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A SURVEY ON THERMAL AWARE ROUTING PROTOCOLS IN WBAN

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Abstract: One of the most promising application areas of Wireless Sensor Networks in recent years has been in the field of Bio-medical research. Smart embedded biomedical sensors have the potential to bring a radical change in medical diagnosis. Tiny wireless sensor motes developed using MEMS (Micro Electronic Mechanical Systems) technology can be implanted inside the human body for monitoring different organs. This paper surveys the Wireless Body Area Networks (WBANs) that are designed for applications in healthcare and focuses on the issue of temperature rise in biological bodies due to the use of Radio Frequency (RF) for communication. The paper examines the following: need for WBANs, need for thermal aware routing protocols in WBANs and existing thermal aware routing protocols along with some findings and gaps.

I. INTRODUCTION

The advances in the micro-electronics industry and wireless technology have led to the development of sensors which can be used for accurate monitoring of inaccessible environment. A collection of such sensors form a network that can be used for efficient monitoring of health, environment, industrial automation etc. These sensors use the wireless medium to communicate amongst themselves and with a central node capable of controlling this network. Such networks are called Wireless Sensor Networks. A class of such sensors which are used specifically for Biomedical purposes are called as Medical Biosensors or Wireless Body Area Networks (WBAN) [1]. Body Area Networks (BANs) unlock the door towards anytime, anywhere health plus wellness monitoring. The development of WBANs technology was began around 1995 by taking into consideration wireless personal area network (WPAN) technologies for enabling communications on, near & around the human body. These motes, having radio communication capabilities collect different biometric data like temperature, glucose level, concentration of certain minerals and gases in blood and communicate the data wirelessly to a base station, usually located outside the body through a multihop wireless network. The base station usually has much higher computation capabilities and can analyze the raw data to come up with critical conclusions [2]. WBAN is still in its childhood and a lot of research is continuously going on in this field. The organization of this paper is as follows. In Section II, Wireless Body Area Networks are discussed. Section III explores the need for Thermal Aware Routing Protocols in WBANs and gives an overview of existing Thermal Aware Routing Protocols. Findings and Gaps are also presented. Section IV concludes the paper.

II. WIRELESS BODY AREA NETWORKS

A. Need for WBAN

In almost every developed country the aging population is raising day by day and the costs of health care is also increasing every other day. The proportion of elderly people is likely to double from 10% to 20% over the next 50 years [3]. Also, in the western world, the ratio of workers to retirees is declining. The number of people living alone is rising. These factors have prompted the introduction of an innovative technology driven improvements towards the existing health-care practices. The concept of Wireless Body Area Network (WBAN) was introduced to completely exploit the benefits of wireless sensor technologies in telemedicine and m-health..

B. WBAN

According to the IEEE 802.15 (Task Group 6), "A WBAN is a collection of low-power, miniaturized, invasive/non-invasive lightweight wireless sensor nodes that monitor the human body functions and the surrounding environment".

WBAN devices have typical communications range of up to 5 metres, while the lifetime, processing and data throughput capabilities vary depending on the application. Implantable devices put more challenges to the energy constraint. A battery powered implanted device ideally must have lifetime of 10-15 years, while supporting functionality including sensing, data processing and network management along with giving due consideration to the battery reserves. Additionally, deployment of implanted devices deep inside the body or under the skin impose channel propagation challenges due to the extreme nature of the propagation medium (tissue). BAN standard allows 2-4 networks per m^2. Monitoring applications need a lot of sensors or actuators on the same body area network. BAN standardization group expects a maximum of 256 devices per network [4].

In order to have a reliable wireless communication among sensors, there should be minimum interference. There is a need to protect the transmitted data and also to maintain the integrity of received information. The time delay must be lower than 125ms for the medical applications and for non-medical applications it need not to be more than 250 ms. Jitter must also be controlled. Emergency packets must be assigned higher priority as compared to the other packets in the network, thus enabling different devices to have different data rates.

III. ROUTING IN WBAN

A. Need for Thermal Aware Routing Protocols in WBAN

Wireless Body Area Networks most commonly use Radio Frequency (RF) for communication due to their cheap infrastructure setup and accessibility. These RF waves get induced into the tissue which is exposed to radiation during communication in a biosensor network. This initiates the motion of atomic particles thereby causing heat. Other sources of heat generation in a biosensor network are radiation from the Sensor Node's Antenna and Power dissipation by sensor node circuitry [2]. A high temperature of the embedded nodes for a very long time might damage the surrounding tissues. The heat produced by the sensor nodes might also encourage the growth of certain bacteria that would otherwise be absent and have a subtle effect on the enzymatic reactions inside the body [5]. So the communication protocols must aim at reducing the temperature rise of the nodes in the in-vivo sensor network [8].

B. Thermal Aware Routing Protocols

Routing in wireless sensor networks has been a well studied problem. Most of the routing protocols in wireless sensor networks are designed to be energy efficient. Since they are not designed for Medical Biosensors, they do not consider the possibility of restricting the communication of the sensor nodes due to the excessive generation of communicating waves. The wireless sensor nodes used in WBASNs are tiny, light-weight and limited power sources. These sensor nodes have different levels of energy and generate different size of data while the Wireless sensor Networks. (WSNs) nodes almost have same level of energy and data rate. Thus, employing routing algorithm of WSN cannot support WBANs sensor nodes. The selection of WBANs routing algorithms should support the heterogeneous sensors network. All these routing protocols that are designed for wireless sensor networks are not feasible for medical biosensor network. Also, these medical biosensors are used in critical applications such as organ monitoring and prosthesis; the communication should not only be hazard free but also be in real time [1]. Communication radiation and power dissipation of the implanted sensor nodes can cause serious health hazards [5-6], [10].

To avoid the heat generation, basically some thermal aware routing algorithms were proposed for temperature scheduling in an implanted sensor network: Thermal Aware Routing Algorithm (TARA), Least Temperature Routing (LTR) protocol, and Adaptive Least Temperature Routing (ALTR) protocol, Hotspot Prevention Algorithm (HPR), Thermal Aware Shortest Hop Routing Algorithm (TSHR), Least Total Route temperature (LTRT), Lightweight Rendezvous Routing (LR). In this section, various thermal aware routing algorithms are introduced.

TARA [11] was an early approach on thermal aware routing for an implanted sensor network. It is a routing

Protocol that sends packet by following a withdrawal strategy. It defines a hotspot region that is above a threshold value of temperature. When a node sends a packet to a hotspot, it withdraws the packet from it and the packet is sent back to the sender. After the cooling period, the packet is sent again to destination. The protocol does not consider the shortest path, just only withdraws packet from hotspot.

In LTR [12], packet is sent to next node if it is destination. Packet is generally sent to the node that has the least temperature. If the number of hops increases above a threshold value, the packet is discarded. If the next node is already visited then the second minimum temperature node is selected for packet transmission.

ALTR[12] is an advancement of LTR. Packet is sent to the least temperature node but if the number of hops is increased above threshold value, Shortest Hop Routing (SHR) is followed in packet transmission. Hotspot Prevention Algorithm (HPR) [9] uses shortest hop routing algorithm for sending packet to the destination which does not have any hotspot. If the next hop is the destination, packet is sent to it. If the next hop has temperature below a threshold, packet is sent to it. But if the next hop is above a threshold temperature, it is assumed that there is a hotspot there. Then packet is forwarded to the coolest neighbor that is not yet visited. The problem with the HPR is that temperature information has to be propagated to other nodes and it is a huge overhead.

The Thermal Aware Shortest Hop Routing Algorithm (TSHR) [13] has been presented for the application where there is a high priority for delivering a packet to the destination, and if the packet is dropped, it is retransmitted.

LTRT [14] has tried to solve the problems involved in previous algorithms. It tries to send packet through a path which creates the least temperature from the source to destination. The algorithm uses Dijkstra algorithm to determine the shortest path from the source to destination. It avoids hotspot formation and redundant multi-hops. The problem with the algorithm is that temperature information is to be propagated to every node with a regular interval. After the shortest path is created, the function of temperature schedule is established. Maintaining Dijkstra algorithm is a huge overhead for an implanted sensor network.

Limitations of earlier thermal aware routing algorithms resulted in LR (Lightweight Rendezvous Routing) Algorithm [15], a lightweight event based approach to schedule temperature in an implanted sensor network. With this algorithm, nodes are divided into small clusters. In each cluster, nodes are subscribed to temperature increasing event. By performing services (temperature or blood pressure sense etc), when a node's temperature is increased above a threshold value, it stops that service. It also immediately contacts corresponding subscriber (through broker) to start that service.

Table 1: Comparison of existing thermal aware routing protocols

Reference	**Year**	**Simulation**	**Topology**	**Performance Evaluation**	**Comparison with other protocols**	**Application**
Tang et al.	2005	MatLab	2-D area with 12 nodes implanted	Maximum temperature Rise Average temperature Rise Average delay Percentage of packets meeting deadline	SHR protocol	--NA--
A. Bag et al.	2006	C	4X4 mesh topology 50 connected nodes	Average temperature rise Average delay in packet delivery Average power consumption of sensor nodes Total number of packets dropped in the network Lifetime of network	SHR and TARA	Delay sensitive applications
A. Bag et al.	2007	C	4X4 mesh torus topology 100 densely connected nodes	Maximum temperature Rise of any node Average packet delivery delay in a network Total number of packets dropped	SHR and TARA	Remote cardiac patient monitoring
Takahashi et al.	2008	Java	5 X 10 Mesh topology	Average temperature rise Average delay of arrival packets Percentage of lost packets Lifetime	LTR and ALTR	--NA--
Tabandeh et al.	2009	C++	4X6 mesh torus 100 connected nodes	Maximum rise in temperature Average delay Lifetime	SHR, TARA, LTR, HPR, TSHR	High priority traffic
Rossi Kamal et al.	2011	Java	10 nodes are deployed in 6X6 topology	Maximum temperature Rise of any node Dissipated Energy on different nodes	TARA, LTR, ALTR, HPR, LTRT	Joint operation of cancer hyperthermia, radio-therapy and chemo-therapy

C. Findings and Gaps

Initial study has been carried out on understanding the various issues related to biosensor networks. From the literature survey, it is clear that most of the existing thermal aware routing algorithms for implanted sensor nodes suffer from problems like hotspot creation, packet delivery delay, maximum hop or computational complexity. There is a need of an efficient routing algorithm that takes into account the parameters and issues of healthcare applications into consideration. A state of the art comparison is performed for the various existing thermal aware routing protocols as shown in Table 1. It was also observed that lesser attention is given to increasing the lifetime of a network. The definition of lifetime depends on the underlying network application [16]. Therefore, more optimal solutions or alternatives need to be designed for obtaining the optimal operating policy for the network while the constraint on the maximum safe temperature level is not exceeded. The solution needs to be fault tolerant due to usage in critical applications. The biosensor nodes should be adaptable to other nodes failures or temporary shutdowns. Some nodes may be inaccessible due to the high amount of residual heat surrounding it or some failure, the protocol needs to be designed to route the data around such inoperable nodes as those nodes cannot be attended often due to their placement in the body.

There should be lesser control messages network and continuous monitoring is required. There is a need for an energy efficient algorithm that takes into account the real time applications into consideration.

IV. CONCLUSION

Wireless Body Area Networks (WBAN) is a promising technology which can revolutionize next generation healthcare. In this paper, we discussed the need for wireless body area networks and the thermal management problem related to the area. We also presented some existing thermal aware routing protocols proposed to avoid the heat generation in the tissues. A comparison of various thermal aware routing protocols is also given and various gaps in the literature are highlighted. For WBANs to have wide acceptability there are several issues that need to be addressed. Engineers, researchers and practitioners from multiple disciplines must come together and strive hard to overcome technical roadblocks in order to bring the vision of ubiquitous healthcare network to reality.

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