Network Lifetime and Throughput Analysis in Wireless Body Area Network using Forwarder Node Approach

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Abstract - *Wireless body area network (WBAN) finds great application in healthcare systems. For health monitoring it is essential that an authentic data reaches the sink node, which is then forwarded to external healthcare application. The untrusted sensor nodes hamper the performance of WBAN network. Further, the energy consumption of sensor nodes should be efficient for improving the throughput of the network. The sensor node classification approach will be proposed in future work to improve the efficiency of WBAN even more. This classification approach prominently depends upon feature extraction and these features are obtained from the implemented transmission of WBAN. Here in this paper, the performance of the network is analyzed in terms of network lifetime, throughput, residual energy and path loss. Further, the futuristic approach of using and manipulating WBAN data is discussed.*

Key Words: WBAN, ANFIS, LPP, PSO, Cost function, Residual energy

1. Introduction

Wireless body area network (WBAN) is the miniature form of wireless sensor network (WSN). A WBAN provides a continuous health monitoring of a patient without any constraint on his/her normal daily life activities. With the increase of world population, governments and societies now pay more attention on health applications. In recent years, WBAN has drawn a lot of interest and emerges as a promising technology to provide human beings with better health-care practice [1]. Many technologies have proved their efficiency in supporting WBANs applications, such as remote monitoring, biofeedback and assisted living by responding to their specific quality of service (QoS) requirements. Due to numerous available technologies, selecting the appropriate technology for a medical application is being a challenging task.

Wireless Body area networks (WBANs) constitute an active field of research and development as it offers the potential of great improvement in the delivery and monitoring of healthcare. WBANs consist of a number of heterogeneous biological sensors. These sensors are placed in different parts of the body and can be wearable or implanted under the user skin. Each of them has specific requirements and is used for different missions. These devices are used for measuring changes in a patient vital signs and detecting emotions or human statuses, such as fear, stress, happiness, etc. They communicate with a special coordinator node, which is generally less energy constrained and has more processing capacities. It is responsible for sending biological signals of the patient to the medical doctor in order to provide real time medical diagnostic and allow him to take the right decisions [2].

The WBAN common architecture consists of three tiers communications: Intra-BAN communications, Inter-BAN communications and beyond-BAN communications. Intra-BAN communications denote communications among wireless body sensors and the master node of the WBAN. Inter-BAN communications involve communications between the master node and personal devices such as notebooks, home service robots, and so on. The beyond-BAN tier connects the personal device to the Internet. Communications between different parts is supported by several technologies, such as Bluetooth, IEEE802.15.4. IEEE802.15.6 was designed especially for WBAN applications while responding to the majority of their requirements.

However, it looks less performing in some cases in comparison with other technologies supporting WBAN. Wi-Fi, Bluetooth and mobile networks can be solutions for implementing WBAN applications, since each technology offers specific characteristics, allowing it to meet the constraints of some applications. There are various WBAN applications cover numerous fields in order to improve the users' quality of life [2]. Figure A shows the deployment of various type of sensors in human body. These sensors forward their data to the sink node called as personal server and this server further sends it to the external healthcare application.

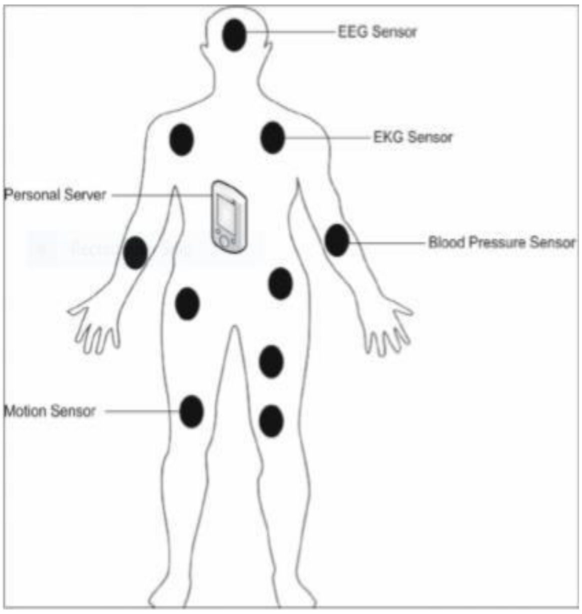

Figure A: WBAN network [3]

WBANs support a number of innovative and interesting applications. These applications include several areas such as smart health care, assisted elderly living, emergency response and interactive gaming. As noted previously, many researches classified WBAN applications as medical and non- medical application [2]. Thus it becomes really important to analyse the network lifetime and throughput analysis in wireless body area network. Figure B shows the data collected from body sensors is sent to the internet for further processing. This vital information is later used by the healthcare application.

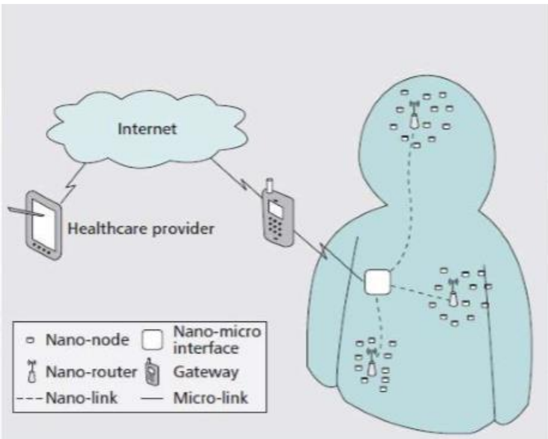

Figure B: Intrabody nanonetwork for healthcare applications [4]

2. Related Work

Xiaoming Yuan, et.al (2018) presented dynamic interference in WBAN taking human mobility into consideration. The dynamic interference is investigated in different situations for WBANs coexistence. This inference is generated by varying number of interfering nodes from neighbour WBANs owing to human mobility in multi WBAN coexistence scenario. A three dimensional Markov chain model is developed to investigate the interference dynamics on network performance of IEEE 802.15.6 based CSMA/CA protocol. As per extensive numerical results, the interference generated by mobile neighbour WBANs the network design and management as well as the interference mitigation can be improved to a great extent [5].

Sriyanjana Adhikary, et.al (2018) presented how the critical health data must be prioritized over periodic ones to deliver it within the stipulated time. The objective of this paper is to maximize the system throughput by allocating the available bandwidth fairly based on the criticality of the data and mitigating inter-WBAN interference in a densely populated network by optimizing the transmission power. The problem is modelled as a Linear Programming Problem (LPP) and solved it using Particle Swarm Optimization (PSO). As per simulation results, the proposed solution converges quickly then 802.15.6 [6].

K. Kalaiselvi, et.al (2018) presented how sensor nodes in Wireless Body Area Network (WBAN) can be classified for improving the performance in terms of classification rate, packet delivery ratio and latency. The paper proposed a system that constitutes feature extraction and classification modules. It suggested sensor node classification algorithm which incorporates ANFIS classifier based trusted and un-trusted sensor nodes detection and classification system in order to improve the efficiency of the WBAN networks [3].

Haipeng Peng, et.al (2017) presented Chaotic Compression Sensing (CCS) to solve the energy saving and data security problem in WBANs. It has vast storage space as it stores only matrix generation parameters. The proposed technique aimed at image transmission, modified CCS is proposed, which uses two encryption mechanisms, confusion and mask, and performs a much better encryption quality. As per simulation results, the energy efficiency and security are strongly improved, while the storage space is saved. This method has performed exceptionally well for image encryption [7].Figure C shows BBN (Body to Body Network) and vulnerability from eavesdropper.

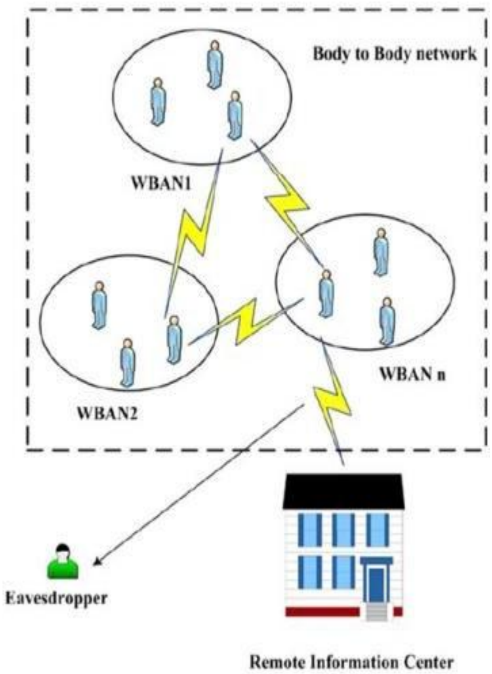

Figure C: Several WBANs forming a BBN (Body to Body Network)

Sudip Misra, et.al (2016) presented Network Management Cost Minimization framework, NCMD, for opportunistic WBAN which addresses the problem of increased network management cost and data dissemination delay. These issues are result of factors such as dynamic changes to the on- body network topology and, mutual and cross technology inference among coexisting WBANs and radio technologies. These factors sum up to increase the energy consumption rate of sensor nodes and their energy management cost. The proposed framework is thought to minimize the dynamic connectivity, inference management and data dissemination costs for opportunistic WBANs. As per simulation results, significant improvement in the network performance in achieved as compared to existing solutions [8].

3. Methodology

The implemented technique is based on the selection of forwarder node. Each sensor node broadcasts an information packet which contains node ID, location of node on body and its energy status.

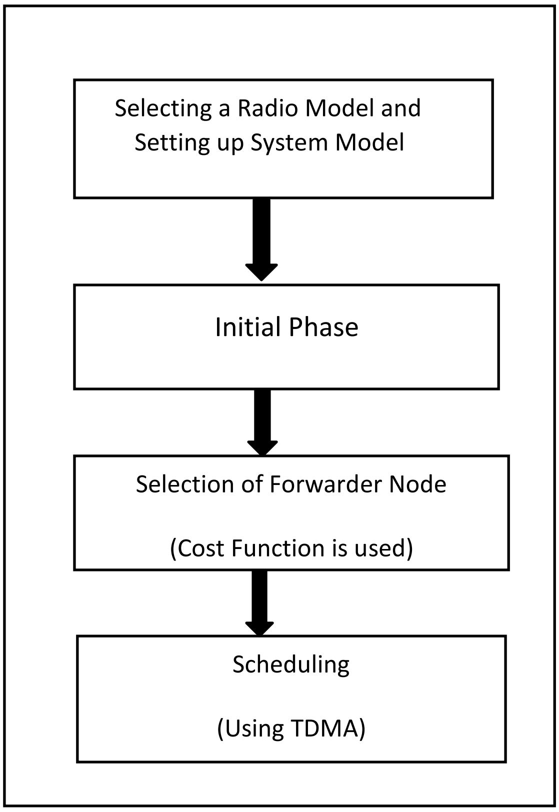

Figure D: Methodology

Once sensor nodes are informed with the location of neighbours and sink, data is forwarded by selecting a forwarder node through a cost function. This forwarder node assigns a Time Division Multiple Access (TDMA) based time slots to its children nodes. This scheduling of sensor nodes minimize the energy dissipation of individual sensor node. In the future research work, features of WBAN will be studied and promising features would be extracted to improve the overall efficiency through a classification algorithm.

The limited numbers of nodes in WBANs give opportunity to relax constraints in routing protocols. Keeping routing constrains in mind, we improve the network stability period and throughput of the network.

3.1 System Model

We have considered an eight sensor radio model for this study. The various sensor in human body are positioned in specific location as per their relevance with particular type of data. All sensor nodes have equal power and computation capabilities. Sink node is placed at waist. Node 1 is ECG sensor and node 2 is Glucose sensor node. These two nodes transmit data direct to sink.

3.1.1 Initial Phase

Sink broadcast a short information packet which contains the location of the sink on the body. After receiving this control packet, each sensor node stores the location of sink.

Each sensor node broadcasts an information packet which contains node ID, location of node on body and its energy status. In this way, all sensor nodes are updated with the location of neighbours and sink.

3.1.2 Selection of next hop

For saving energy and enhancing network Throughput, we proposed a multi hop scheme for WBAN. In this section, we present selection criteria for a node to become parent node or forwarder. To balance energy consumption among sensor nodes and to trim down energy consumption of network, this multi-hoping approach elects new forwarder in each round [10]. Sink node knows the ID, distance and residual energy status of the nodes. Sink computes the cost function of all nodes and transmit this cost function to all nodes. Further, A node with minimum cost function is preferred as a forwarder. All the neighbour nodes stick together with forwarder node and transmit their data to forwarder. Forwarder node aggregates data and forward to sink. Forwarder node has maximum residual energy and minimum distance to sink; therefore, it consumes minimum energy to forward data to sink. Nodes for ECG and Glucose monitoring communicate direct to sink and do not participate in forwarding data. The decider cost function is given as:

$$C.\,F(\mathrm{i}) = d(i) \,/\, R.E(i) \qquad [10]$$

C.F(i) = Cost function
d(i) = distance between the node i and sink
R.E(i) = Residual energy of node i

3.1.2 Scheduling

Forwarder node assigns a Time Division Multiple Access (TDMA) based time slots to its children nodes. All the children nodes transmit their sensed data to forwarder node in its own scheduled time slot. When a node has no data to send, it switches to idle mode.

4. Performance Metrics and Results

A performance metric measures behaviour, activities, and performance. It assesses how well approach is accomplishing its objectives. It provides data and gives off outcomes that appraise clearly defined quantities within a range that facilitates improvement and upgrading.

4.1 Network life time

It represents the total network operation time till the last node die. Figure E shows that the implemented transmission approach has longer stability period. This is expected, due to the appropriate selection of new forwarder in each round. Hence, each node consumes almost equal energy in each round and all the nodes die almost at the same time i.e. after the completion of 8000th round.

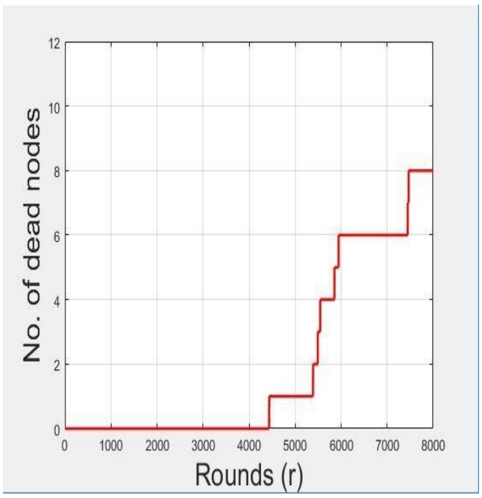

Figure E: Analysis of network lifetime

4.2 Throughput

Throughput is the total number of packets successfully received at sink. Number of packets send to sink depends on the number of alive nodes. Figure F clearly shows more alive nodes send more packets to sink which increases the throughput of network.

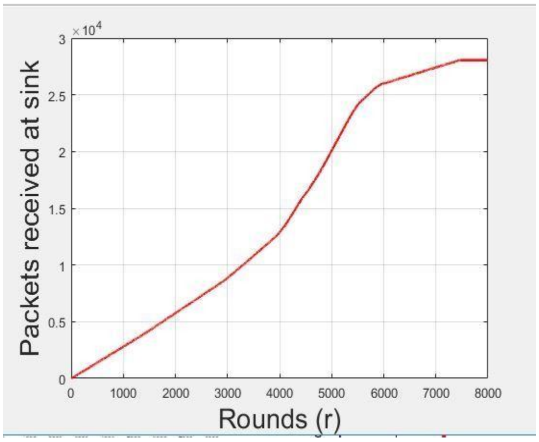

Figure F: Analysis of Throughput

4.3 Residual Energy

In order to investigate the energy consumption of nodes per round, we consider residual energy parameter to analyse energy consumption of network. Figure G shows the average energy of network consumed in each round. The implemented approach use multi hop topology, in which each farthest node transmits its data to sink through a forwarder node. Forwarder node is elected using cost function and selection of appropriate forwarder in each round contributes to save energy.

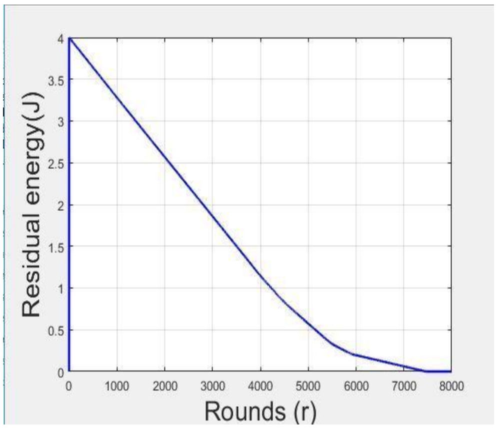

Figure G: Analysis of remaining energy

4.4 Path Loss

Path loss is the difference between the transmitted power of transmitting node and received power at receiving node. It is measured in decibels (dB). The implemented multi hop approach reduces the path loss as shown in figure H. It is due to the fact that multi hop transmission reduces the distance, which leads to minimum path loss.

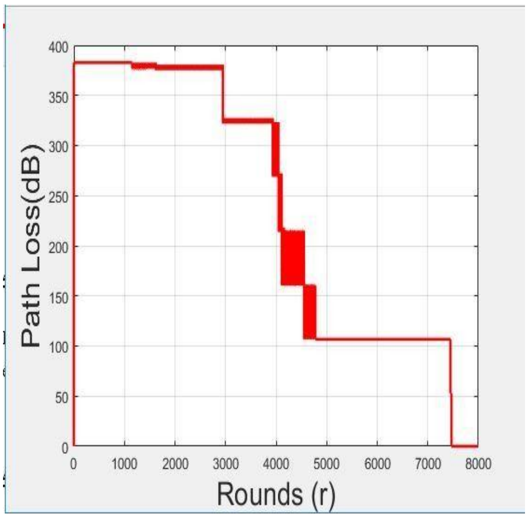

Figure H: Network path loss

5. CONCLUSIONS

The implemented transmission model improves energy consumption of sensor nodes and thus increases the network lifetime and throughput. In the future aspect of this work, sensor node classification through Adaptive Neuro-based Fuzzy Inference System (ANFIS) would be studied. This ANFIS classifier detects the trusted and un-trusted node. The particular distinguishing features of trusted nodes are extracted from sensor nodes and these extracted features would be optimized using either existing or proposed soft computing technique. The selection of best features would help improve the classification even more.

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