Quality of Service in Wireless Sensor Networks: A Review and Challenges

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Abstract- Reliability plays an important role in Wireless Sensor Network (WSN). Nodes to sink data transmission reliability is important for monitoring the sensor field, where the sensors are deployed and sink to nodes data transmission reliability for acknowledgement and software configuration. Only one transmission protocol for reliable transmission cannot be adopted for all applications and scenarios of WSNs. In this paper we discuss existing works which implement data transmission protocols that ensure reliable transmission of information over the channel to improve Quality Of Service (QOS) of WSN. Existing works are compared to help the research scholar to choose proper technique based on WSN application type and its constraints.

Index Terms- Wireless sensor networks, Reliability, Quality of service, Protocol

I. INTRODUCTION

Wireless sensor network is internetwork of sensor nodes which communicate wirelessly to send the sensed information from the sensing field to base station through sink node, in turn the base station is connected to external network to reach end user[9]. Sensor nodes communicate in multihop manner [16].Various protocols are used for reliability of data transmission in WSN. Two types of data transport protocols used during erroneous channel condition for data transmission are

A. *Automatic Repeat Request (ARQ) protocol*
B. *Forward Error Control (FEC) protocol*

A. Automatic Repeat Request (ARQ) protocol

In this scheme when receiver finds any error in received data it sends a negative acknowledgement to transmitter so that it can retransmits the message and this continues until positive acknowledgement is received from receiver. ARQ-technique depends on the retransmission strategy to recover the original data packets [11].

B. Forward Error Control (FEC) protocol

FEC protocol depends on check bits added to the transmitted packet so that it can be corrected for errors at the receiver to recover packets without any error [13]. Two types of classification in FEC are block codes and convolution codes [12].

II section discusses different optimization metrics used to compare performance of different data transmission protocols.III section provides various energy models for power consumption metrics analysis in WSN. IV section provides the survey on existing work[19][20]. V section concludes the discussion.

II. OPTIMIZATION METRICS

Optimization metrics used to evaluate performance of various data transmission protocols are

1) Coding gain.
2) Throughput.
3) Bit error rate (BER).
4) Symbol error rate (SER).
5) Packet error rate (PER).
6) Latency.
7) Power consumption.
8) Decoding energy per bit.
9) Packet delivery rate.

Coding gain: For given BER, difference between the Signal to Noise Ratio (SNR) values of coded and uncoded system is coding gain [6].

Throughput: Throughput is the successful delivery of a message over a communication channel[4].

Bit error rate: The bit error rate is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a performance measure of reliability and does not have any unit. It is expressed as a percentage [21]

Symbol error rate: The symbol error rate is the ratio of number of incorrect received symbols to the total number of symbols received. Symbol is declared incorrect if minimum one bit in symbol is erroneous [18].

Packet error rate: The packet error ratio is the ratio of number of incorrectly received data packets to the total number of received packets. A packet is considered incorrect if minimum one bit is erroneous [3].

Latency: Delay between transmission and reception of data [4].

Power consumption: Power consumption of the network [1].

Decoding energy per bit: Energy required for decoding a bit [5].

Packet delivery rate: Successful delivery of packets per unit time [2].

III. ENERY MODELS

Energy models are used in WSN for analysis of power consumption based on transmission strategies. Two types of transmission strategies are end to end strategy and node to node strategy.

A. *Energy model for end to end strategy*

Total energy consumed in network is given by

$$Etotal=Etx+Erx \quad (1)$$

Where *Etx* is energy consumed while transmitting the data, *Erx* is energy consumed while receiving data. Further

$$E_{total}=\sum_{i=1}^{m} NEtx(b) + \sum_{i=1}^{m} NErx(b) \quad (2)$$

Where *N* is number of bits. *Etx(b)* and *Erx(b)* are the power required to transmit and receive single bit respectively.

B. Energy model for node to node strategy

The energy required to transmit and receive single bit information is given by

$$E_b=E_{tx} + E_{rx} + E_{Dec} \quad (3)$$

Where E_{Dec} is energy spent on decoding single bit.Energy consumed while transmitting and receiving can be written as

$$E_{tx}=((P_{tx}+P_o)\ n/R+P_{st}T_{st})/k \quad (4)$$

$$E_{rx}=(P_{rx}(n/R)+P_{sr}T_{sr})/k \quad (5)$$

Where *Po* is transmit power, *Ptx, Prx* are power consumption in the transmit and receive circuitry. Pst, Psr are startup power consumption at transmitter and receiver respectively. *Tst, Tsr* are startup time in transmitter and receiver respectively, *R* is data rate, n is packet length and *k* is number of information bits.

IV. EXISTING WORK

A. Error correction codes in WSN: an energy aware approach

[15] Mohammad Rakibul Islam develops a framework for finding the suitable error control code for WSN. First bit error characteristics in sensor network is analyzed to determine whether their BER varies smoothly enough to be traced down. State machine is used to model the wireless channel, where each state corresponds to BER. Two parameters are analyzed; one is duration for which it exists in any of the states and BER variation between two states. Above two parameters decide usefulness of adoptability technique in FEC. Adoptability technique fails in two cases one is when BER rate is constant and the other case is when there is fast variation of BER over a time, then it is not possible to find suitable FEC because of the processing time required, therefore it hardly accomplishes any improvement. Graph of number of erroneous bytes per packet (NCBPP) distribution standard deviation distribution for 10 traces at Transmitter Receiver (TR) distance (6meters to 13meters) is analyzed. In this work set up made are 1) 4 hour traffic flow, 2) 3.2kbs speed, 3) transmission power is 90mW. NCBPP increases gradually with TR distance. Multipath interferences get strong when signal power becomes weak. Allan deviation (in bytes) is plotted versus time interval (in seconds) to show how fast the bit error rate changes. Frequency versus burst error length analysis graph for 1000 packets is plotted and it is observed that most of the bit errors are either single or double bit errors; presence of burst error is rare. Reed solomon codes(RS) with different error correcting capabilities like RS(15,11), RS(31,26), RS(31,21), RS(31,16) and RS(31,11) are simulated. Power consumption and BER analysis is made for all RS codes and RS(31,21) turns out to be a optimal choice.

B. Forward Error Correction in Sensor Networks

[7] Jaein Jeong, Cheng-TienEe, implemented and tested few versions of FEC protocols.WSN channel error characteristics are analyzed in this work using Mica Mote transmitter and receiver.analysis shows that most errors are single bit or double bit errors and burst errors are rarely present. This work implements three types of simple encoding scheme in indoor and outdoor environment which are less complex. Simple encoding schemes chosen for low power and small memory WSNs are Odd weight column code with 13 bit code word and 8 bit data (SECDED(13,8)),Odd weight column code wit 30 bit code word and 24 bit data (SECDED(30,24)) and quasi cycle code with 16 bit code word and 8 bit data(DECTED(16,8)).All codes reduce the packet error rate close to zero in outdoor environment where most errors are single bit or double bit. When most of the errors are burst errors in indoor environment,

the codes are not efficient in reducing packet losses, but packet loss is still lower than that of not using error control codes.SECDED (13,8) produces smallest packet drop rate among three. Flat form used is chipcon CC 1000 radio, in indoor and outdoor environment.

C. Experimental investigation of Reed Solomon error correction technique for wireless sensor networks:

[10] Cheng-Lai Cheah, Poh-Ling Tan, and Chee-Kit Ho proposed forward error correction code which reduces the PER for distances less than 40 meters. Experimental setup is done for investigation of error pattern for WSN (At transmitting end, the CC2520 IEEE 802.15.42.4Ghz RF transceiver is used to send 10000 random data packets, with 114 bytes length which is approximately equal to maximum packet length of IEEE 802.15.4 Wireless sensor network of 122 bytes. Receiver used is CC2520 2.4 Ghz RF transceiver) .Experimental investigation shows that 82% of error packets occur because of burst error and 18% are caused by random errors. RS code is used for burst error correction. PER is investigated before and after correcting errors. PER v/s distance graph before and after error correction is plotted. For the target of 10-3 packet error rate (acceptable by most of internet protocols (IP) applications, proposed work improves the distance by about 10m compared to the WSN without error correction. Packet error rate v/s received signal strength indicator (RSSI in –dBm) before and after error correction is plotted. For the target of 10-3 Packet error rate, proposed technique improves the RSSI by about 8DB compared to the wireless sensor network which does not uses error correction technique.

D. A hybrid adaptive coding and decoding scheme for multihop wireless sensor networks

[8] Imad EZ-zari,Mounir Ariona, Ahamed El Oualkadi, PascalLorenz, proposes an approach for reducing decoding power consumption and to increase the lifetime of the network and also to improve the reliability of the transmission in multihop sensor networks. Hybrid adaptive coding is implemented based on inter node distance. Strong low density parity check(LDPC) codes and RS codes are considered adaptively on the basis of channel conditions and inter node distance. If d<dcrossover Friss free space model is used. If d>dcrossover two ray ground reflection model is used. This work uses MTE routing algorithm. If d<dcrossover data is encoded by RS code else data is encoded by LDPC code. Energy consumption is less and network life time is improved. It is observed that performance for clustered wireless networks is not analyzed in this work.

E. Adaptive forward error correction(AFEC) for best effort wireless sensor networks

[22] KanyU, FilipBarac, mikaelGidlund and johan Akerberg proposes an adoptive FEC protocol scheme on the medium access control. RS codes with different error correcting capacity are employed..Markove model with M states is used with S(i) states. Transmission starts from state (0) that is the FEC code with low error correcting capability, S(M) is the state with high error correcting capability. In adoptive switching concept transmitter evaluates the channel conditions and makes the changes to coding according. If channel error conditions improve the receiver will switch to a low power FEC .If channel is distorted, the transmission will transit to a more powerful code. Switching technique is based on the number of acknowledgements (ACKS) received inside a window of L previously transmitted packets. Packet error rate window$(PER)_{WIN}$ within the window is found and it is compared with a defined switching threshold PER_T for determining whether to switch to a error correcting code with higher capacity or a error correcting code with lower error correcting capability. Adoptive algorithm does not require a dedicated feedback channel.

In AFEC code ranking is given for different codes, the highest code rate will give the lower overhead in to encoded packets, resulting in high capacity for information payload. Error correction capability of RS (*n*, *k*) code is given by

$$t= \lfloor (n-k)/2 \qquad (6)$$

Where *n* is total number of symbols, *k* is total number of information symbols in a code word. AFEC can provide higher throughput and reduced power consumption compared to static FEC. Since AFEC cannot provide the Packet delivery rate as high as strongest static FEC scheme, it is suitable for packet loss tolerant WSN applications. It is observed that reliability of acknowledgement is not considered in this work.

In [15] step by step approach for finding suitable data transmission protocol is provided. In[7][10]emphasis is given for error pattern rather than power consumption, computational requirement and storage space. Hybrid adoptive coding[8] is implemented by considering inter node distance. Channel conditions are estimated for adaptive FEC [22] based on acknowledgement received.

Table 1.Provides the comparison of reviewed works and their suitability for particular WSN application.

Table 1: Comparison Table

Author	Network Topology	Type of protocol	Application suitability
Mohammad Rakibul Islam	Multihop	FEC,RS CODE RS(15,11), RS(31,26), RS(31,21), RS(31,11), RS(31,16)	WSNs which depend on BER of channel
Jaein Jeong	Point to point	FEC	WSNs with single and double bit error pattern
Cheng-Lai Cheah	Point to point	FEC,RS code	WSNs with bursty channel and which are not tolerant to PER over short distance.
Imad EZ-zari	Multihop	FEC,RS,LDPC	WSNs with more life time and reliability in transmission
KanyU	Point to point	FEC,RS CODE,RS(15,5),Rs(15,7) Rs(15,9),Rs(15,11),Rs(15,13)	Packet loss tolerant WSNs

V. CONCLUSION

This paper provides review on different protocols for reliable transmission of data in WSN during bad channel conditions. Different existing works are discussed to improve reliability of transmission.WSN and their suitability for different applications and WSN constraints are analyzed. In existing works QOS is improved by means of reliable data transmission protocols. Future challenges involved to improve QOS of WSN are 1) resource limitations like power required for transmission, Memory size.2) Data redundancy that is, similar event is sensed by the nodes.3) Dynamically changing network like node failure, link failure and topology.

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