

Temperature Aware Routing Protocol in the field of Wireless Body Sensor Network



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Abstract: *Wireless Body Sensor Network (WBSN) has come into view as a trending field in the recent years, having major application in the medical field. In this, few sensor nodes are put on or around human body which gathers the data and that data is processed for early detection of diseases where we can start early treatment, data is gathered while surgeries are performed. Based on the criticality of the information, it is very important to have routing protocols which are efficient and can be effectively used to gather the data[2]. In WBSN, one of the major concern is whenever we place sensor nodes on the human body, as they are used to gather the data, the temperature of those sensor node increases due to load and which need to be minimize in an effective way, how the packets need to be send in order to minimize the network load, energy saving mechanisms, efficient and effective packet delivery [3]. These few parameters bring the need of routing protocols into the picture. In this paper, we have critically reviewed all the routing protocols proposed so far which take temperature of the node as a metric, popularly known as Temperature-Aware Routing Protocols. We hope this help readers in their future work.*

Keywords: *WBSN (wireless Body Sensor Network), Sensor node, Sink node, Relay node, Temperature*

I. INTRODUCTION

According to various survey conducted by Department of Economic and Social Affairs of United Nations Secretariat, the population of elderly people was 759 million in 2010 which is predicted to go up to 15% of total world population in 2050. With such a huge number one of the major concern comes with elderly people is of their health maintenance and now a days technology try to provide the solution. Where every data, every device is moving towards online platforms to increase user ease, one major area i.e. health monitoring has gain a lot of popularity in previous years because of the statistics discussed. We all know that elderly people have to go for periodic checkup which includes a lot of cost as well as energy and time consumption and major concern in timely treatment due to the age factor, if in any case treatment is delayed it can lead to human life loss. So, a major idea came into the picture of early age disease detection which is done via one of the mechanism i.e. Wireless Body Area Networks which performs data gathering using bio signals. To get the user data we popularly use concept of sensors and these sensors capture the data from the user and use it to evaluate many parameters.

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A WBSN is a field which is used for human health monitoring and disease detection in the early stages where various sensors are placed with a strategy on human body or inside the human tissues for effective prediction and data gathering process by connecting to various other wireless link for communication. It mainly aims to enhance the quality of human life, its usage is not limited to medical field where as various non-medical field as well such as sports, entertainment etc. Whenever we talk about wireless body sensor networks, they recognizes the bio signals which concerns about the temperature rise as these sensors are being applied on human body and if it crosses the threshold value then they can harm the human tissue to a great extent. There are various temperature-aware routing protocols available currently such as TARA (Thermal Aware Routing Protocol), LTR (Least Temperature Routing) etc. now people are more self-aware about their health and believe in early detection and treatment which leads to motivation in developing energy saving and more effective routing protocol for efficient human health monitoring. In Fig 1, WBSN's include various parameters such as temperature of body, blood pressure, glucose levels, ECG, EEG signals in various fields[4]. If we see the battery of each node is limited in WBSN so applications need to be built in a way which consumes low power, low latency and more reliable medium of communication. Whenever we talk about WBSN network, it mainly consist of one Coordinate Node (CN) and others are popularly known as sensor nodes. The sensor nodes work on various parameters as discussed above to gather data and transmit the same on wireless network. Every node is concerned about the energy associated with it so whenever it runs out of the energy, a major concern arises of its replacement which can be troublesome task if the sensors are placed in the body[5]. To reduce this issue, the conventional focus lies on reducing the energy consumption and increasing the network efficiency so that it works for long. Sensors also specifies few levels (0,1,2...7) where top 3 levels are given priority to medical data where as others can be used for other purpose data accumulation process. The paper is being organized as follows, Section I is introduction; Section II consist of deep discussion of all the temperature aware routing protocols proposed so far; Section III contains all the open issue areas which need to be considered while developing any routing mechanism, Section IV is conclusion and Future Scope.



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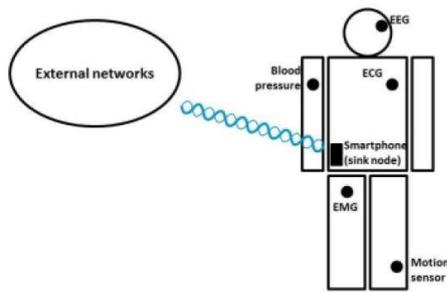


Fig 1: Example of a WBSN

II. TEMPERATURE-AWARE ROUTING PROTOCOLS

In this section, we will talk over thoroughly various routing protocols available for WBSN network which take temperature as measure while deciding the routing path with their advantages and disadvantages that's why called as temperature aware routing protocols. Main plan of these protocols is to keep the temperature low so that precautions can be taken in order to prevent any human tissue damage. The taxonomy of the available routing protocols are as follows in Fig 2:

2.1 TARA (Temperature Aware Routing Protocol)

This protocol proposed temperature very first as metric in the category of thermal aware routing protocol which takes into account antenna radiation and the power dissipation as two significant sources of heat. One assumption made by this protocol is that there is no availability of temperature sensor in the node, so using those two major sources plus by observing the sensor activities the temperature of the node will be measured [6].

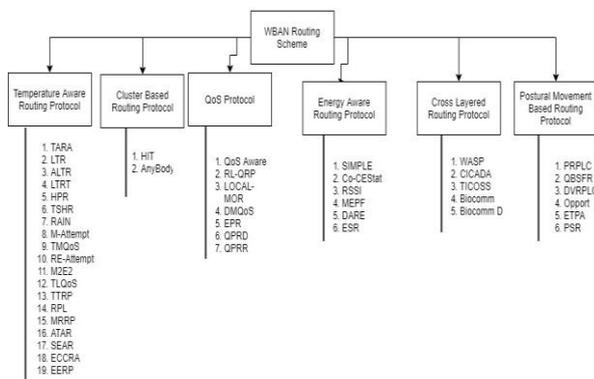


Fig 2: Taxonomy of various protocols for WBAN

In this protocol, we have two phases popularly known as setup phase and data forwarding phase. In the first phase, a list of all the neighboring nodes is maintained with number of hops information so that each and every node in the network know how to reach the sink node. In the second phase, taking temperature metric into account nodes forward the data packet forward to the next hop continuously until it reaches the sink node. As here temperature is considered, so if temperature of any node increases above a threshold value it is called as hotspot node, and if any packet is at hotspot

node it is put into buffer until the temperature drops, and packet existing in buffer if exceeds then it will be dropped. Also, a withdrawal strategy is implemented in which if packet reached to hotspot node and it is the intermediate node, packet will choose another path to avoid that area. The detailed working is as follows, as soon as hotspot node is encountered, node will check for availability of next hop node where the packet can be send and if no such node available then packet will be diverted back to check for another path. When this strategy is used, packet carries the hotspot node information with it.

One of the main advantages of this protocol is that temperature metric is being introduced, using this withdrawal strategy will equilibrium the load by avoiding the hotspot nodes as these nodes carry a lot of packets leading to increase in temperature but major point to consider here is that packet need to spend some considerable amount of time in network resulting into low network lifetime and high delay.

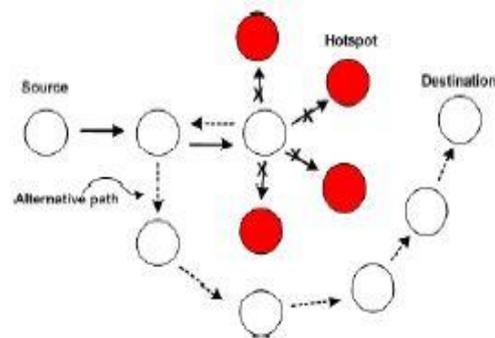


Fig 3: example of Temperature – Aware Routing Algorithm

2.2 LTR (Least Temperature Routing)

LTR, popularly known as Least Temperature Routing has its basis on TARA protocol only. The initial set up phase works same as that of TARA with improvement in mechanism of forwarding the data packets in the network. LTR promote the data packet directly to destination node with taking least temperature into account i.e. packet will be promoted to the coolest neighboring node in the network from the beginning. It also introduced a parameter MAX HOPS, defined as packet drop mechanism whenever the received packet's hop count exceeds to prevent it going very far in the network[6].

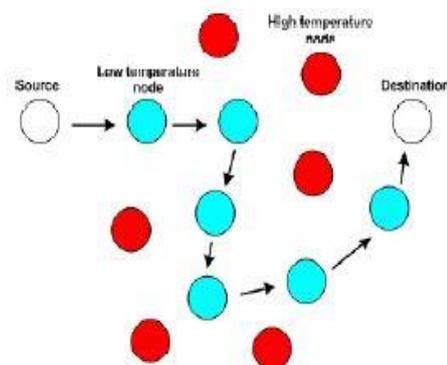


Fig 4: Example of Least Temperature Routing

2.3 ALTR: Adaptive Least Temperature Routing

ALTR[6], introduced a new parameter MAX HOPS ADAPTIVE, which examines the hop count value each time a packet is received by a node. If the value is low it follows the same way as LTR follows and if the value is greater than the new parameter introduced, to prevent the packet being dropped it follows the path according to shortest hop algorithm. One more concept is being introduced known as “proactive delay” in which whenever a packet is obtained by the node, which has no more than two outgoing neighbors and the coolest surrounding node has high temperature then packet before forwarding will be delayed with one time unit. An example of this protocol is being shown below[6].

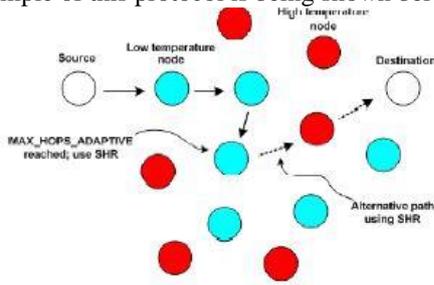


Fig 5: Example of ALTR

2.4 LTRT (Least Total-Route Temperature) Routing

This protocol is basically a hybrid of LTR protocol and SHR (Shortest Hop Routing) implementing perspective of end to end connection. Route calculation takes temperature as first base and then implementing shortest hop algorithm. The mechanism is as follows firstly temperature of all the neighboring node will be collected and a weighted graph will be build having vertices representing as node and edges representing all the possible route. On the graph developed, Dijkstra’s algorithm will be used to figure out Single Source Shortest Path(SSSP) resulting into lowest temperature route[7].

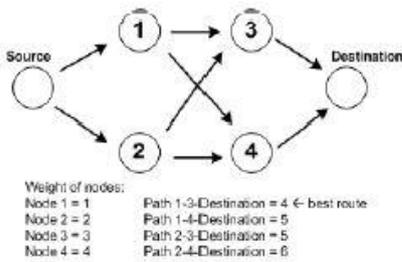


Fig 6: Example of LTRT

2.5 HPR (Hotspot Preventing Routing)

This protocol is improvement in Least Temperature Routing (LTR) and Adaptive least Temperature Routing (ALTR). By the means of using Shortest hop algorithm and a threshold value it anticipate the setup of hotspot nodes as well as prevent packets from opting the suboptimal paths which further reduces the delay. It contains two phases, known as Setup phase and routing phase. In the initial phase, routing table will be formed using the information of shortest path available in the network and temperature of the nodes. In the routing phase, HPR calculates the threshold value dynamically as compared to previous protocols where threshold value is being predefined, the dynamic calculation of the threshold value is being done on the neighbor node temperature and current node temperature. If the next hop

temperature overpasses the value then the packet will be routed to the coolest surrounding node. Similarly like LTR, HPR uses MAX HOPS parameter, for the sake of prevention of routing loops packet will be dropped if it overpasses the threshold value[8].

2.6 TSHR (Thermal-Aware Shortest Hop Routing)

This protocol is an improvement in HPR, in terms of threshold value where the value is considered one as fixed and other as dynamic. The fixed threshold value is being applied to all the nodes and represent the maximum temperature allowed in the network. The dynamic value of threshold is calculated based on the temperature of the node and its neighbor node. The major advantage of this protocol is that no packet is dropped, as if hop count exceed the threshold, using SHR packet is forwarded further in the network[9].

2.7 RAIN (Routing algorithm for network of homogeneous and ID Less Bio-sensors)

In this protocol, network is of homogeneous nature so it states that why we need to maintain the ID of nodes as it creates an overhead of maintaining the ID’s. In place of having static ID, a temporary ID will be maintained in order to maintain the smooth communication. In this protocol, energy is saved by mainly preventing neighboring nodes from sending multiple copies to sink node of same packet[10].

2.8 M-attempt

Abbas et al [11] states four phases i.e. initialization, routing, scheduling, data transmission. In the first phase, hello packet will be send throughout the network to establish the connection. In the second phase, based on temperature and energy metric path with minimum hop count will be selected. In the next phase, the sink node will create a TDMA (Time Division Multiple Access) plan for all the root nodes. In the last phase i.e. data transmission phase, all the data from root node is propagated to the sink hub[11].

2.9 TMQoS (Thermal aware multi constrained intrabody routing protocol)

This is multi check intrabody routing protocol. The main aim of this protocol is to sustain temperature of a node on acceptable level. In this protocol a routing table is being maintained containing multiple shortest path. It also introduces Beacon packet concept where a routing table constructor is used to induce a routing table which take hop count, delay and temperature value as the parameter[12].

2.10 Re-Attempt (Reliability Enhanced-Adaptive Threshold based Thermal-aware Energy efficient Multi-hop Protocol)

Javaid et al [13] proposed that the sink node will be spotted between the nodes and nodes will be arranged in descending manner in terms of data rate. The node with low data rate will be placed where human body is having maximum mobility leading to lower mobility area will have higher data rate node. It also contain the similar four phases like M-attempt, the initialization phase is same, in the routing phase the route with less hop count will be chosen where depending on the data, i.e.

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critical data will be sent by direct communication whereas using multi hop communication normal data will be send. In the scheduling phase, time slot are given to sink and root node for communication. In the last phase, data will be transmitted to sink node on the allotted time slot[13].

2.11 M₂E₂

Rafatkhan et al. [14] proposed this thermal and energy efficient routing protocol. In this four phases are proposed, in the initialization phase, “hello message” will be broadcasted. In the routing phase, data will be send to medical server where the data will be sent from sink node to medical server using a direct communication leading to no energy stipulation because of criticality of the data. If home-signal is not prevailing then routing table will be formed using implanted nodes and multi-hop link for communication of data. In the last phase, as per the allocated time slot data will be transferred[14].

2.12 TLQoS (Thermal Aware Localised QoS routing protocol)

Monoware et al. [15] introduces an integrated rate control technique aiming to minimize the thermal effect in the bio medical sensors and also to avoid choking while communicating within the nodes. To prevent excessive heating and any injury to the human tissue, temperature of the node is presented in the mentioned protocol at an adaptable level[15].

2.13 TTRP (Trust and Thermal Aware Routing Protocol)

It is a proposed thermal alive routing protocol providing trusted and hotspot free network communication. Kumar et al. [16] is having his main aim at preventing communication from faulty and malicious nodes present inside or outside of the network. It consist of three phases namely trust estimation which further consist of direct and indirect phase which is responsible for calculating the trust level for intermediate nodes. Second phase is route discovery which aims at selecting trustworthy and hotspot free node communication. Last phase is route maintenance which aims at re-initiating the route discovery phase whenever a node becomes hotspot leading to inactive route formation[16].

2.14 RPL

This is popularly known as self-healing or adaptive routing protocol where whenever a node is marked hotspot node, then the node itself decides the efficient path for communication of data based on low temperature and low power metric[17].

2.15 MRRP (Multipath Ring Routing Protocol)

It contains of two phase i.e. multi path construction phase and data delivery phase, in the former phase, to reduce congestion in the network multipath are developed. Various ring levels are defined starting with the value 0; whenever a packet will be received by the node the ring value will be updated to 1 and broadcast the packet. Which will make all the sensor node organized into a ring fashion. In the later phase, data will be transmitted according to the ring level value until it reaches to the sink node[18].

2.16 ATAR (Adaptive thermal aware routing protocol)

In this protocol, Faisal et al [18] improvised the MRRP routing protocol by reducing the temperature rise and expanding the

network life. Few assumptions have been made such as sensors will have a fixed position in network, sink is put in the middle of the human body(as shown in figure as well) and will be destination node for every sensor node, every sensor node will have static transmission power and range, after the initial phase location of every neighbor node will be known in the network, critical data can be communicated via single hop communication, normal data is communicated via multi hop, forwarder node selection depend on the temperature rise status. It contain two phases, one is Initialization phase and other is data transmission phase. In the former as shown in figure distance of each node will be calculated from the destination node and network will be organized into different levels say R1,2,3.. etc. whenever a packet is received by a node it will update its ring field value by 1 and rebroadcast the setup packet. The packet broadcasted will be comprised of its Source ID, Destination ID, Temperature and Ring Level. The main aim of this phase is to develop the ring levels[18].

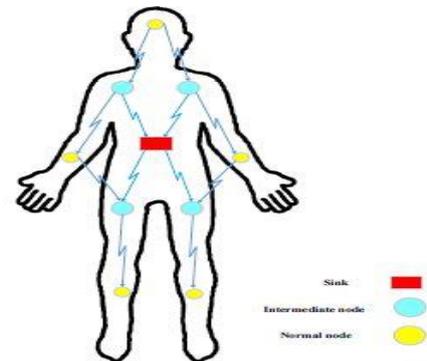


Fig 7: node placement and communication on the human body

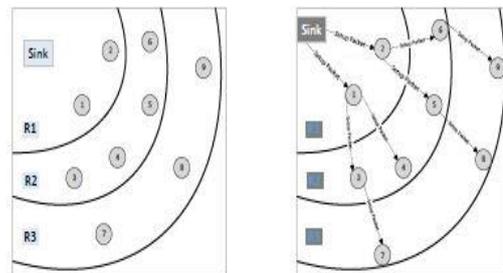


Fig 8: ATAR: initialization phase

In the later phase i.e. data transmission phase, when data packet is received by relay node, the ring level will be compared with the received packets ring level. If it is less then packets ID will be verified with node ID, if matches, it will be rebroadcasted until it reaches to sink node and If the value is greater than neighbor node will maintain the ID, temperature and packet will be discarded and this maintained information will be used in an intelligent manner to forward the data next time.

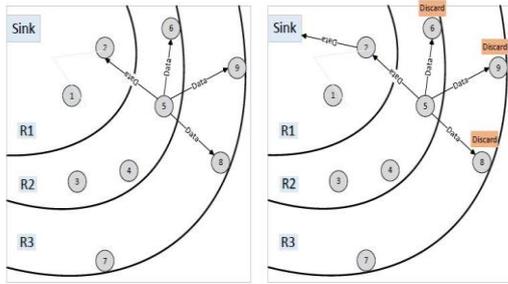


Fig 9: Data Transmission Phase

2.17 SEAR (Simplified Energy-balanced Alternative Aware Routing)

The simulation results exhibit as SEAR (Simplified Energy-balanced Alternative-aware Routing) achieves extensively, greater network throughput and network residual energy, end-to-end delay is additionally minimized. Although WBAN (Wireless Body Area Networks) is a partner utility branch over wireless sensor networks, there are still variations among the networks [1].

Finally, WBANs adopt star topology, in as much as WSNs are essentially multi-hop networks. In the recent years, there are various articles regarding wireless area networks. The protocol does not undertake an elect routing structure like a spanning tree, yet doesn't put a constraint on the kinsman function, and link attributes about the node however calculates the external hyperlink attribute concerning every node within the network.

2.18 ECCRA (Energy Consumption Control Routing Algorithm)

The ECCRA (Energy Consumption Control Routing Algorithm) adopts the node freelance transmission hyperlink and considers the routing course hop count, node transmission power, and other energy to pick a route along the smallest total strength consumption, so much in the end minimizes the energy utilization over the network and outstretch the existence cycle over the network. ECCRA doesn't assume the periodical drawback concerning the network brought about via adjustments within body posture[1].

2.19 EERP (Energy Efficient Routing Protocol)

The EERP (Energy Efficient Routing Protocol) calculates the lay regarding every path to span the quality on the trough and considers the other strengths of the node, the path power consumption, and therefore, the node work kind, up to expectation efficiently saves the power consumption of the transmission[1].

SIMULATION RESULTS FROM PERFORMANCE COMPARISON

- 1) **FIXED TOPOLOGY MODEL**, here they initially compared the end-to-end delay, network residual power, and network out turn over SEAR, ECCRA, EERP into a fixed topology. As the network tends by stability the energy consumption within the network tends in imitation of flatness.

For WBAN, SEAR has a tussock about uneconomical remaining energy than ECCRA or EERP. Therefore, SEAR will sincerely administer and cut power consumption within the network. Because the whole energy over device nodes within a wireless body area network is proscribed, SEAR is better than the contrary 2 routing algorithms.

EERP has greater network outturn performance than ECCRA so result over that makes whole use of the nodes moving away from the network.

The yield regarding the network decreases progressively due to the fact on the energy slander about the nodes and consequently the congestion of data over the network because the time of simulation grows. By scrutiny the end-to-end delay regarding the transmission of packets, network residual energy, and network out turn on a number of routing algorithms inside the hooked up topology model, the conclusion was once so SEAR performs properly regarding residual energy regarding the network, network output, yet end-to-end extend within the installed topology in contrast to ECCRA and EERP.

MOBILE TOPOLOGY MODEL As a result of the human behavior between Wireless body area networks is dynamical perpetually, that was once essential after matching the overall performance concerning these performance parameters below numerous stipulations about human motion, as end-to-end delay, power consumption, and network output.

SEAR has higher strength performance than ECCRA and EERP since efficiently reducing power consumption within the network and above the soundness about the complete network. Because the whole strength on sensor nodes is proscribed among wireless body area-network, it's explicit SEAR is better than ECCRA and EERP in wi-fi body area network whether using the mobile topology model or the fixed topology model.

SEAR has a beneficial output, therefore, the performance over EERP is better than ECCRA. However, along with the upward push about simulation time, network yield indicates a downtrend. EERP indicates greater outturn than ECCRA as a result of such will accurately protect the nodes that are near in leaving the network.

III. OPEN ISSUES

Whenever we talk about routing protocols, there are few major challenges which come in our path to develop an efficient routing mechanism. In this section we will discuss them to give reader an insight view of which parameters need to be considered in developing an efficient mechanism for future purpose

3.1 Bio-effects

Whenever we talk about WBSN's, nodes are placed on or around or inside the human body, working of nodes will give temperature rise and going to produce heat. So to prevent human body tissues from damage we need to keep these factors into our mind where routing protocols which are energy efficient and less power consumption are proposed.

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Authors	Approach	Objective	Limitations
Tang et al., 2005	TARA [6]	Calculate temperature from neighbour node and redirect packet from hotspot area	Less Network lifetime, high packet delay
Bag & Bassiouni, 2006	LTR [6]	Minimization of temperature and redirecting packets from hotspot area	Less network lifetime with high packet drop ratio
Bag & Bassiouni, 2006	ALTR [6]	Minimize overall temperature	Less network lifetime, end to end delay considering average temperature metric
Takashi et al., 2007	LTRT [7]	Minimization of heat produced by bio-medical sensors	Less network lifetime, does not provide hotspot avoidance
Bag & Bassiouni, 2007	HPR [8]	Overcome problem of hotspot	Less Network Lifetime
Bag & Bassiouni, 2008	RAIN [9]	ID less data transmission in homogeneous system	High packet delay
Tabandeh et al. (2009)	TSHR [10]	Prevention of hotspot formation and reduce the node temperature	Less Network Lifetime
Javed, Abbas and Fareed (2013)	M-Attempt [11]	Redirect packet away from hotspot area	No alternative route in case of dead nodes, non-uniform load
Mostafa and fuad (2014)	TMQoS [12]	Maintaining of node temperature at an acceptance level and guarantee QoS	Path loss is high
Ahmad and Javaid (2014)	RE-Attempt [13]	Redirect packet away from hotspot link and increase the network lifetime	Less Network lifetime
Omid(2014)	M ₂ E ₂ [14]	Redirect packet away from hotspot link and increase the network lifetime in WBSN	Node temperature is high
Mostafa and fuad (2015)	TLQoS [15]	Maintaining node temperature, prevention of loop with guarantee QoS demand	Less Network lifetime
Ali, Pardeep and Adnan (2017)	TTRP [16]	Protect data and maintain the temperature rise of bio medical sensor node	High end to end delay
Mercy (2017)	RPL [17]	Self-healing routing protocol	High packet drop ratio
Huang (2013)	MRRP[18]	Ring formation to maintain the communication	Less network Lifetime
Faisal jamil (2019)	ATAR[18]	Using ring mechanism for transmission in an intelligent way	Less network Lifetime
Jaisong Mu (2019)	SEAR[1]	Energy efficient routing	Less network Lifetime

Table 1: A critical review of Temperature Aware Routing Protocol

3.2 Network Topology

In general there are two type of network topology present i.e. Single Hop and Multi hop. In former one is generally used for sending the critical data as a single link is used to send the data which leads to no requirement of routing protocol but major limitation is of lossy nature of human body. In multi-hop, intermediate nodes are used to transmit the non-critical data leading to the requirement of routing protocols. Natarajan et. al[2] conducted an experiment to check the reliability of two topologies and result come out as multi-hop is more reliable and is more efficient to use for WBSN.

3.3 Packet Delivery Delay

When we talk in terms of WBSN's, its major application is in medical field where the data need to be send from source to destination in a specified duration or with some deadline, so it always remains a challenging task to send packets with minimum possible delay in the network.

3.4 Energy Consumption

When nodes are placed on or around human body, our aim is to implant less number of nodes and to get maximum data for efficient predictions. With less number of nodes, one of the major issue comes with the energy as nodes are used to transfer the data which leads to consumption of energy of nodes. So it remains an open issue to how to get more and more data while saving the energy of the nodes.

3.5 Reliability

Reliability of delivery of data can be measured by Packet Delivery Ratio (PDR) and Bit Error Rate (BER). PDR can be defined as the number of packets received by packets generated by sender. BER can be defined as ratio of error bit to the bits generated by sender. For medical applications, reliability plays a pivotal role as any error can lead to mistreatment for the patient. Thus more reliable routing protocols will always be in demand.

3.6 Node Heterogeneity

In WBSN's, sensor nodes are generally heterogeneous in the nature. As per application, sensor node will have different requirement and constraints. Node may vary in size, capacity in terms of computation, communication and capacity of energy, might have different QoS requirement, one place might be high data rate is the priority and other place longer delay might not be an issue.

3.7 Data Aggregation

This might be considered as a mechanism to save energy as data will be received from different sources and need to be comprised or fused before further transmission for efficient predictions. If this technique is not considered then the data sent to next node will be larger which may lead to more network load hence more energy consumption.

3.8 Quality of Service (QoS)

This factor need to be considered carefully as each application might have its own needs such as minimum delay, packet loss, data rate etc. and when these requirements are not met, it might create an issue for the application eg. Whenever a surgery is being performed, an electrocardiogram being used for heart rate monitoring need to provide real time measurement of the patient, if any error

is there or delay is there it might be of no use. Few protocols proposed in this field are [4-6]

IV. CONCLUSION AND FUTURE SCOPE

WBSN (Wireless Body Sensor Network) has emerged as a field in recent years and many of the routing protocols are being proposed in this field which talk about energy consumption, quality of service, temperature as one of the main metric, cluster based, cross layered, Human Body Posture movement etc. when we introduce medical field and patient come into the picture one of the major concern is timely and efficient treatment. WBSN plays major role in early detection of the disease so that early phase treatment can be started. In this paper we have discussed routing protocols thoroughly proposed so far with their advantages and disadvantages. We hope this review help the readers in their future research work.

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