**Indonesian Journal of Electrical Engineering and Computer Science**
Vol. 4, No. 3, December 2016, pp. 594 ~ 604
DOI: 10.11591/ijeecs.v4.i3.pp594-604


# Wireless Body Area Networks Routing Protocols: A Review

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***Abstract***

*Wireless Body Area Networks (WBANs) are designed for monitoring the patient's conditions and assist them in critical health situation. Tiny size wireless sensors sense the data related to patient health. Further, the sensed data sends to base station for further process. The base station sends the data to the nearest sink node or to the nearest medical center or hospital. In order to complete this entire process, wireless sensors need efficient routing without any error or delay. The routing protocols have been suffered with various challenges and issues which are related to the routing and energy issues. This paper provides a comprehensive survey of important existing routing protocols for WBANs. Paper also discusses the protocols strengths, limitations with their critical analysis.*

***Keywords: s****ensors, routing, energy, implanted, consumption*



## 1. Introduction

Wireless Body Area Networks (WBANs) is an emerging field for health care centers and hospitals. Recent advances in Information and Communication Technologies (ICTs) make small size wireless sensors more efficient to sense the data and enable the design of intelligent physiological sensor nodes [1]. These intelligent sensors are implanted on human body for different purposes such as to measure the temperature, heartbeat, blood pressure. These sensors are capable to detect early vital signs and sending this data towards the sink node or to the doctor for further processing [2]. After receiving the data, doctors initiate some important decisions related to the patient's health for further treatment. WBANs are specially designed for old patients to fulfill their special medical care anytime and anywhere [3]. The hospital facilities doctors consultation to monitor the patient health conditions are expensive and sometimes impossible for patient and their families to maintain all these resources [4]. Through this new wireless technology, patients avail all the facilities by remote management system [5].

In WBANs, all devices including sensors, Personal Digital Assistant (PDA) or smart phones are connected with each other through wireless connections. These all devices have limited energy/power to maintain their connections and services. To minimize the energy and power in these tiny size sensors is significant due to dangerous effects of heat on human body and lead to damage the tissues [6].

WBANs are divided in to three tiers: intra, inter and extra. In intra tier, sensors send the sensed data towards the base station. In inter-WBANs, the base station sends the collected data towards the sink node. In extra WBANs, the sink node sends the data which it receives from base station towards the medical center [7]. Figure 1 shows three tiers of WBANs.

Wireless Sensor Networks (WSNs) can be deployed for monitoring and alerting about natural disasters, bio medical health monitoring and military operations [8]. Routing protocols that are designed for Mobile Ad hoc Networks (MANETs) and WSNs are not suitable for WBANs due to its special requirements and certain conditions. Some challenges are similar in both (WSNs and WBANs) fields and some are different, as shows in Table 1 [9].

*Received August 30, 2016; Revised October 7, 2016; Accepted October 28, 2016*

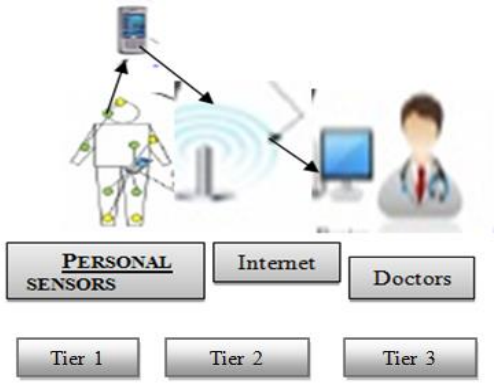


Figure 1. Three Tiers Communication in WBAN

Table 1. Differences between WSNs and WBANs

| Challenges | WSNs | WBANs |
|---|---|---|
| Types of Node | Homogeneous | Heterogeneous |
| Mobility Range | Environment monitoring in meters (m) and kilometers (km). | Human Body monitoring in centimeter (cm) and meters (m) |
| Number of nodes | Many redundant nodes for wide area coverage | Fewer, limited in coverage |
| Network Topology | Fixed and static | Dynamic (due to body movement) |
| Wireless Technology | Bluetooth , Zigbee, GPRS | Low power Technology |
| Biocompatibility | Not considered | Considered for implanted and external sensors |
| Energy Requirement | High but easy to provide | Limited but difficult to provide |
| Node replacement | Easy to replace | Difficult to replace |
| Node Size | Small is preferred but not necessary | Small in size |
| Node Lifetime | Several months/ years | Several years/ months, with small battery capacity |
| Source of Energy | Mostly wind or solar power | Vibration (body movement), Thermal (body heat) |

WBANs networks have suffered with various challenges such as postural body movement, limited resources, temperature, heterogeneous environment, Quality of Services (QoS) and security [8]. In this paper, our main focus on temperature issues in WBANs. The main objective of this review paper is discussing the temperature aware routing protocols with their critical analysis in the field of WBANs.

The rest of the paper is organizes as follows: Section 1 describes the general information about WBANs. Section 2 provides existing related work on WBANs routing protocols. Section 3 discusses the routing issues and challenges. Section 5 provides detailed description of temperature routing protocols. Last section concludes the paper with future direction.

## 2. Related Work

WBANs have emerged with new technologies in the field of healthcare. The patient's vital body parameters are collected by wearable sensors and move towards the sink by using short-range wireless communication techniques [9]. WBANs have three levels including power sensor nodes, master nodes and Internet or local level. In first level, the low battery sensor nodes needed which are operated for long period of time without recharging [10]. These are implanted in body or placed on body. The second level nodes are used to controlling all other sensors and also called gateway or coordinator nodes. In addition, these master nodes require

less power because of its applications. The last level is Internet or local level which is used for monitoring. These three level nodes main requirement is energy and still energy consumption is one of challenge in WBANs. Different types of routing protocols are used to route the data and also have impact on energy consumption in WBANs [11]. Sensor nodes have limited energy that is associated with its life time.

1. All paths are defined for data routing and must be energy aware and do not produced much heat as nodes are directly planted in the human body.
2. The main problem associated with energy efficient routing is the implementation of complex algorithms.

Many routing protocols have been developed for efficient routing but still have some weaknesses. Some of them do not focus on delay tolerant and postural information [10]. Many protocols do not focus on temperature rise. Much research has been done in development of routing protocols. Liang, et al [11] proposed a Prediction based Secure and Reliable (PSR) routing framework for reliable and secure routing. Khan, et al [12] proposed an Energy Aware Wearing Routing Protocol (EPR) for reduced the traffic load and energy consumption. In this proposed model, an energy aware and QoS aware routing protocol for communication devices in healthcare system is presented. However, these protocols still have suffered with many issues.

Nadeem, et al [13] proposed a stable increased throughput multi-hop protocol for link efficiency in WBANs. Thermal aware routing protocol is proposed to minimize heating in sensors. Cluster based routing scheme have been proposed to reduced delay, power consumption and increase network life time and link quality [14].

Postural-Movement-based routing protocols were proposed for handling the link disconnection that occurs due to the body movement. Cross layered routing protocol has proposed for solving the issues of network and MAC layer [15]. After a short introduction about some protocols, in routing section, we will discuss these all protocols in detail.

## 3. Design Issues Of Routing Protocols

WBANs are connected with the remote monitoring systems therefore these systems need to maintain high level of reliability and low level of latency [2]. In order to design the efficient routing protocol for WBANs is a challenging task because of network unique requirements. Next sub-sections discuss some routing issues WBANs.

a) Dynamic Nature of Network

The nature of WBANs network is dynamic due to nodes mobility, dynamic topologies and environmental changes. The dynamic nature of network also decreases the network life time [16]. Due to body postural and movement, link quality also varies as a function of time. Thus routing protocols should be adaptive to handle topological changings of network.

b) Heterogeneous Environment

Different types of nodes are used to measure different parameters in WBANs. These heterogeneous nodes are used for memory, power consumption and computation processes. Thus, the heterogeneous nature of environment causes many challenges in WBANs.

c) Topological Partitioning

Topological partitioning is another issue in WBANs due to body postural movement and short range of communication devices. To handle this challenge, efficient routing protocol is required. The protocols might be single hop, multi-hop and also cluster based communication which is depending on the network size.

d) Energy Efficiency

Energy utilization is one of the major challenges in WBANs because replacing the batteries is not convenient and cause of discomfort of patients. The sensor nodes batteries life time depend on sensor batteries and applications. Maximum usage of energy leads to overheating which is harmful to damage the body tissues for patient [22-23]. Therefore energy consumption and network lifetime is very important in WBANs. However, still these networks have faced the energy consumption issues due to limited energy resources.

**e)** Interference and Temperature Rise

Temperature rise is another issue to design a routing protocol in WBANs. There are two main reasons behind temperature rise: antenna radiation absorption and energy consumption of

nodes. Thus, there is a need to design and develop energy efficient routing protocols which utilize minimum energy and has less interference.

f) Limited Resources

WBANs have very limited resources such as short communication range, limited energy and storage capacity, low bandwidth. Thus, routing protocols should be capable to handle these constraints.

g) Security and Privacy

Security and privacy is another significant issue in WBANs. The security should be existing for all tires and authentication and integrity of devices must be guaranteed. Security must be achieved on both system and data level [11]. Different types of security techniques are used to ensure security. On the other hand, privacy refers to rights of patients in order to control the data collection and used for personal information. In order to keep the patient data secure, WBANs have to fulfill all the major security requirements.

h) Quality of Services (QoSs)

QoSs are required for different type of data transmission in WBANs. The author in [18] describes the patient data into three types including critical, sensitive and ordinary data. In critical data, the sensors collect the data of EEG, heartbeat. Insensitive data, sensors collect the data based on video streaming, image processing, vital signals and monitoring respiration. In last, the ordinary data is based on temperature body movement information. The routing protocols must be design to fulfill all QoSs requirements based on application need and data category. QoSs require high packet delivery ratio, low level of packet transmission delay, minimal collisions and retransmissions [17]. QoSs can be evaluated at higher layers of protocols.

## 4. Existing Standards

In WBANs, designing a communication standard for low powered devices is another big challenge for researchers because low power sensors nodes still suffered and not able to fulfill the QoSs requirements. In this section, we discuss some exiting adopted standards for WBANs:

a. IEEE 802.15.4 and ZigBee: ZigBee is designed for low powered short range sensor nodes. This standard is used at an application layer for defining the application framework. For physical and MAC layer, the ZigBee is adopted with the standard 802.15.4 as a complete protocol stack.
b. IEEE 802.15.16: IEEE 802.15.16 is another standard which aims to support WBANs requirements and handle low cost, low power and reliable transmission. This standard has data rates up to 10 Mbps [18]. This standard main objective is to minimizing the Specific Absorption Rate (SAR). This standard further divided into three layers:
    1. Narrowband (NB),
    2. Ultra Wideband (UWB)
    3. Human Body Communication (HBC)

## 5. ROUTING

### 5.1. Classification of Routing Protocols

For WBANs, routing protocols have been categorized into different types including MAC layer protocols, QoSs aware routing protocols, temperature-aware routing protocols, cluster-based routing protocols, and postural movement based routing protocols and cross layered routing protocols. Figure 2 shows the categorization of WBAN protocols.

In this paper, our main focus is to highlight the temperature aware routing protocols for WBANs. In this section, existing temperature aware routing protocols for WBANs are discussed with their comparison, critical analysis and possible solutions.

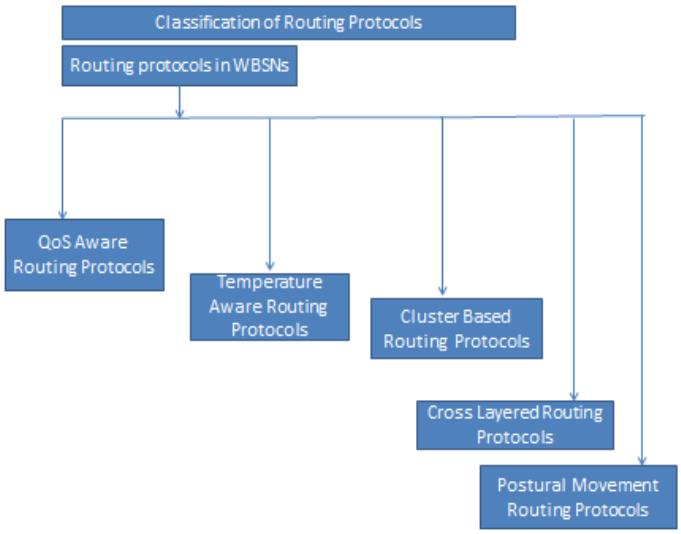


Figure 2. Classification of WBANs Routing Protocols

### 5.2. Temperature Aware Routing Protocols

Temperature aware routing protocols specially designed to minimizing the sensor node overall temperature during communication process. Basically the idea behind these protocols is to route the data from different routes to address the temperature issue. In WBANs, many sensor nodes are implanted inside and on the human body. These sensors generate electric and magnetic fields due to radio signals. The electric and magnetic fields cause of temperature rise because of antenna radiation absorption, and power consumption of nodes [19].

The temperature rise will result to damage the human sensitive tissues and reducing the blood flow. Energy absorption rate per unit time is calculated by using Equation 1.

$$SAR = \sigma|E|2P \text{ --- } (W/kg) \quad (1)$$

In Equation 1, σ is used for electrical conductivity of tissue, E shows magnetic field by radiation. P is the density of tissue.

The temperature aware routing protocols are further classified into different types, the next section discusses these types.

### 5.3. Classification of Temperature Aware Routing Protocols

Temperature aware routing protocols are further classified into different types as shows in Figure 3. In this section, we discuss some common types of temperature aware routing protocols.

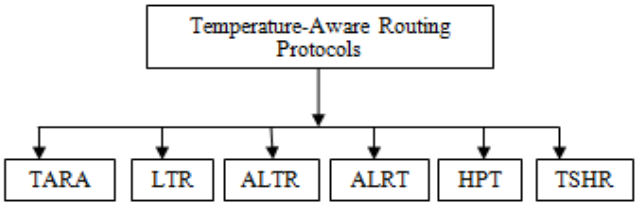


Figure 3. Classification of Temperature Aware Routing Protocols

#### a. Thermal Aware Routing Algorithm (TARA)

Temperature Aware Routing Algorithm (TARA) [20] was proposed for minimizes the temperature generated by the implanted sensors in human body. It is most primitive routing

protocol. Initially each node counts the transmitted and received packets of neighbor nodes and then calculates communication radiation and energy consumption. A threshold value is assigned to each node, when a node's temperature exceeds this value which is called hotspot node. In routing phase, the hotspots nodes are not utilized. For example in Figure 4, when a packet sends through a route which has hotspot node. Then packet is send back to the source node to choose an alternate path which has no hotspot node. In case of destination as a hotspot node the packet is not send and buffered until node drops its packet. After cooling the hotspot node temperature beneath some threshold, these hotspot nodes can be used for another routing. TARA suffers from high end-to-end delay, low reliability, as well as high energy consumption because packet needs to traverse many hops due to this withdrawal strategy.

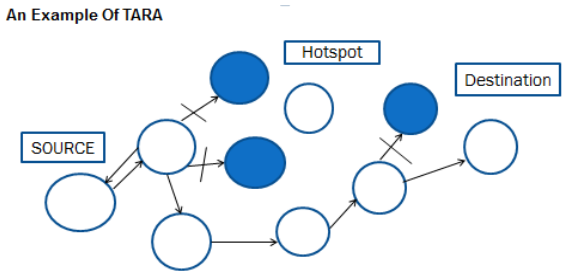


Figure 4. Routing in TARA

Finite-Difference Time-Domain method is used in TARA to measure the temperature of each node and SAR (Specific Absorption Rate) of antenna radiation. Penne bio heat equation is also used for this purpose, which is discussed in [33]. TARA only considers the temperature of node and fined the alternate path. In this way number of transmissions and overall network temperature increased. TARA also increases end-to -end delays and suffered with packet loss ratio, and has low reliability, link probability. End-to-end delay can be minimize by assigning priorities to different packets.

**b. Least Temperature Rise (LTR)**

LTR [21] is designed to minimize the issues that occur in TARA. Its main purpose is to reducing the heat of sensors which are implanted in human body, end-to-end delay and power consumption. It is assumed, that each node is temperature aware about all neighbor nodes. In this protocol, the node with least temperature is selected from source to destination. LTR forwards the packets directly to destination in case when hotspot node do not buffer the packet like in TARA. Each packet contains hop-count information and records the nodes to avoid looping, which is incremented whenever a node forwards it. When a packet exceeds a predefined threshold value or max-hops which depend on the network diameter then it is dropped. Figure 5 shows the LTR routing process.

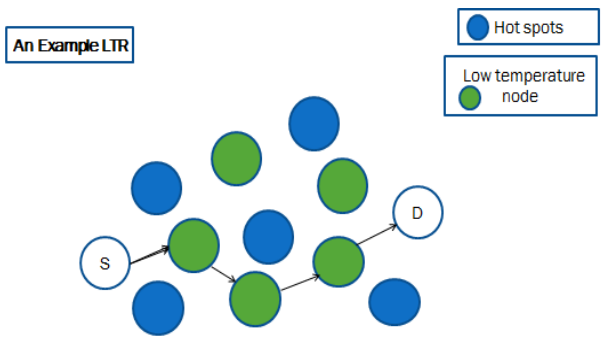


Figure 5. Routing in TARA

**c. Adaptive Least Temperature Routing (ALTR)**

The Adaptive Least Temperature Routing (ALTR) [19] protocol is an improved form of LTR. In ALTR, if hop count is higher than MAX_HOP ADAPTIVE, than Shortest Hop Algorithm (SHR) is used. ALTR uses proactive delay strategy for cooling the temperature of nodes and then follows that path. By using this technique a packet can be delivered by attaining minimum delay instead of packet dropping. ALTR reduces the temperature at node level but use of SHR increases the overall network temperature and delay also increases when it is waiting to cool down the node. Figure 6 shows the ALTR protocol routing process.

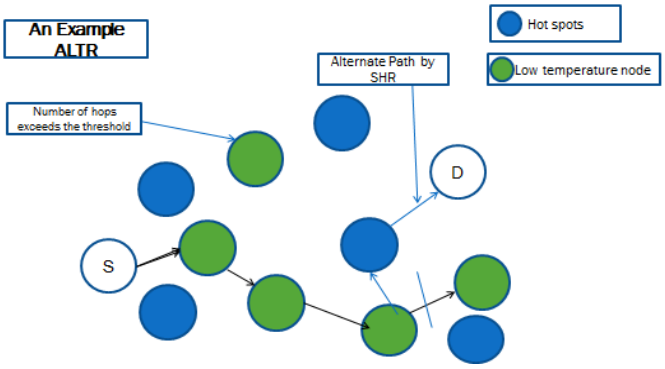


Figure 6. Routing in ALTR

**d. Least Total Route Temperature (LTRT)**

LTRT combines the characteristics of LTR and SHR [22]. LTRT aims to find the node with minimum temperature and to address the problem of redundant hops. Single Source Shortest Path (SSSP) algorithms from graph theory is used to calculate the route with total least temperature. Dijkstra's algorithm is used for transmission. LTRT calculates the temperature of sensors into graph weights. The step by step procedure of LTRT discuss as follows:

1. Transfer weight of the sensor nodes to the weight of outgoing edges which are connected to the node. Then a weight graph comes into existence to calculate all possible nodes from source to destination.
2. Apply SSSP algorithm on the weights graph of the nodes in order to figure out the routes with total least temperature.
3. Periodically update the routes to avoid the excessive temperature rise of the nodes. Figure 7 shows the LTRT protocol process.

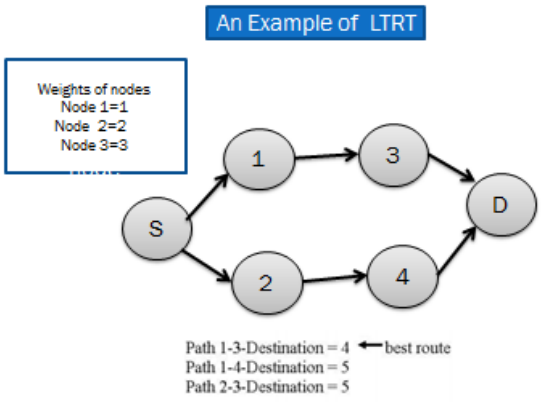


Figure 7. LTRT Protocol Process

**e. Hotspot Preventing Routing (HPR)**

HPR specially designed for delay sensitive data [23]. The sensitive data is related to heart beat and breathing monitoring. HPR is an improved version of LTR and ALTR. The main objective of LTR and ALRT is to find the route with least temperature. These protocols do not focus on delay issues. The main aim of HPR is to minimizing the delay for sensitive data and also prevent the formation of hotspots [24].

There are two phases in HPR: 1. Setup phase, 2. Routing phase. In setup phase, all nodes in the network share initial temperature information and shortest path also built a routing table. In routing phase, packets are routed from shortest path until hotspot nodes are not formed. A hop-count is associative with each packet, which is preventing from looping. If destination node is neighbor node than packet is transferred directly otherwise packet sends to the next hop which is less than threshold temperature. Threshold value is calculated by its own and neighbor average temperature. If the temperature of next node exceeds from threshold value than packet is transferred by coolest node even it has long distance.

**f. Routing Algorithm for Networks of Homogenous and Id-less Biomedical Sensor Nodes (RAIN)**

RAIN is a temperature aware routing protocol to reduce the temperature rise and energy consumption of all nodes [25]. The author described that RAIN contains homogeneous and Id-less nodes and contains temporary ID. These temporary IDs are randomly generated between 1 to 2^16 and ID 0 is reserved for sink node. RAIN also uses an algorithm for prevent a duplicate packet by checking the queue whether it contain a specified packet ID.

This mechanism helps to minimize energy consumption. RAIN contains three phases: setup, routing and status update phase. In routing phase, each packet has unique hop-count [N=node ID, T= Time when packet is generated from source, R= Random number] which prevents it from looping.

In status update phase, the sink node informs all its neighbor nodes, if it receives any data packet by sending the packet's ID to reduce the power consumption of the node.

**g. Thermal-Aware Shortest Hop Routing (TSHR)**

TSHR [26] is a thermal aware routing protocol and enhanced version of HPR. TSHR is specifically designed for reducing the temperature without increasing the power consumption and average delay. The difference between HPR and TSHPR is its usage of two kinds of threshold values. A fixed threshold value that is same for all nodes in the network and a dynamic is specific to all nodes based on the temperature of node and its neighbor node. Fixed threshold value is used for every transmission while dynamic threshold value is used for highlighted the hotspot nodes. TSHR is suitable for high priority applications because it handle retransmission of dropped packets.

**h. A New Energy-Efficient Routing Protocol (M-ATTEMPT)**

M-ATTEMPT is a thermal aware as well as energy efficient routing protocol to reduce the network temperature and delay of critical data [27]. In M-ATTEMPT, the transmission of sensitive data nodes increases their transmission power. Then it directly sends towards the sink node for minimizing the delay. In case of ordinary data, multi-hop communication is used and route with less hop-count is selected, if two or more routes are available. A sink node does not receive any ordinary data until all critical data has received.

M-ATTEMPT defines a threshold to control the rise in temperature and if any node's temperature goes beyond that threshold, it is called hotspot node. These hotspot nodes are not used for transmission because of their high temperature.

M-ATTEMPT works with four phases, these phases are: initialization phase, routing phase, scheduling phase and data transmission phase. In initialization phase, all nodes broadcast the hello packets, and share their temperature information. In routing phase, routes with hop counts are selected for transmission. In scheduling phase, sink node uses Time Division Multiple Access (TDMA) scheme to schedule all root nodes, while in transmission phase these root nodes send their data packets towards sink node.

## 6. Comparison of Temperature Aware Routing Protocols

Table 2 shown the comparison of all aforementioned temperature aware routing protocols on the basis of delay, temperature, and packet delivery ratio and address scheme.

Table 2. Temperature Aware Routing Protocols

| Protocols | Goal | Delay | Temperature Rise | Address Scheme | PDR | Discarding Mechanism |
|---|---|---|---|---|---|---|
| TARA | Reduce possibility of over heating | Very high | Very high | Global | Very low | No |
| LTR | Reduce energy consumption and temperature rise | High | High | Global | Low | Yes |
| ALTR | Reduce end to end delay | Medium | Low | Global | High | No |
| LTRT | Find route with minimum temperature | Low | Very low | Global | Very high | Yes |
| HPR | Prevent formation of hotspot, and reduce end to end delay | Low | Very low | Global | High | Yes |
| RAIN | Reduce temperature rise and average delay | Low | Very low | Local | High | Yes |
| TSHR | Medium | Very low | Low | Very High | No | No |
| M-ATTEMPT | Low | Low | Very low | High | Yes | No |

The first temperature aware routing protocol TARA is designed to address the issue of temperature rise implanted in human body. It performs well to reducing the temperature and load balancing. But in case of temperature rise, it follows the withdrawal strategy. The use of withdrawal strategy increases the end-to-end delay and consumption of transmission power. As compared to TARA, LTR and ALTR work better in terms of reducing temperature rise and end-to-end delay. But these both protocols do not guaranteed for deliver the packets to the correct destination. To overcome the issues of these protocols, LTRT was designed that work better in terms of reducing delay and temperature by using SSSP (single source shortest path) algorithm and graph theory. To handle the delay sensitive data, HPR is used because it ensure to minimize the end-to-end delay [28]. TSHR is modified form of HPR that uses two types of threshold and works better in terms of reducing temperature rise.

All temperature aware routing protocols use global address scheme but RAIN uses local address scheme by using random number generator. M-ATTEMT is thermal routing protocol that works in heterogeneous environment and works efficiently as compared to other routing protocols in terms of increasing packet delivery, temperature rise and energy consumption [29].

## 7. Conclusion

Wireless Body Area Networks (WBANs) are an emerging field that offers wide range of comforts and monitoring applications for early detection of different diseases of patients. Routing the data between sensors and towards the sink is a challenging task due to human body movement and some other specific constraints of body. In WBANs, routing protocols are divided in to five major categories: temperature based, cluster based, cross layer, postural movement and QoSs based routing protocols. In this paper, we only critically analyzed and discussed the temperature aware routing protocols for WBANs. Temperature aware routing protocols consider only temperature rise they do not focus on other routing issues like delay, energy consumption and packet delivery. This review will help the researchers to design an efficient temperature aware routing protocol for WBANs. In future, we will review main requirements and challenges of energy aware routing protocol for WBANs.

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