PERFORMANCE ANALYSIS OF ZIGBEE BASED WIRELESS SENSOR NETWORK

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Abstract - *In this paper zigbee based wireless sensor network performance is analysed and optimized using two different sensor optimization techniques. (a) Random on off time ratio (b) Coding technique. Basic concepts of wireless sensor network is studied in this paper and performance of both techniques are compared and analysed in terms of energy consumption and lifetime of wireless sensor network.*

***Key Words*: Zigbee, WSN, Lifetime, Energy Consumption**

1. INTRODUCTION

ZigBee is a new standard developed by the ZigBee Alliance for personal-area networks (PANs). Consisting of more than 270 companies (including Freescale, Ember, Mitsubishi, Philips, Honeywell, and Texas Instruments), the ZigBee Alliance is a consortium that promotes the ZigBee standard for a low-rate/low-power wireless sensor and control network. The ZigBee protocol stack is built on top of IEEE 802.15.4, which defines the Media Access Control (MAC) and physical layers for low-rate wireless personal-area network (LR-WPAN). The ZigBee standard offers a stack profile that defines the network, security, and application layers. Developers are responsible for creating their own application profiles or integrating with the public profiles that were developed by the ZigBee Alliance. The ZigBee specification is an open standard that allows manufacturers to develop their own specific applications that require low cost and low power.

The ZigBee specification has undergone multiple modifications. The major milestones in its revision history are listed here:

- In 2004, the ZigBee Alliance published its first specification, which supported a home control lighting profile. However, the ZigBee Alliance no longer supports the 2004 specification.
- In February 2006, the ZigBee Alliance published the ZigBee Stack 2006, which contained modifications to ZigBee 2004.
- In October 2007, the ZigBee Alliance published two feature sets called ZigBee and ZigBee PRO. The ZigBee feature set is interoperable with ZigBee PRO. If a network is based on the ZigBee PRO stack, devices from the ZigBee feature set stack can join the network as end devices. Likewise, if a network is based on the ZigBee stack, ZigBee PRO devices can join the network as end devices.

Wireless Sensor Networks (WSNs) have garnered a considerable amount of attention over the last half a decade, primarily due to the unique applications they enable. However, one of their advantages, the ability to be deployed in otherwise inaccessible environments, also plays an important constraint on the operation of such networks - the energy source at sensors. Except for environments where an energy source can be harnessed in a low cost manner, the very survivability of WSNs depends upon how energy efficiently the sensors operate in performing their required functions. While there have been numerous efforts at developing routing and communication protocols for WSNs [5], the primary concern is the energy efficiency of all these solutions.

In this research work, we focus on the primary operation in any WSN: collection of sensor data from the sensors in the field to the sink for processing (the *data gathering* process), and aim to improve the energy efficiency of such a process. Since data gathering is the most important and frequent operation in a WSN, energy gain obtained through the optimization of this process can help extend the lifetime of sensor networks significantly. In this work a hybrid technology is used which comprises of duty cycle and network coding duty cycle.

Low-cost, low power, multifunctional sensor nodes that are small in size and communicate untethered in short distances have been developed due to the recent advances in micro-electro-mechanical systems (MEMS) and wireless communication [1]. These tiny sensors have the ability of sensing, data processing, and communicating with each other. Wireless Sensor Networks (WSN) which rely on collaborative work of large number of sensors are realized.

Sensor nodes can be used within many deployment scenarios such as continuous sensing, event detection, event identification, location sensing, and local control of actuators for a wide range of applications such as military, environment, health, space exploration, and disaster relief [2]. Although a large volume of research has been performed and some algorithms are proposed, there is ongoing research on this subject in recent years. One of the challenging subjects and design constraints in WSNs is efficient energy consumption. Since a sensor node is a microelectronic device, it can only be equipped with a limited power source (<0.5 Ah, 1.2 V). In most application scenarios, replenishment of power resources might be impossible or infeasible [2]. Moreover, each node plays the dual role of data originator and data router, in multi-hop sensor networks; therefore dis-function of nodes can cause serious problems in the sensor network [2]. Furthermore, most of the application based on long time monitoring directly affects the network efficacy and usefulness.

Main sources of power dissipation are used during data processing, data transmission, data reception and idle listening. The power consumed during transmission is the greatest portion of energy consumption of any node [3]. Considering the limited capabilities and vulnerable nature of an individual sensor, a wireless sensor network has a large number of sensors deployed in high density (high up to 20nodes/m3 [4]). Since the nodes are deployed densely and in an adhoc fashion, many nodes stay inactive for long periods and idle listening power dissipation becomes significant. Therefore these nodes can be considered as redundant and can be put to sleep. The main idea will be scheduling sensors to work alternatively and the system lifetime will be prolonged correspondingly.

The algorithm that we proposed is self-configured, fully distributed, and localized. It operates in the network layer as the sensors that are sleeping and awake are essentially differentiated in their routing functionalities. Since the working environments for WSNs are hostile and remote working environments, it would not be convenient or possible to configure network manually after deployment. For this reason self-configuration is necessary. In order to erase the need for a global synchronization overhead, the proposed algorithm has to be distributed and localized. This favors also scalability of the network.

Wireless Sensor Networks (WSN) consists of spatially distributed autonomous sensor nodes which are organized into a cooperative network [6]. WSNs are usually deployed to monitor physical or environmental properties, such as temperature, vibration, pressure, motion, or pollutants. The development of WSNs was initially motivated by military applications such as battlefield surveillance. However, they are increasingly being used in many industrial and civilian application domains, including industrial process monitoring and control [7], machine health monitoring [8], environment and habitat monitoring [9], and medical diagnostics [10].

2. LITERATURE REVIEW

A number of studies have been proposed to address the issues of transmitting vital signs in nursing homes, homes and hospitals over wireless transmission. Patient monitoring systems [11] are gaining their importance's the fast-growing global elderly population increases demands for caretaking. These systems use wireless technologies to transmit vital signs for medical evaluation. According to Kinsella and He's [12] report from the US Census Bureau, the global elderly population is fast growing and will outnumber the population of children in near future. The aging society is bringing its impact on many developing countries and presents a stark contrast with the low fertility rate of these countries. The changes brought about by the aging society include an increasing demand for caretaking; thus, patient monitoring systems are gaining their importance in reducing the need for human resources. Caretaking homes and hospitals have been planning on the use of biological sensors to effectively minister to their patients. Vital signs, such as body temperature, blood pressure, and sugar level, can be regularly collected and remotely monitored by medical professionals, achieving a comprehensive caretaking system.

ZigBee [13] is an open standard technology to address the demands of low-cost, low-power WMNs via short range radio. ZigBee [14] is targeted at RF applications that require a low data rate, long battery life, and secure networking. Its mesh networking also provides high reliability and more extensive range. The ZigBee devices can be combined with WWANs to achieve a seamless platform of wireless patient monitoring. The ECG and heart rate data can not only help the caregivers to know the urgency of the fall-induced injury, but also show the probable reasons of falls. IEEE 802.15.4 is a standard which specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs). It is maintained by the IEEE 802.15 working group. It is the basis for the ZigBee.

Varshney [15] proposed a framework of patient monitoring systems, including patient monitoring devices, ad hoc wireless networks, and the receivers for healthcare professionals. This framework uses four routing schemes (multicast, reliable multicast, broadcast, and reliable broadcast) and several enhancing schemes to improve the transmission reliability over wireless ad hoc networks.

Jovanov *et al.* [16] present wireless distributed data acquisition system. The system uses personal digital assistant as a mobile client to acquire data from individual monitors and synchronizes collected records with existing records on the tele medical server. Each client device uses local flash memory as a temporary storage until reliable connection with a mobile client is established.

Istepanian and Petrosian [17] present an optimal zonal wavelet-based ECG data compression method, which reaches a maximum compression ratio of 18:1 with low-percent RMS difference (PRD) ratios for a mobile tele cardiology model. The method also attains an ambulatory speed of up to 100 km/h in urban channel profiles with a bit error rate of less than 10−15 and with an average reduction of 73% in the transmission time.

Varshney and Sneha [18] proposed protocols for power management under varying user densities, power levels, and numbers of hops to support a diversity of devices.

Their scheme provides a reliable message delivery at reasonable transmitted power.

Cypher *et al.* [19] surveyed previous work on wireless communications in support of healthcare networks. The authors only consider the case of one-hop transmission. From an analytical perspective, while using IEEE 802.15.4 standard for ECG, the maximum payload size only allows up to 118 samples per frame bringing the accumulation delay 236 ms.

The minimum data sampling rate of 1 sample per frame results in an accumulated delay of 2 ms.

3. SYSTEM MODELLING

A wireless sensor network of area 200x200 square meter, number of nodes considered is 1000, path loss exponent is taken 2. Each sensor is configured with zigbee technology 802.14.5 ieee standard for transmission and reception of information. A cluster head is considered at the center of wireless sensor network. Energy of battery installed to drive single node is 25kJ power capacity. Energy consumption per bit by transmitter is $\alpha_{11} = 0.937uJ$, $\alpha_2 = 0.0172uJ$ is the energy consumed per bit in the transmit zigbee.

Energy consumption by a supply node per second across a distance d with path loss exponent n is,

$$E_{tx} = R_d(\alpha_{11} + \alpha_2 d^n) \quad (1)$$

Where R_d is the data rate of transceiver relay, α_{11} is the energy consumption per bit by the transmitter and α_2 is the energy consumption per bit in the transmit op-amp [22]. Total energy consumption in time t by a source node (leaf node) without acting as a relay (intermediate node) is,

$$E_s = t[p(r_s e_s + E_{tx}) + (1-p)E_{sleep}] \quad (2)$$

where E_{sleep} is the idle mode energy consumption of a sensor node per second, r_s is the sensor's average sensing rate and it is equal for all the nodes, e_s is the energy consumption of a mote to sense a bit, the probability p is the average proportion of time t that the sensor node use in active mode. Thus, p is the duty-cycle. A sensor node remains in the idle state with probability (1-p) till time t. The energy consumption per second by an intermediate node which act as a relay mote is given by [23]

$$E_{txr} = R_d(\alpha_{11} + \alpha_2 d^n + \alpha_{12}) \quad (3)$$

Where α_{12} is the energy consumption by the sensor node to receive a bit. Total energy consumed till time t by an intermediate (relay) node is

$$E_r = t[p(r_s e_s + E_{txr}) + (1-p)E_{sleep}] \quad (4)$$

The total energy consumption in the bottleneck zone in time *t* for a *p* on time ratio WSN is given by [23]

$$E_d = E_{agd} + E_{2gd} + E_{3gd} + (1-p)tN\frac{B}{A}E_{sleep} \quad (5)$$

$$E_d = \left[\frac{m+1}{2}\right] Npr_s t\frac{A-B}{A}\left(\alpha_1 \frac{D}{d_m}\frac{n}{n-1}\right) + Npe_s r_s t\frac{B}{A} + pr_s\frac{N}{A}t\iint\left(\alpha_1\frac{x}{d_m}\frac{n}{n-1} - \alpha_{12}\right)d_s + (1-p)tN\frac{B}{A}E_{sleep} \quad (6)$$

When *p*=1 (all motes are in on condition) and *m*=7 the energy consumption in the bottleneck zone to relay the data bits that are generated inside as well as outside the sensor network becomes same as in a general or non-duty cycle based WSN [5]. Thus, the equation (6) also covers the general network scenario without considering duty cycle of nodes.

The lifetime of a wireless sensor network is significantly depended on the consumption of energy at the different node level. Let E_b is the initial battery energy available at each sensor node. In a network of N nodes, the energy reserve at the start is $N \cdot E_b$.

The performance of a wireless sensor network strictly depends on the failure statistics of the sensor nodes. The failure pattern of sensor nodes depends on the rate of depletion of energy. The network lifetime demands that the total energy consumption is no greater than the initial energy reserve in the network. The limitation on network lifetime can be achieved by calculation of the total battery energy (N. E_b) available in a WSN is depleted completely. The following inequality holds to estimate the upper-bound of the network lifetime for a duty cycle based WSN [23].

$$E_D \le \frac{NB}{A}E_b$$

$$t \le \frac{d_m B E_b}{K_x} = T_{upper}D \quad (7)$$

where the term K_x is given by

$$K_x = p\alpha_1\frac{n}{n-1}r_s\left[D(A-B)\frac{m+1}{2} + \int\int x d_s\right] + Bd_m[p - r_s(e_s - \alpha_{12}) + (1-p)E_{sleep}] \quad (8)$$

And $T_{upper}D$ is the lifetime upper bound of the WSN with on time ratio (p). The amount of energy consumption is maximum when *p=1* (i.e. all node active condition) and the lifetime minimizes in a WSN. The energy efficiency of the network increases with low duty cycle which enhances the lifetime of the network. r_s is defined as

$$r_s = \frac{Databits}{(A-B)\frac{N}{A}} \quad (9)$$

Where Databits =1024 bits, area is πD^2,

4. RESULTS & DISCUSSION

4.1 Comparison of Energy Consumption in Zigbee based WSN

In this paper area of wireless sensor network is considered 200x200 square meter, diameter of bottleneck zone 60m, number of nodes 1000, battery energy 25kj, sleep energy 30uj,hop length 2, number of bits 960 and threshold 12 bit are considered.

Fig 1 shows energy consumption per node in zigbee based wireless sensor network with change in on off timing. When on time ratio value is 0.01, energy consumption is minimum i.e. 40uJ, and on time ratio 0.1, energy consumption is 998uJ. With increase in duty cycle increases energy consumption decreases. Energy consumption due to random on off timing technique and coding technique is compared and it concluded that coding technique performed better.

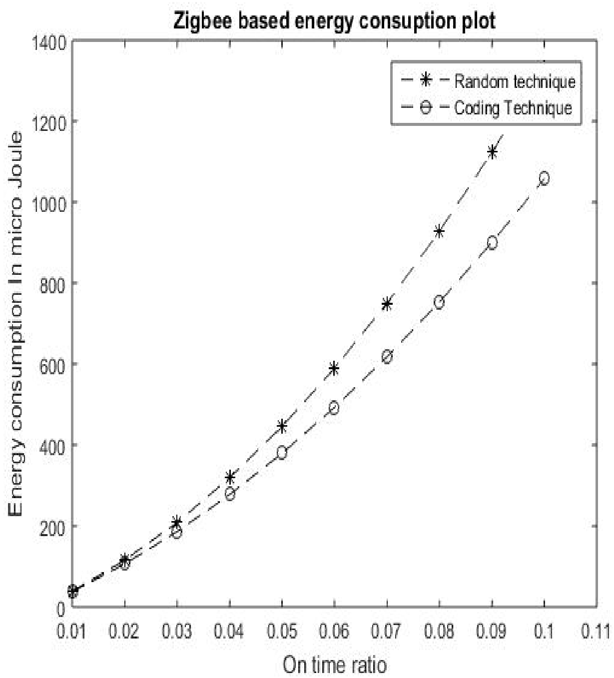

Fig- 1: Energy Consumption Comparison of Zigbee based Sensor Network using Random & Coding Technique

From the figure it is observed that energy consumption is maximum for random on off timing wsn and minimum for coding based technique.

Energy consumption of ZIGBEE based WSN for two different techniques random on time ratio and coding technique is illustrated in table1.

Table- 1: Energy Consumption Comparison

S. No.	On time ratio	Technique-1(uJ)	Proposed technique(uJ)
1	0.01	102	98
2	0.04	235	220
3	0.06	540	430
4	0.07	710	600
5	0.08	835	680
6	0.1	1240	1015

4.2 Lifetime Comparison of ZIGBEE based WSN

Fig. 2 shows lifetime variation in wireless sensor network with change in on time ratio. When duty cycle value is 0.01, lifetime for m=7 is 6.02x10^8 seconds. With increase in value of on time ratio lifetime decreases and with the increase in value of m (traffic density) lifetime again decreases. For coding technique and m=7 and p=0.01 lifetime is 5.7x10^8 seconds.

Table- 2: ZIGBEE Modelling Parameters

Number of Nodes (N)	1000
Sensor Network Area (A)	200 m2
Path Loss Exponent	2
Alpha11	0.937uj
Alpha12	0.387uj
Alpha2	0.0472uj
Sleep	30uj
Hop Length	2m
No. of bits	1024
m (Data traffic)	7

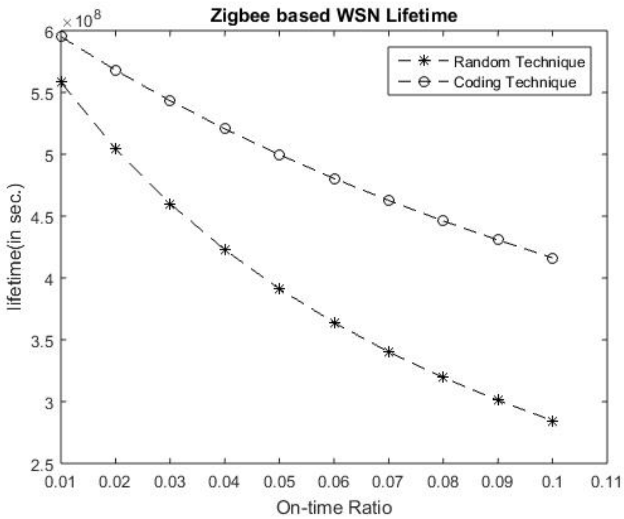

Fig- 2: Lifetime Comparison of ZIGBEE based Sensor Network using Random & Coding Technique

5. CONCLUSIONS

In this paper analysis of ZIGBEE based wireless sensor network is done. Implementation is based on static network. Total number of node is taken 1000 and area is taken 200 square meter. Two techniques random and coding are used to analyses performance of WSN. According to simulation results coding technique performance is bettor compared to random technique.

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