diversity and error control coding. These techniques are employed for achieving high data rates low bit error rates. Multiple antennas are used to provide diversity in fading and increase the data rate of the link. The Diversity gain will reduce the PER leading to fewer retransmission and multiplexing will increase the link rate, which reduce the congestion and delay on the link. The advantages of diversity with high data rate are also achieved by using OSTBC coding.

After physical layer the Access layer designing comes into consideration this layer controls how the user share the available spectrum this layer control the functionality in terms of sharing of channel when the users are not accommodated by the system then this layer deny the access to users .this layer also responsible for retransmission for providing error free communication. The link SINR varies randomly over the time this may leads fading and interference. The flexibility in link connectivity that comes out from varying link parameters such as power and data rates has major implications for routing. However it is much more challenging to support high data rates and low delays over a multi hop sensor network so this is one of the main difficulties in using an ad hoc wireless sensor network to support multimedia applications that require a high data rate and low delay. In this paper a physical layer link and MAC protocols has been proposed for sensor network. Various techniques for reducing bit error rate and achieving coding gain are also proposed because by achieving the good coding gain the life time of sensor nodes is increased that is the major quality of service parameter for sensor network.

The remaining paper is organized as follows: In Section 2, we describe briefly the various types of proposed transmission methods and MAC Protocols available in the literature that are used in ad hoc sensor networks. Section 3, transmission and link plan with MAC protocols have been proposed for different applications. In Section 4, results have been analyzed in terms of bit error rate. Final concluding remark of the paper is presented in section 5.

2. Related Works

Wang,et.al.(2001)[1],introduced a classical approach to achieve a certain BER at the low signal to noise ratio(SNR) by introducing forward error correction (FEC) in the communication. There are many error correcting codes available for wireless body area networks such as by Peterson,et.al.(2007)[2].In ARQ, the packet should be retransmitted by transmitter again and again if the error has been occurred at receiving side.In Proakis,et.al (2012)[3],for achieving the high SNR it is better to use higher order of modulation whereas the quality of same communication link become poor for lower order of modulation to achieve the same value of BER. In February 2012[4], IEEE80215.6 becomes a standard for WBANs where many ECS for WBANs is introduced. In a survey of wireless body area network by Ullah, et.al.(2012)[5],the power consumed by implant and wearable sensors should be very low because these devices are battery operated and replacement of these devices are very complex medical procedure .Another challenge which are faced in WBANs is the interference cause by the presence of other networks (Barakah& Ammad,2012)[6].A Low duty cycle XT-MAC protocols was introduced by Quan Nguyen-Trung, et.al.(2014)[7], for target tracking in wireless sensor network. This XT-MAC protocol is associated with EMRP routing algorithm to enhance system performance in terms of end-to-end delay and energy efficiency. The tracking accuracy should also maintain throughout the cycle. Te-Li Wang,et.al.(2014)[8],introduced a CBA-EVT : a traffic adaptive energy efficient MAC protocol for wireless sensor networks in this both delay and energy consumption are taken into consideration while calculating the sleep schedule.Pei Huang,et.al.(2015)[9],introduced the RC-MAC protocol that integrate duty cycling and receiver centric scheduling.

There are several types of decoding algorithms also exists such as syndrome decoding, maximum likelihood (ML)decoding, viterbi algorithm using trellis and maximum a posteriori (MAP) decoding out of these all decoding methods the best suited method for wireless body area network is MAP decoding with the BCJR algorithm that is used in Turbo codes and belief propagation[BP] by Pearl,et.al.(2014)[10].In 2015. The GMSK modulation schemes is analyzed by Rajoua,et.al.(2015)[11] for coded and uncoded system then it is found that GMSK technique is good for wireless sensor network because of its good BER performance and power efficiency. Praveena,et.al.(2017)[12],calculated the energy efficiency of Raptor code and compare that with BCH code for WBANs in different type of fading channels such as Nakagami, Rayleigh and Rician .In this the authors take the distance between nodes greater than 10m. Ahmed,et.al.(2018)[13] connect two WBANs using UMTS here the medical data uses the adaptive convolutional code and UMTS code and for non-medical data use the UMTS code only for decoding purpose the soft decision decoding and viterbi algorithms is used. In Rajan Kadel,et.al.(2018)[14],the main parameters considered in the performance judgment of any wireless sensor network is Bit error rate(BER),packet error rate(PER),packet acceptance rate(PAR),received signal strength(RSS) and throughput efficiency etc.Ning Ma,et.al.(2019)[15],give a distributed coding scheme of multimedia data compression algorithm for wireless sensor networks. This algorithm is based on gradient-domain ROI which enhance the coding efficiency of the severe motion region and improve the decoded image while reducing the code rate and quality.
3. Materials and Methods for Link Design

Wireless sensor network works in many environments such as military applications where temperature is very low, underwater applications where the water proof arrangement is required and underground applications where the chances of signal loss is very high another aspect of designing is to design a network for a particular work such as wireless multimedia sensor networks which sense audio, video and image. Another example is wireless body area network where wearable and implant sensors inside the human body should be used for monitoring human health issue .so according to the task and environment the selection of transmission strategies and MAC protocols are given in the next section one by one.

3.1. Modeling of biological Sensor network for medical applications

In wireless body area sensor networks basically there are two functions for nodes sensing and transmission. The modulation order also plays an important role in the quality of the physical layer of any communication link. In this type of sensor network the sensors used are basically of digital type and the output of these sensors is in the form of bits so the requirements of DAC and ADC are not here. In wireless body area networks there are three types of nodes (Rajan kadel,2019): implant node, body surface node and external node .The major criteria while selecting an ECC (error correcting codes) and modulation strategies for this network is life time of implanted and wearable devices because these devices are battery driven and when battery becomes weak then the replacement of this is a complicated surgical procedure in these medical situations. In addition of that the bit error rate and minimum delay in transmission of data also played an important role in these sensor networks. In this section a transmission and reception strategy for this network has been proposed. The proposed network architecture is shown in Figure 1, which shows that data are coming from multiple sensor nodes directly in contact with human body these sensor nodes sensing the data and the data from these sensor node is received in the special modules at discrete time intervals after that various channel coding procedures and modulation processes are performed on data according to the requirement of transmission applications.

![Fig. 1 Data transmission from source to destination in Biological sensor network](image)

These networks are comes in the category of Event driven wireless sensor network and usually operate in light traffic load condition. The Receiver -centric MAC protocol is best suited for that type of biological sensor network. When an event is detected, a large number of packet is generated this protocol easily adapt two situation .To handle bursty traffic triggered by an event this protocol underlying the data gathering tree structure of WSNs and the multichannel technique supported by IEEE802.15.4.Due to the high througput associated with that protocol the energy efficiency is also improved. This protocol helps us to design multichannel.

3.2. Modeling of Wireless Multimedia sensor network link for multimedia applications

In this type of sensor network the sensors are in the form of cameras and microphones to collect video and audio data. There are a number of limitations associated with wireless sensor network such as battery life time, computational, storage and communication capability of nodes. The quality of service requirement (QoS) of this network is high bandwidth for storage, multimedia information fusion, synchronization between events and device. The requirement of any sensor network is the deployment of a large number of sensor nodes for covering a monitoring area .According to an article on WMSN[15],the network is divided into three levels the function of level one nodes is to collect the environmental information. The function of level two node is to aggregate the information and process that aggregated information and after that the information is transmitted to the level three, the function of level three is to control the overall functioning of the network the high data rate is the major requirement of WMSNs if we focused on level two nodes that are responsible for overall transmission of data to the final destination the by applying OSTBC coding at physical layer level at this stage of transmission.
then the data transmission rate increase and bit error rate performance also been improved. The figure2, shows the physical layer implementation of that application.

![Figure 2](image)

**Fig. 2** Data transmission from source to destination in Multimedia sensor network

CBA-EVT protocol at MAC layer is best suited for that type of sensor networks. CBA-EVT uses the cost benefit analysis considering both delay and energy consumption for determining the sleep schedule inside the network. This protocol is designed for a wide range of traffic load condition. This is very effective in case of energy savings and used in wide range of online network condition. This is a receiver oriented approach in which each sensor adjust its time slot when to walk up for packet reception. Each sender node walk up in light of receiver’s schedule and goes up to sleep after transmitting all packets to the receiver.

3.3. **Modeling of Wireless area sensor network link for security applications**

These networks are installed in area for monitoring or tracking unwanted targets. In that data or information is transferred to the destination. That destination is not far away from sender. Long distance transmission is not required in that situation because the aggregated data is transferred to the central hub that are equipped with internet capability so this center node transfer data to the destination from where the controlling action should be taken. The Low duty cycle XT-MAC Protocol is best suited for that application. The designing of target tracking system is need to deal with several factors such as energy consumption, tracking efficiency and processing capability of sensor node. This protocol is used with EMRP routing algorithm to enhance the system performance in terms of end-to-end delay and energy consumption with the management of tracking efficiency.

4. **Simulation Results**

In this section, the bit error rates of proposed transmission links are discussed. Set of architectures are evaluated in terms of signal to noise ratio and bit error rate. The performance of these transmission network architectures are discussed in the following subsections. A BPSK modulated system with error control coding is considered and performance of system is compared with other transmission methods. For simulation a random binary data is created.

All the parameters used in simulation are shown in Table 1.

| Type of Channel | Rayleigh Fading Channel |
|----------------|-------------------------|
| Type of modulation | BPSK                  |
| $E_{\text{amp}} (J/\text{bit/m})$ | $10^{-10}$              |
| $E_{\text{elec}} (\text{nJ/\text{bit}})$ | 50                      |
| $E_b/N_0(\text{dB})$ | 0 to 20 dB              |
4.1. **Bit Error rate performance for biological sensor network transmission**

Fig. 3 shows the bit error rate calculation of the transmission link for biological sensor network. When distance is small (less than 40 m) then the difference between energy per information bit for coded and uncoded system is also very less but after that as the distance of transmission increase that difference increases by using Error control codes in the link energy per information bit is reduced so life time of link increase, this reduction is just because of coding gain.

![Bit error rate calculation of link with error control coding](image)

**Fig. 3** Bit error rate calculation of link with error control coding

4.2. **Bit Error rate performance for multimedia sensor network transmission**

Fig. 4 shows the bit error rate calculation of OSTBC transmission that are proposed to use in paper for the transmission of multimedia data. Multimedia data is compressed by using various transformation techniques after that to achieve the high data rate that compressed data is transmitted by OSTBC coding.

![Bit error rate calculation of link with OSTBC transmission](image)

**Fig. 4** Bit error rate calculation of link with OSTBC transmission
4.3. Bit Error rate calculation of different transmission methods used in WSNs

For medical field applications, Bit error rate also played an important role. In sensor network for the transmission of signals the transmission strategies are selected according to the requirement of environment and the required accuracy of data. In that section figure5, shows the bit error rate calculation of different transmission methods for WSNs. In this the bit error rate of DSSS(Direct sequence spread spectrum)with ASK modulation, BPSK with diversity order 1 and soft decision decoding with BPSK is shown. Results showed that as the complexity of system increase the bit error rate performance is improved.

![Graph showing BER vs E/N0 for different transmission methods](image)

**Fig. 5. Different transmission methods for WBASNes**

The Performance Comparison of all transmissions methods are collected in Table 2.

| Mode of transmission          | Transmitted bits | Total Error bits | BER    | Performance                           |
|-------------------------------|------------------|------------------|--------|---------------------------------------|
| DSSS with ASK                 | 2000             | 976              | 0.4895 | Poor BER Performance but complexity is less |
| Coherent BPSK with diversity order 1 | 10000           | 1464             | 0.1464 | Good BER system complexity depends on diversity order |
| BPSK with soft decision decoding | 3.616x10^4      | 101              | 0.002793 | Very Good BER performance but complexity is high |

Table 2-Comparitive Performance
5. Conclusion

In this paper a physical link design and corresponding MAC protocols are proposed for the transmission of data in case of different wireless sensor network applications. In this the bit error rate performance of different schemes are analyzed. every application has their own quality of service requirement. So in this paper we tried to cover maximum possible transmission and MAC protocols combinations. The error control schemes used in biological sensor network provided a wide range of data rate and coding gain. According to requirements of data rate the transmission method should be selected and coding gain helps us to reduce the circuit energy consumption.

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