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Pm-EEMRP: Postural Movement Based Energy Efficient Multi-hop Routing Protocol for Intra Wireless Body Sensor Network (Intra-WBSN)

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Abstract

Intra-WBSN plays an important role in health monitoring, military and consumer electronics. It iscomposed of wireless bio-sensor nodes which are strategically placed on the body. Due to body posture movement, network topology of Intra-WBSN changes continuously. It plays a significant role in Intra-WBSN. In proposed Pm-EEMRP, network stability, energy efficiency and high throughput are the prime parametersfor body posture movement in which sensing informations from bio-sensor nodes are forwarded to relay nodes. Relay nodesare deployed in cloths, which aggregate these data and forward it to body network controller (BNC). It provides reliable and comfortable health monitoring. Through simulation, the proposed routing protocol provides better network stability, improved energy efficiency and high throughput in comparison to conventional routing schemes.

***Keywords**: Intra body sensor network (Intra-WBSN); Postural movement; Energy efficiency*

1. Introduction

Healthcare has high priority in daily life. A lot of attention has been gained from academic and commercial sector to provide regular, comfortable and cost effective health monitoring [1-2]. Through the advancement in sensing and communication technology, Intra-WBSN is a new emergence of wireless sensor networks. Strategically placed miniaturized and intelligent bio-sensor nodes are deployed to monitor vital information like heart rate, blood oxygen saturation, glucose level, body temperature etc. Bio-sensor nodes sense these information and send it to body network controller (BNC) [3-4]. A smart phone or personal digital assistance (PDA) is used as a BNC. It received these data and forward to Sink (such as medical server, laptop), the data is further send to medical experts or health monitoring destination to take necessary action via regular infrastructure such as internet, Wi-Fietc [5-6].

Intra-WBSN are consists of low-powered, miniaturized bio-sensor nodes. They are powered by energy constraint battery. Energy efficient utilization of bio-sensor nodes have a paramount importance [7-8]. So that the network can provide long-term health monitoring. Communication strategy consumes 80% energy available on bio-sensors nodes [9, 10]. Routing schemes play a significant role to provide reliable and effective communication between biosensor nodes Routing protocol area prominently involved all aspects which makes overall system make energy efficient [11].

Posture movement play a significant role on the performance of intra-WBSN. Bio-sensor sensor nodes are placed at required position. Due to posture movement location of bio-sensor changes frequently [12]. Consider an example when body is in standing both hands move in random manner. During walking both hand and leg are move backward and forward direction. In Sitting phase both hands and both legs move in random manner.

In this paper, postural movement based an energy efficient multi-hop routing protocol for Intra-WBSN has been proposed. Multi-hop topology is utilized to increase the energy efficiency. Normal sensing data from bio-sensors forwarded through relay node while critical data is directly forwarded to BNC. The relay nodes are deployed in patient's cloth. They can be

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easily replaced or recharged, which permitted easy maintenance of Intra-WBSN. Through MATLAB simulation it is verified that proposed routing protocol showed better performance in comparison of multi-hop and forward based routing protocols.

Remaining parts of the paper has been arranged as follows. Section 2 summarize some related works. Energy consumption analysis for intra-WBSN has been discussed in section 3. Detail of proposed routing protocol has been described in section 4. Section 5 explained simulation results and their analysis. Section 6 concluded the paper and future scope. Finally references are provided at the end of the paper.

2. Related Works

Postural movement leads a significant effect on the performance of Intra-WBSN. Many routing schemes have been proposed which support mobility of posture in intra-WBSN.A brief summary some of routing protocol have been discussed in this section.

Authors in [13] proposed On Body Store and Flooding (OBSFR) Routing Protocol which is based on store and forward mechanism. Each bio-sensor nodes send multiple copy of sensing packets to BNC through multi-path. When BNC received the packet and check whether the packet is received or not. If packet is received before then the packet is discarded. If packet is not received the packet is stored and buffered, and start to search the sender id. OBSFER routing protocol can support body posture movement through packet flooding scheme but it cannot be feasible for emergency data transmission for Intra-WBSN.

Probabilistic routing with Postural Link (PRPLC) [14] has been proposed on the basis of similar approach on OBSFR.PRPLC proposed a new cost function Link Likely hood Factor (LLF).Each bio-sensor nodes calculate LLF in the form of HELLO message. When bio-sensor nodes are connected to BNC, the buffered packet is delivered to BNC otherwise buffered and store packet wait when link is connected.

Authors [15] proposed distance vector routing with postural link cost (DVPRLC) to minimize delay through intermediate nodes. DVPRLC protocol also used the concept of storing and forwarding schemes like OBSER [13] and PRPLC [14]. A minor difference in their operation, DVPRLC used the concept of distance vector schemes to compute accumulated pathcost between bio-sensor node and BNC.A Link Cost Factor (LCF) is exchanged through Hello-message. If a bio-sensor node is in the coverage of BNC the packet is directly forwarded to BNC, if not, the bio-sensor node (i) compute least LCF among its (k) neighbor biosensor nodes, and the forward the packet to BNC. If the condition in not applied the bio-sensor nodes buffered the packet until it does not encountered the forwarding policies.

Opportunistic routing scheme has been proposed [16] by considering body posture movement. Through placement of relay nodes a simple network model has been proposed. BNC is placed on wrist while relay nodes are placed on the waist. During posture movement bio-sensor want to send sensing information to BNC, it send a short message request to send (RTS) to BNC. If the RTS message is acknowledged within a specific time slot which employed thatBNC is in the line-of-sight (LoS) with bio-sensor nodes. Bio-sensor nodes start sending the packet to BNC directly. If BNC is in non-line-of-sight (NLoS) with bio-sensor nodes then bio-sensor nodes send a short message to relay called wake up signal. When relay node isready it send a message to bio-sensor nodes and BNC to proceed the communication. After receiving packet successfully the BNC send receive acknowledgement (RACK) packet to bio-sensor node. If bio-sensor is not able to receive RACK packet in given specific time interval, whole procedure will be repeat until successful transmission.

In [17] authors proposed routing scheme iM-SIMPLE for Intra-WBSN. The proposed routing scheme achieved high throughput, energy efficiency and support body posture movement. Multi-hop communication is utilized to enhance the energy efficiency. Sensing data from biosensor nodes is forwarded to BNC through intermediate node (forwarder node). The selection of forwarder nodes are based on the cost-function.

3. Analysis of Energy Consumption

Let n= Number of deployed Bio sensor node
K= Number of relays.
N/K = Number of nodes associated with relays.

Energy consumption to transmit the sensing data of bio sensor node can be computed as

$$E_{BSN} = L.E_{elec} + E_{amp}(L, d_{SR})$$

Where E_{elec}= Energy consumption due to electronics circuits.
E_{amp} = Energy consumption by the transmit amplifier circuit. *L* is the packet size.E_{amp}depends on reference distance $d_{o.}$ The value of d_o is 10cm.

$$E_{BSN} = L.E_{elec} + E_{amp}.L.{d_{SR}}^4 \qquad \text{if } d_{SR} > d_o \tag{1}$$

$$E_{BSN} = L.E_{elec} + E_{efs}.L.{d_{SR}}^2 \qquad \text{if } d_{SR} < d_o \tag{2}$$

Energy consumption of a relay node

$$E_R = (\tfrac{N}{K}).L.E_{elec}+(\tfrac{N}{K}).\ L.E_{DA}+ L.E_{elec}+ E_{amp}.L.{d_{RBNC}}^4 \tag{3}$$

Energy Consumption a relay node and its associated nodes

$$E_{Relay} = E_R + (\tfrac{N}{K})E_{Node} \tag{4}$$

Total energy consumption of network

$$E_{Total} = K.E_{Relay} \tag{5}$$

$$E_{Relay} = \left(\frac{N}{K}\right).L.E_{elec} + \left(\frac{N}{K}\right).L.E_{DA} + L.E_{elec} + E_{amp}(L){d_{RBNC}}^4+\left(\frac{N}{k}\right)L.E_{elec}+ n \times E_{amp}(L)\times {d_{SR}}^4$$

$$E_{Total}=2\ N.L.E_{elec}+n.L.E_{DA} + E_{amp}.L.{d_{RBNC}}^4 + n.E_{amp}.L.{d_{SR}}^4 \tag{6}$$

4. Pm-EEMRP: The Propsed Protocol

In this work we proposed postural movement based data routing protocol for Intra-WBSN. Multi-hop topology is utilized to improve the energy efficiency. The protocol detail are described in following sub-sections.

4.1. Network Model

In proposed paper we deployed ten bio-sensor nodes as shown in Figure 1. It is assumed that human body is in standing position. Initial positions of bio-sensor nodes are described in Table 1, the position of relay nodes are given in Table 3. BNC is the centroid of initially placed bio-sensor nodes. Since human body is in standing phase, in this stage bothhands change their positions randomly, so bio-sensor node 4, 5 and 9 change their positions randomly. Rest all bio-sensor nodes do not change their positions. To increase the energy efficiency we vary the packet size which depends on the characteristics of body sensor, either these sensors are wearable or implantable [18]. A brief outline about wearable and implant bio-sensor nodes have been discussed in Table 2. CHIPCON CC240 and NORDIC nRF2401A transceivers are generally used for Intra-WBSN. NORDIC nRF2401A is a single chip and it consume less energy in comparison of CHIPCON CC240 [19]. For simplicity it is assumed that all deployed biosensor nodes have same energy about 0.5J while relay nodes have energy about 1J.

4.2. Network Configuration Phase

BNC broadcast a HELLO message to all bio-sensor nodes. HELLO message contains the position of BNC in the body. Every bio-sensor node received this HELLO message and stores the position of BNC. Then all bio-sensor nodes relay a short message which contains node IDs, Its position and available residual energies in each round. In this way all bio-sensor nodes are updates the BNC position, relays information, available residual energy and optimum route to BNC. Contain of HELLO message has been shown in Figure 2.

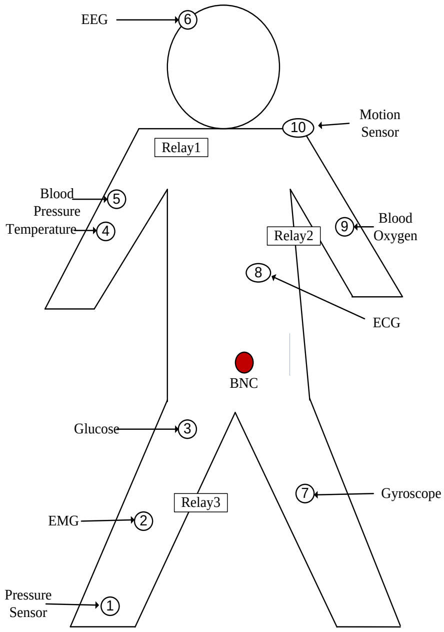

Figure 1. Deployment of bio sensor nodes

Table 1. Deployment of bio-Sensor [1, 2]

Sl. No	*x* coordinate (m)	y coordinate (m)
1	0.15	0.12
2	0.20	0.40
3	0.30	0.70
4	0.35	0.40
5	0.40	0.50
6	0.20	1.35
7	0.55	0.45
8	0.80	1.25
9	0.90	1.21
10	0.85	1.60

Table 2. Bio-sensors functions and their deployment [1, 2, 3]

Bio-sensor	Function	Deployment
Pressure	Measuring pressure distribution of human body.	Wearable
EMG	Nerve conducting electrical information are measured which is produced by human muscles	Wearable
Glucose	Measure the quantity of glucose which is circulating in the blood.	Implantable
Temperature	Monitoring the human body temperature	Wearable
Blood Pressure	Measure the peak pressure of systolic and minimum pressure of diastolic	Wearable
Motion	Monitor the physical movement of human body.	Wearable
EEG	Monitor electrical activities of human's scalp.	Wearable
Accelerometer/Gyroscope	Monitor and recognize the posture movement of human body	Wearable
ECG	Monitoring human cardiac activity.	Wearable
Blood Oxygen	Measure oxygen saturation for human blood	Wearable

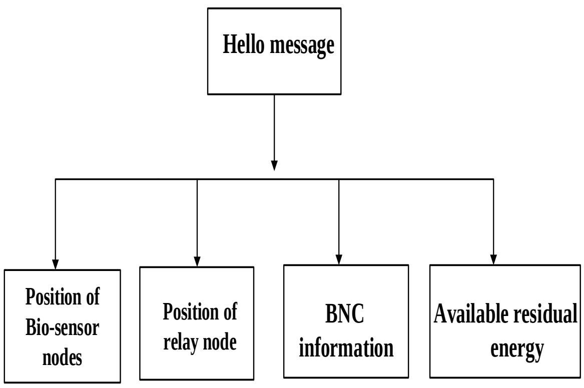

Figure 2. Format of HELLO message

Table 3. Position of relay node

Position of Relay	*x* coordinate (m)	y coordinate (m)
1	0.37	1.40
2	0.30	0.40
3	0.40	0.30

4.3. Data Routing and Communication Flow

Due posture movement Rb-EEMRP introduced a relay based routing scheme. To increase the energy efficiency multi-hop mode of communication is utilized. Bio-sensor nodes 4, 5 and 6 are attached with relay 1, bio-sensor nodes 8, 9 and 10 are assigned with to relay 2 and bio-sensor nodes 1, 2, 3 and 7 are assigned with relay 3. Relay nodes aggregate normal sensing data and forward to BNC.Furthermore, if the distance between biosensor node and BNC is less than distance between bio-sensor node and relay, then bio-sensor nodes directly transmit data to BNC otherwise data is forwarded through relay. In case of emergency, data from bio-sensor nodes are directly transmitted to BNC. The mobility pattern and communication flow diagram of proposed routing scheme is shown in Figure 3.

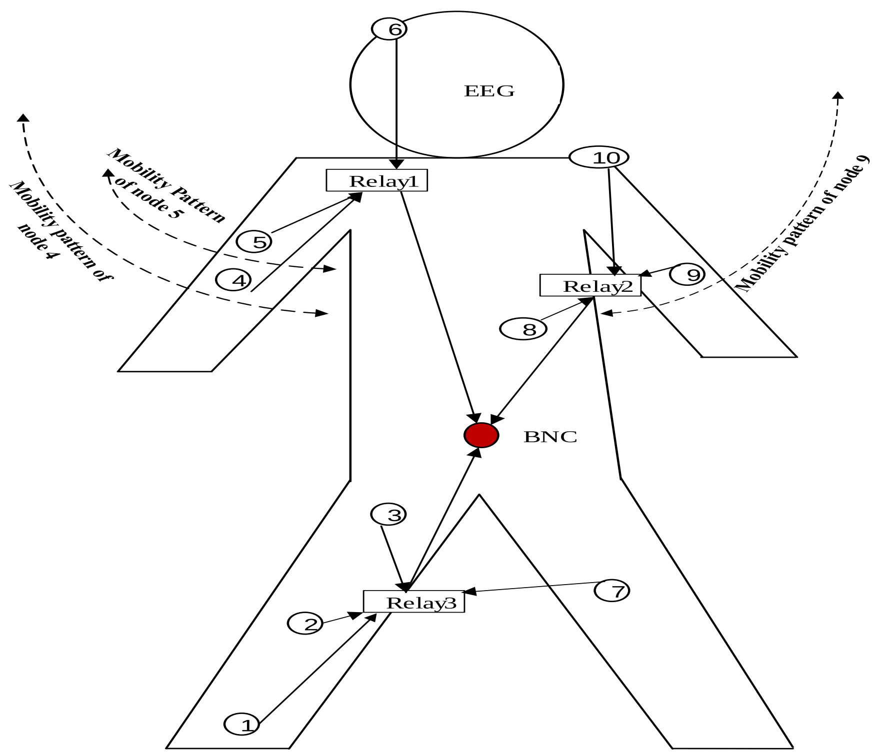

Figure 3. Mobility pattern and commination flow

5. Simulation Results and Their Analysis

5.1. Performance Parameters

The performance parameters for existing protocols are defined as

a. Stability Period: Network operation time at which the first node dies is defined as stability period. At the time when first node dies, the network becomes unstable.
b. Residual Energy: It is defined as the sum of remaining energies of all biosensor nodes in every round.
c. Network lifetime: It represents as total network operational time, from the network establishment to death of last node.
d. Throughput: The total number of packets success-fully received at BNC in each round.
e. Path loss: It is defined as the reduction of power level, when the data is routed from source to destination. It is measured in decibels (dB).

5.2. Stability Period

Figure 4 describe comparison of number of nodes dead after equal number of rounds of Multi-hop, forward based and Pm-EEMRP routing protocols. Deployment of relay nodes play a significant role to balance the energy in Pm-EEMRP. The proposed routing scheme achieved 184% and 19.41% improvement in network stability with comparison of multi-hop and forward based routing schemes. PmEEMRP achieved 11.26% increment and 8.19% decrement of network lifetime in comparison to multi-hop and forward based routing protocols.

5.3. Residual Energy

Comparison of average energy consumption of network has been shown in Figure 5. Initially energy of all nodes is 0.5 Joule and total energy of the network is 5 Joule. PmEEMRP protocol uses multi-hop communication through relay nodes. Biosensor nodes forward the sensing data to its assigned relay nodes. Since relay nodes reduce the transmitting range in comparison of multi-hop and cost function based routing protocol, which minimize energy consumption of bio-sensor nodes. PmEEMRP has better residual energy in comparison to existing protocols

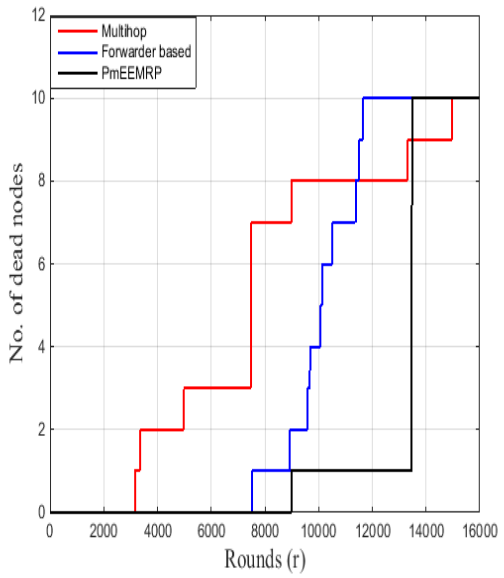

Figure 4. Number of nodes dead vs round

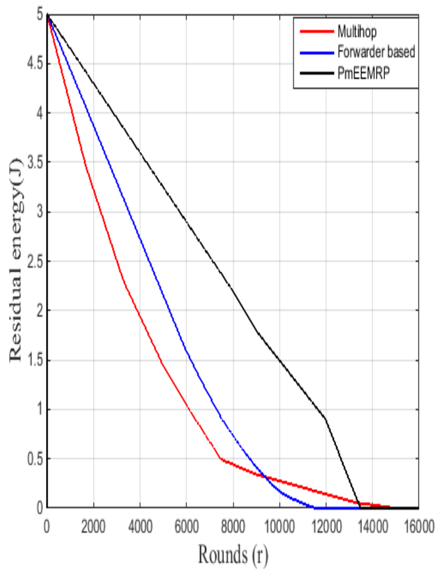

Figure 5. Network residual energy vs round

5.4. Throughput

Total number of packets successfully received at BNC is defined as throughput. The patient monitoring system requires routing protocols should have maximum throughput. Number of packet received at BNC depends on the average network life of Intra-WBSN. Average network life corresponds to number of bio-sensor nodes alive. More number of bio-sensor nodes alive have better probability of packet receiving at BNC. Figure 6 describes that Pm-EEMRP protocol gives 156.49% and 45.79% higher throughput with comparison multihop based and cost function based routing protocols.

5.5. Path-Loss

Figure 7 describe the analysis of path-loss of Pm-EEMRP, multi-hop and cost function based routing protocols. We use constant frequency 2.4 GHz and path loss coefficient n of 3.38 and standard deviation σ of 4.1. The proposed Pm-EEMRP protocol shows higher path-loss in comparision existing Intra-WBSN protocol.

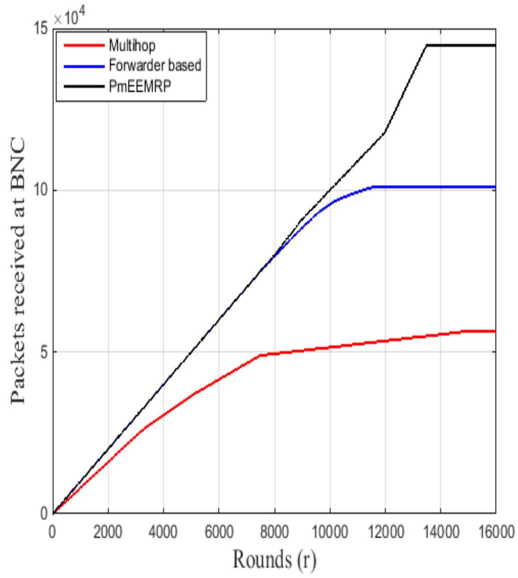

Figure 6. Throughput vs rounds

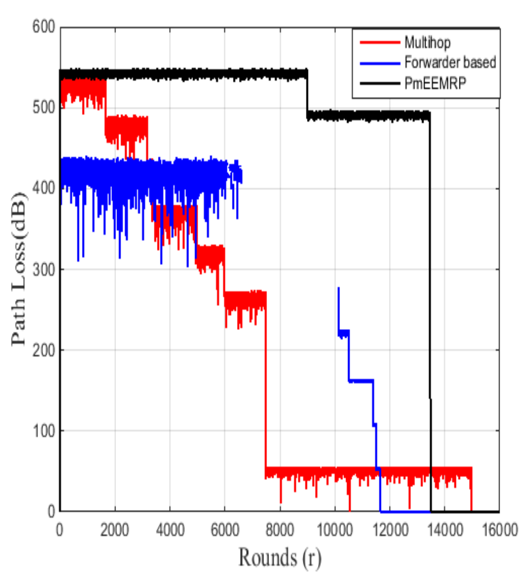

Figure 7. Path-loss vs rounds

6. Conclusion

In this paper bio-sensor nodes are strategically placed on human body at required positions for monitoring vital parameters. Body posture movement plays a significant effect on the performance of Intra-WBSN.In proposed Pm-EEMRP, relay nodes are placed on the patient's clothes. They are easily rechargeable and replaceable which permits easy maintenance of Intra-WBSN. With the help of linear programming, it is validated that proposed scheme shows enhanced performance in comparison to existing protocols in term of stability period, network lifetime, residual-energy and throughput at the cost of deployment of relay nodes. Our future work is focused on energy efficient routing schemes for Intra hospital networks.

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