

Research Article

Energy Efficient Transmission in Wireless Sensor Networks

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Abstract: Aim of this study is analyzing energy conservation which is one of the most vital aspects in Wireless Sensor Networks (WSNs) for better network durability, since sensor nodes have limited resources of energy. In our propose technique, we have shown that how in presence of existing Error Control Coding (ECC) techniques and decoder complexity energy efficiency increased. That is by estimating transmitter power for each sensor node in given environment. Since adoption of ECC reduces required transmitter power for reliable communication, while increase processing energy of decoding operations. Required transmitter power for sensor nodes in given environment for different coding techniques like Reed-Solomon (RS), Convolutional (CC) energy efficiency and bit error rate has been analyzed for different E_b/N_0 .

Keywords: Bit error rate, error control coding, transmitter power, wireless sensor networks

INTRODUCTION

WSNs are currently being considered for many communication applications, including industrial, security surveillance, medical, environment and weather monitoring. Due to limited battery lifetime at each sensor node, minimizing power consumption is useful for reliable network operation. Limited battery lifetime requires low power sensing, processing and communication system. Energy efficiency is of paramount interest and optimal WSN should consume minimum amount of power needed to provide reliable communication (Akyildiz *et al.*, 2002).

Sensor nodes consist of three parts sensing unit, processing unit and transceiver. ECC is a classic approach used to increase link reliability and lower required transmitter power. However, lower power at transmitter comes at cost of extra power consumption due to decoder complexity at receiver. Stronger codes provide better performance with lower power requirements have more complex decoders with higher power consumption than simple error control codes (Howard Sheryl *et al.*, 2006).

New approach for transmitter design of sensor nodes has been proposed to lower required transmitter power. In this approach, estimation of multi-path fading effect on signal for given environment helps to lower transmitter power, otherwise if we take average value of fading effect then most of times we have to transmit extra power that minimizes WSN efficiency.

As we know that required transmitter power for any sensor node in WSN depends upon distance

between sensor nodes, frequency that is used for transmission, data rate and required signal to noise ratio at receiver if we consider free space path loss model (Howard Sheryl *et al.*, 2006). Due to multi-path fading effect on signal in free space we need to transmit more power to detect and receive signal at receiver reliably that consumes more power and limit battery life time.

Normally we take value of multi-path fading effect on average (4-10 dB) in our approach we estimate that effect for given environment, frequency and elevation angle, so that we accurately estimate transmitter power at each sensor node (Howard Sheryl *et al.*, 2006). International Telecommunication Union model help to estimate multi-path fading effect for given environment (Pellenz *et al.*, 2010). Required transmitter power for sensor nodes in given environment for different coding techniques like Reed Solomon, Convolution codes energy efficiency and bit error rate has been analyzed for different E_b/N_0 .

LITERATURE REVIEW

In order to improve reliability of data sent in wireless channel, techniques such as ARQ (Automatic Repeat Request) and FEC (Forward Error Correction) are employed (Sanchez *et al.*, 2007). FEC employs error correcting codes to combat bit errors by adding redundancy (parity bits) to information packets. Receiver uses parity bits to detect and correct errors. FEC techniques are associated with unnecessary overhead that increases energy consumption when channel is relatively error free. In ARQ technique only

error detection capability is provided; receiver requests to transmitter retransmission of packets received in error.

Usually an ARQ scheme uses Cyclic Redundancy Check (CRC) codes for error detection. At receiver, CRC code verifies packet. If it detects errors, node asks a retransmission for transmitter (negative acknowledgement). If reception is correct, a positive acknowledgement is sent to transmitter node. Hybrid ARQ schemes be developed using combination of FEC and ARQ schemes. Some typical error control techniques for WSNs are discussed in Sanchez *et al.* (2007).

Energy consumption of these schemes is very important. Although a strong error control correct many errors, energy consumed be too high for an energy constrained sensor network. Using same error control scheme for whole network could be a good choice in some cases, not always. Sometimes it is needed to apply best error control available, while in other cases less error control should be used. Choice of error control technique is based on number of hops packet traveled within sensor network. If a sensor node has to send a data packet to sink node, before packet reaches its destination it travel through some other nodes of network. If packet gets lost at first hop, only energy to send packet from a sensor to a specific node is lost. If packet is corrupted after few more hops, much more energy be spent to transmit packet through network. In this sense, a packet is more important if it travels through more nodes in network and consequently, more energy is being consumed.

New approach for transmitter design of sensor nodes has been proposed to lower required transmitter power. In this approach, estimation of multi-path fading effect on signal for given environment helps to lower transmitter power, otherwise if we take average value of fading effect then most of times we have to transmit extra power that minimizes WSN efficiency. In given environment for different coding techniques like Reed Solomon, Convolution codes energy efficiency and bit error rate has been analyzed for different E_b/N_0 .

ECC is a classic approach used to increase link reliability and lower required transmitter power. However, lower power at transmitter comes at cost of extra power consumption due to decoder complexity at receiver. Stronger codes provide better performance with lower power requirements have more complex decoders with higher power consumption than simple error control codes (Howard Sheryl *et al.*, 2006). Required transmitter power for sensor nodes in given environment for different coding techniques like Reed Solomon, Convolution codes energy efficiency and bit error rate has been analyzed for different E_b/N_0 .

Estimation of required transmission power: In this section we describe estimation of transmitter power for sensor nodes on basis of given meteorological conditions and how in presence of existing error control coding techniques and decoder complexity energy

efficiency be increased. To increase battery life time of sensor nodes we need exact estimated transmitter power so that we consume power efficiently and communicate reliably. For that we need to know distance between transmitter and receiver sensor nodes, frequency used for communication and multi-path fading effect. Estimation of multi-path fading effect due to meteorological conditions for given environment given as Data (2003):

$$\chi_\sigma = a(p) \times \sigma dB \quad (1)$$

Here σ is standard deviation of signal for considered period and propagation path that depends upon on reference standard deviation of signal, antenna averaging factor, frequency, elevation angle of antenna and $a(p)$ that is time percentage factor. χ_σ gives cumulative distribution of fading with respect to time. For estimation of reference standard deviation of signal we need wet-term of refractivity that depends upon given meteorological conditions (T, P, H). For free space model path loss is estimated as given by Friis law (Howard Sheryl *et al.*, 2006):

$$PL(d) = PL(d_0) + n.10.log_{10}(d/d_0) + \chi_\sigma dB \quad (2)$$

here,

χ_σ : (Multi-path effect) that actually attenuate signal and decrease signal level

d_0 : Reference distance

d : Distance between two sensor nodes

n : For different environments

$PL(d_0)$: Reference path loss

Path loss also is defined as ratio of received signal power to transmitted power as given below (Data, 2003):

$$PL(d) = S_{RX}(d)/P_{TX} \quad (3)$$

Received signal power to noise power ratio depends upon data rate R bandwidth B and given E_b/N_0 :

$$S/N = (R \times E_b)/(N_0 \times B) \quad (4)$$

From that we estimate minimum required transmitter power for given distance, frequency, received signal strength in terms of E_b/N_0 and bandwidth (Data, 2003):

$$P_{TX} = \eta E_b/N_0 m k T B (4\pi d/\lambda)^2 \quad (5)$$

here,

η : Spectral efficiency

m : Noise proportionality constant

k : Boltzman constant

Noise proportionality constant actually antilog of Receiver Noise Figure (RNF). Receiver power defined as difference between transmitted power and path loss:

$$P_{RX} = P_{TX} - PL(d)dB \quad (6)$$

For coded system transmitted power is estimated as given below, where ECC_{gain} is coding gain due to different coding techniques that actually minimizes required transmitter power. Transmission energy is just required transmitter power divide by data rate (Nandi and Kundu, 2011):

$$P_{TX,ECC} = (P_{TX})/(10^{ECC_{gain}/10}) \quad (7)$$

$$E_{b_{TX}} = P_{TX}/R \quad (8)$$

ECC_{gain} computed as difference between un-coded SNR and coded SNR. When higher order coding used then coding gain increases and required power decreases:

$$ECC_{gain} = SNR_U - SNR_{ECC} \quad (9)$$

For convolutional code bit error rate is given that based on hard or soft decision (Nandi and Kundu, 2011):

$$P_e = Q(\sqrt{5E_b/N_0}/(1 - 2exp(-E_b/2N_0)^2)) \quad (10)$$

For reed solomon codes (Wicker, 1995):

$$P_b = 2^{(m-1)}/((2^m) - 1) \times P_e \quad (11)$$

RESULTS AND DISCUSSION

In this section, we analyze and describe results for required transmitter power in WSNs for Frequency 2.45 GHz, Environments (n = 2, 3, 4), Coding techniques (Convolutional, Reed-solomon) and also find bit error rate for given $E_b = N_0$. Simulation parameters are given in Table 1, whereas, Table 2 details the IEEE802.15.4 specifications.

Figure 1 shows results between required transmitter powers for free space path loss model excluding multi-path fading effect at frequency 2.45 GHz versus distance between sensor nodes (1-100) m. We see that required power increase with increasing distance. After analyzing required transmitter power for given E_b/N_0 8.3 dB we analyze transmitter power for estimated multi-path fading effect for given environment and average that is given in range (4-10) dB (Wicker, 1995).

We clearly see in Fig. 2 that for estimated power we need less power than standard value that is given in range that saves energy and increase battery life time.

Figure 3 shows required power versus distance for signal without fading effect and with fading effect we see that signal with fading required large power than signal without fading effect. It means if we do not

Table 1: Simulation parameters

Frequency (f)	400 MHz-10 GHz
Distance (d)	1-100 m
Voltage (v)	1.2-3.7v
Environment (n)	2, 3, 4
Temperature (T)	300 K
RNF (Receiver Noise Figure)	5 dB
E_b/N_0	8.3 dB
ECC_{gain} (coding gain)	1, 2.3, 4.2 dB
Antenna (planar)	16*5 mm

Table 2: IEEE802.15.4 specifications

Frequency	Channels	Data rate	Bandwidth
2.45 GHz	16	250 kbps	83.5 MHz

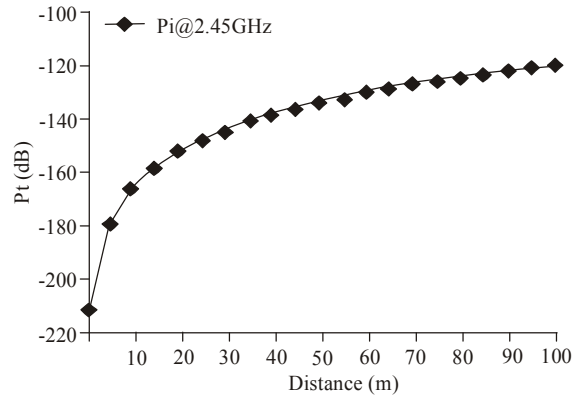


Fig. 1: Required transmitter power versus distance

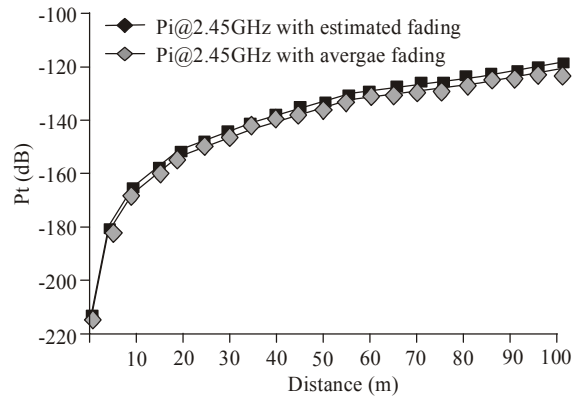


Fig. 2: Transmitter power versus distance for estimated fading

include that effect we transmit less power that causes difficulty in signal detection.

As we have earlier analyze required power for free space model with and without fading now we see that effect shown above required transmitter power versus distance in Fig. 4 for various environments. We see that for n = 2 (free space) required power is minimum and for n = 4 (large scattering) required power is maximum and it increases with distance.

Figure 5 shows that required power is maximum for Un-coded and less value for coded system like RS, CC-Hard decision, CC-Soft decision and minimum for CC soft decision for frequency 2.45 GHz.

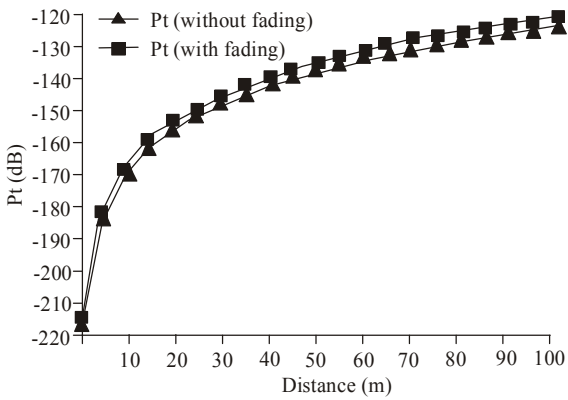


Fig. 3: Transmitter power versus distance with and without fading

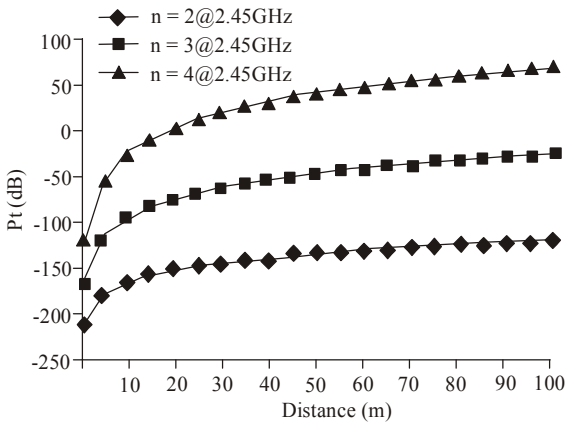


Fig. 4: Transmitter power versus distance for various environments

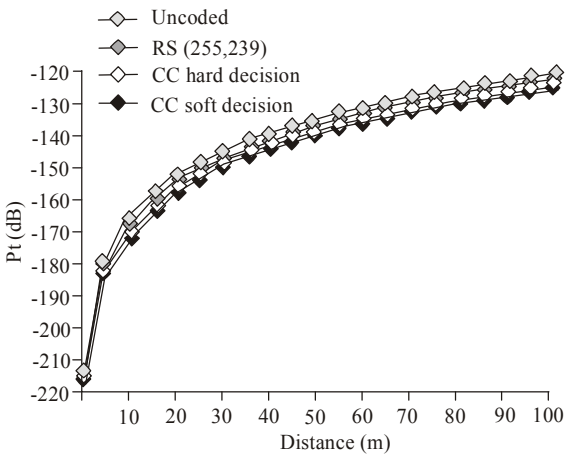


Fig. 5: Transmitter power versus distance for various channel coding techniques

Figure 6 shows required transmitter energy that is transmitter power divide by data rate for coded and uncoded transmission between sensor nodes. For uncoded sensor requires maximum energy and for CC-soft decisions it requires minimum energy.

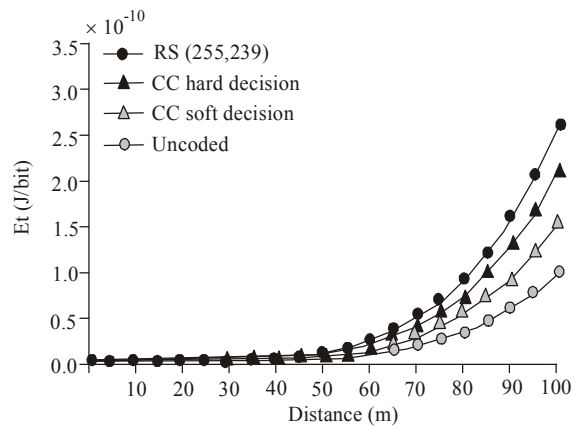


Fig. 6: Transmitter energy versus distance for different coding techniques

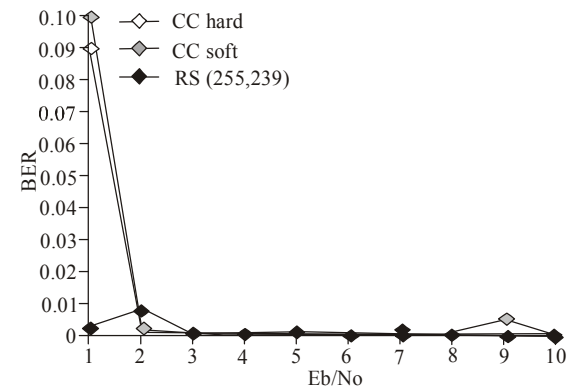


Fig. 7: Bit error rate versus given E_b/N_0

Figure 7 shows bit error rate versus given E_b/N_0 for different coding techniques we see that by increasing E_b/N_0 bit error rate decreases slowly and for RS bit error rate decreases fast.

CONCLUSION

In free space line-of-sight scenarios, ECC is not very energy efficient for frequencies below 2 GHz, ECC be practical for sensor networks placed between buildings, especially when implemented with analog decoders. For indoor environments, ECC is energy-efficient at high frequencies, for sensors placed at opposite ends of hallways or in adjacent rooms, or on multiple floors or in a dense urban environment at all frequencies. Analog decoders offer most energy-efficient ECC solution. Depending on application and environment, analog decoders are energy-efficient when used in a wireless sensor network. A combination of low power consumption and moderately high throughput makes analog decoders quite practical for WSN use. ECC is not always a practical solution for increasing link reliability, especially when implemented

with analog decoders, be a practical method of minimizing energy consumption in wireless sensor network. So to increase link reliability in presence of existing error control techniques and decoder complexity we estimate transmitter power for given environment to increase energy efficiency. Otherwise we have to transmit more power most of time that limit battery life time of sensor node. Required transmitter power for sensor nodes in given environment for different coding techniques like Reed Solomon and Convolution codes energy efficiency and bit error rate has been analyzed for different E_b/N_0 .

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