A Review paper on Routing Protocols in Wireless Body Area Sensor Networks

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***Abstract*- In today's world, the Wireless Body Area Sensor Network (WBASN) is a continuous monitoring system placed on, in or near the human body. WBASN is applied in entertainment, fitness, military, medical, sports and consumer electronics. The WBASN should be connected to a Local Area Network (LAN) or wide area networks using wireless technologies for sending sensor readings to the monitoring center. In WBASN network lifetime is a important challenge due to less availability of energy supply. So designing a routing protocol plays a key role towards making such networks energy efficient. In this paper, we have gathered and analyzed different types of routing protocols that can be used for increasing lifetime of sensor nodes.**

Keywords - Body Node Coordinator; Routing Protocols; Body Area Network; cost function; residual energy; Energy efficiency

I. INTRODUCTION

The BAN is defined by IEEE 802.15.6 task group as "a communication standard for low power devices and operation on, in or around human body to serve a variety of applications including medical, consumer electronics or personal entertainment and others". A WBASN connects individual sensor nodes called as body node (BN) with a central controller called as body node coordinator (BNC). The main concept of WBASN is to monitor a patient's physiological signals constantly such as body temperature, heart beat rate, ECG, blood pressure, EEG, sugar level by using sensors, placed on human body and provides a great way of communication within the network and with outside world. The BNC is responsible for collecting information from BNs. So, direct transmission from BNs to BNC is not economic for WBASN. The reason is limited transmission range of transceivers. This helps us to understand why routing protocols are needed.

Also in WBASN because energy is constrained in power supply of sensor nodes, so it's a key challenge to reduce energy consumption. About 80% of total energy is consumed in transmission and reception purpose. So routing protocols have an important role for making less energy consumption amongst BNs and increase life time of WBASN.

Generally, there are three categories of routing in WBASN. They are direct transmission, multi-hop transmission and cluster based routing. In direct transmission, each BN directly transmits its packets to the BNC. This is most ineffective type of routing, since if distance to BNC is large then in transmitting a packet will consume a lot of energy. So network lifetime will decrease significantly.

In multi-hop transmission, packets are routed through different BNs to its final destination i.e. BNC. For example node m forwards it's packet to node n, if node n has better link connection to the BNC. In this paper we have explained different types of multi-hop transmission techniques such as SIMPLE, LAEEBA, FEEL, HEAT, REEC and also I have given a comparative study.

In cluster based routing protocols BNs are divided into cluster groups based on some criteria. Each group have a cluster head (CH) chosen from the group which aggregates packets from its member nodes and transmits to the BNC. Here we have explained two types of cluster based techniques i.e. SEABAN and EARBAN. Cluster based protocols are more effective than multi-hop techniques, because it adds the advantages of both multi-hop and direct transmission techniques. But in all cases critical data is transmitted directly to the BNC to avoid the delay by routing.

II. PERFORMANCE METRICS

1) *Stability Period* – It is the time till first node die. Also called depletion period.
2) *Residual Energy* – Difference between initial energy and used energy.
3) *Network Lifetime* – Time until last BN dies.
4) *Throughput* – Total number of packets arrived at the BNC.
5) *Path-loss* – It is the difference of transmitted power at the Tx and received power at the Rx calculated in decibels (dB).

III. SYSTEM MODEL

System model for different routing protocols are same with little difference. Here energy model, path loss model and scheduling are expressed which are almost same for all explained protocols.

1. *Energy model*

$$E_{TX}(k,d,n) = E_{Tx_{elec}} * k + E_{amp}(n) * k * d^n \quad (1)$$

$$E_{Rx}(k,d,n) = E_{Rxelec} * k \quad (2)$$

Here E_{Rx} is the energy used in reception, E_{Tx} is tl energy used in transmission, k is the number of bits, d ıs the distance, n is the path-loss exponent, Eamp is the energy dissipated by transmitter amplifier, E_{Tx_elec} and E_{Rx_elec} are energy dissipated by the radio to run the circuitry of Tx and Rx.

2. *Path-loss model*

$$PL_{dB} = PL_{0,dB} + 10 * n * \log(\frac{d}{d_0}) \quad (3)$$

Here PL_{dB} is the path-loss in decibel (dB) at a distance d, $PL_{0,dB}$ is the path-loss at distance d_0, n is the path-loss exponent.

3. *Scheduling*

The BNC assigns different time slots to BNs based on TDMA if the BN has packets to send. Otherwise the BN goes to sleep mode. The BNs transmit only in their assigned time slot. With information control messages are also exchanged.

IV. MULTI-HOP ROUTING PROTOCOLS

Some of the recent algorithms SIMPLE [1], HEAT [3], FEEL [2], LAEEBA [4] are explained below.

A. *SIMPLE (Stable Increased-throughput Multi-hop Protocol for Link Efficiency)*

1. BNC broadcasts a information packet with its location information. Each BN stores this info.
2. Each BN broadcasts a packet with its location, energy status and node ID. So all sensors are updated with other BN's and BNC's location.
3. BNC computes the cost function from the formula; (4)

$$CF(i) = \frac{d(i)}{RE(i)}$$

Here d(i) is the distance from node i to BNC, RE(i) is the remaining energy of ith BN.

4. BNC broadcasts this cost function.
5. The node with minimum cost function becomes the forwarder.
6. The forwarder gathers all packets and forwards it to BNC.

B. *HEAT (Horizontal movable Energy efficient Adaptive Threshold based routing)*

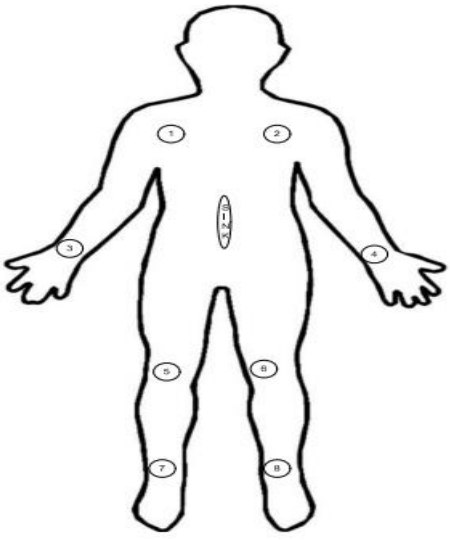

Fig1. Deployment of BNs in HEAT on body

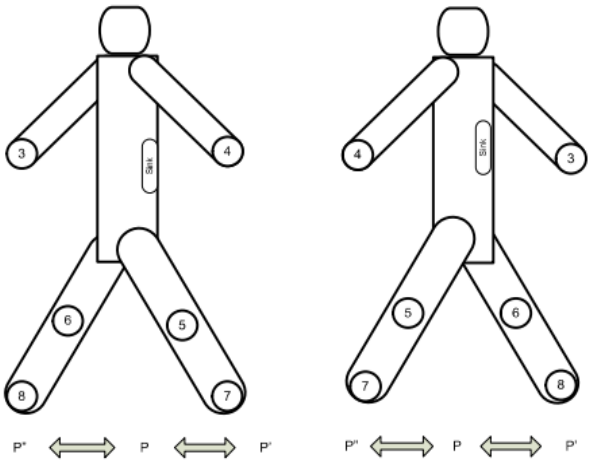

Fig2. Horizontal motion in human body

1. All nodes are updated with other nodes position and possible paths to the BNC.
2. Node sends REQ to sink, sink replies with ACK. Transmission can only occurs when in LOS i.e. position P in fig2.
3. Node 1 and 2 directly transmits to sink.
4. Nodes 4,5,7 are in category 1 and 3,6,8 are in category 2. So when category 2 nodes are in Non-LOS, then category 1 nodes are in LOS.
5. When category 1 is in LOS. nodes 4,5 sends directly to sink and node (4) multi-hop approach through node 5.
6. When node 7 has critical data, it sends directly to sink. Also if a node in NLOS has important data, it sends them to a node in LOS to forward it to sink. These are done to avoid delay.

C. *FEEL (Forwarding data Energy Efficiently with Load balancing)*

1. Sink broadcasts a HELLO message having location of itself, location of other nodes and info about routes to BNC.
2. The nodes update their routing table after receiving the HELLO message.
3. Forwarder is selected in each round based on residual energy of nodes by the sink.
4. The sink then broadcasts the id of forwarder node.
5. The forwarder node gathers all packets and forwards it to the BNC.
6. If a node's energy is lesser than some predefined value it transmits to BNC directly and does not take part in forwarder selection.
7. The advantage of FEEL is the forwarder rotates among all nodes uniformly. So energy is used up more uniformly than SIMPLE.

D. *LAEEBA (Link Aware Energy Efficient scheme for wireless Body Area networks)*

1. Here the forwarder is selected on the basis of cost function as in SIMPLE. But here a different cost function is used. i.e.

$$c_i = \frac{\sqrt{d(i)}}{E(i)} \quad (5)$$

2. But here the nodes do not always send its data directly to the forwarder, instead finds such routes which are fewer hops to sink.
3. Performance is better than SIMPLE.

V. CLUSTER BASED ROUTING PROTOCOLS

Some of the recent algorithms REEC [5], SEABAN [6], EARBAN [7] are explained below.

A. *REEC (Reliable Energy Efficient Critical) data routing*

1. Here BNC is placed in the middle part of human body, so that the BNs are divided into two groups i.e. upper part BNs and lower part BNs.
2. Instead of one forwarder node there are two forwarders for each group of BNs.
3. Step 1 & 2 of SIMPLE is performed here.
4. Then BNC calculates the cost function for each group and sends it to the BNs.
5. In each group one forwarder is selected which have minimum cost function in that group.
6. The forwarder nodes gather data from their respective groups and forward it to the BNC.
7. If a node is closer to the BNC than forwarder it sends directly to the BNC.
8. If a node's energy is less than some predefined value it also transmits to BNC directly and does not participate in selection of forwarder. This helps in less energy consumption due to data aggregation.

B. *SEABAN (SEmi-autonomous Adaptive routing in BAN)*

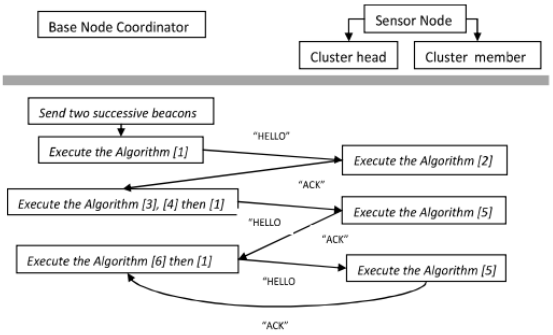

Fig3. Execution flow chart of SEABAN protocol

1. BNC broadcasts two beacons, one for synchronization and other for distance estimation of node from BNC.
2. Then synchronization phase (algorithm 1) is executed by the BNC. This phase is performed at the starting of each round to have a good synchronization between BNs and BNC. A HELLO message is broadcasted.
3. Cluster setup (algorithm 2) phase is executed by each BN. An impact factor (IF) is calculated by the BN. The BN with high values of IF has more chance to become cluster head (CH).
4. Impact Factor of a node i is defined as;

$$I_{imf} = \alpha_1 \left(\frac{E_i}{E_{max}}\right) + \alpha_2 \left(\frac{P_i}{P_{max}}\right) \quad (6)$$

Where Pi and Ei are priority and available energy of node i, α1 and α2 are user defined constants. Priority of onbody nodes are 1 and priority of implanted nodes are 0.5. So that on body nodes will have more priority of becoming Cluster Head.

5. The feasible CHs send ACK to BNC.
6. BNC executes conformation phase (algorithm 3,4,1). In algorithm 3 BNC selects the closest node (let i) to it in every cluster. In algorithm 4, BNC choose i as its CH and sets direct transmission from it. Then by executing algorithm 1, BNC sends HELLO message.
7. After getting the HELLO message, algorithm 5 is executed (execution phase) by the BNs. Non-CH nodes send data to CH and CHs send data to BNC in their assigned time slots.
8. Now after ACK from CHs, BNC starts centralized cluster formation phase (algorithm 6). Here BNC computes IF of those nodes who have more energy than a threshold value and the node with highest IF is chosen as CH. If in a cluster, energy of each node is lesser than threshold, then BNC searches for a relay node nearest to it.
9. Then BNC sends a HELLO message with which a new round starts and algorithm 5 and 6 are repeated.

C. *EARBAN (Energy efficient Adaptive Routing in BAN)*

1. In SEABAN only energy consumption model was taken, but here both energy and distance are considered. Also in SEABAN it is assumed that BNC is in transmission range of all Body nodes.
2. First BNC broadcasts a beacon with timing info for synchronization. After that it executes synchronization phase and broadcasts HELLO message.
3. Then cluster setup phase is executed by all BNs. CH is chosen by using Impact Factor (IF). If a node cannot get into a cluster it sends a HELP message which is replied by HELP-ACK and that node is added to a cluster through a relay node which is a member of a cluster. But in SEABAN the node was just increasing its transmission coverage range.
4. Then Gateway selection phase is executed. Here CHs try to find the pathways towards BNC by 'path explore' message. This path explore message is travels from CH to BNs or other CHs till the message finds BNC.
5. When the BNC finds the path explore message it starts centralized cluster formation phase. It calculates the IFs of all BNs and if the BN is in coverage range, direct transmission is established.
6. Then BNC selects new CHs if it has highest IF. Then gateway nodes are chosen for CHs for transmitting packets to BNC. These gateway nodes are selected based on their energy level.
7. After selecting the CH for each cluster and corresponding paths of CHs towards BNC, BNC allocates time slot based on TDMA for each Body Node and sends HELLO message to all nodes.

8. Then transmission begins. At the end of every round the centralized cluster formation phase is executed.

VI. CONCLUSION

WBASN is used for monitoring of patient 24/7 without any interruptions to their lifestyle. So, careful attention has to be given while managing the system resources for continuous monitoring. In this paper we have gathered and analyzed the important and latest routing techniques for Wireless Body Area Sensor Networks. In multi-hop routing cost function is an important parameter while in cluster based routing Impact Factor is an important parameter. Critical transmissions are always direct transmissions to avoid delay in routing. Also we have given the general system model for WBASN. In all cases good network lifetime is achieved.

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