A Lightweight Temperature Scheduling Routing Algorithm for an Implanted Sensor Network

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***Abstract*—Modern diagnosis system has been evolved to equip human being with advanced health-service. In vivo sensors have come up to contribute in this field with its support in miniature, complex operation as implanted in a human body. Implanted sensor solutions like artificial retina, pacemaker and implanted cardioverter defibrillators, insulin pump, glucose monitor- are remarkable inventions in medical science. But, these implanted sensor nodes exhibit temperature at packet transmission or processing time that can be dangerous for surrounding human tissues. With the advancement of wireless communication and sensor network technology, thermal aware routing algorithms have been proposed for this type of sensor network. But, these algorithms suffer from disadvantages like hotspot creation, computational complexity overhead or redundant hop traversal etc. We also have to consider energy constraints like limited battery life of this miniature form of sensor nodes. We have tried to solve these problems with lightweight event-based communication (publish-subscribe system) in this type of sensor network. We have proposed a lightweight temperature scheduling routing algorithm for this implanted sensor network. Proposed routing protocol is considered to schedule temperature in implanted sensor nodes deployed in the joint operation of cancer hyperthermia, radio-therapy and chemo-therapy.**

Fig. 1. Implanted Sensor Network

I. INTRODUCTION

Body sensor networks [1] have the potential to change the medical diagnosis system [2][3][4][5]. One example of it is smart implanted sensor node that is deployed in artificial retina, glucose monitoring, insulin pumps, blood pressure monitoring etc [6][7][8][9] (Fig. 1) . Implanted sensor nodes generate temperature when they transmit or process packets [6]. In long term monitoring, these generated heat can be very harmful for patients. Also, these nodes are powered by battery which is recharged by IR (infrared ray). The more the IR is exhibited; human tissue becomes sensitive for bacterial attack. Existing thermal aware routing algorithms[10][11][8][12][7] for implanted sensor nodes suffer from problems like hotspot creation, packet delivery delay, maximum hop or computational complexity. Existing communication protocols for sensor network (for example: directed diffusion [13],omniscient multicast or flooding techniques [14] [15]) are not also applicable to this type of network [16] [17].

We have proposed a lightweight rendezvous algorithm (LR) [section 3] 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. In our example scenario, LR schedules temperature for in-vivo sensor nodes deployed for the joint operation of hyperthermia, radiotherapy and chemotherapy in cancer treatment [18].

II. MOTIVATION FOR LIGHTWEIGHT TEMPERATURE SCHEDULING ROUTING FOR AN IMPLANTED SENSOR NETWORKS

With the advancement of smart implanted sensor nodes and wireless technology, communication protocols have also been proposed for temperature scheduling in an implanted sensor network. These protocols namely thermal aware routing algorithms suffer from limitations like hotspot creation, complexity overhead or event maximum hot traversal etc. These limitations motivated us toward an alternative solution- a lightweight event based approach to schedule temperature in an implanted sensor network.. TARA [10] was an early approach on thermal aware routing for implanted a sensor network. It is a routing protocol that sends packet by following a withdrawal strategy. If defines a hotspot region that is above a threshold value of temperature. When a node sends a packet to a hotspot, it withdraws from it and the packet is 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[11], 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[11] is an advancement of LTR. Packet is sent to the least temperature node but if the number of hops is increased above threshold value, SHR is followed in packet transmission. HPR 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 [7] is that temperature information has to be propagated to other nodes and it is a huge overhead. LTRT [12] 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 Djsktra algorithm is a huge overhead for an implanted sensor network

Limitations of these thermal aware routing algorithms have inspired us for LR, (Lightweight Rendezvous Routing), a lightweight event based approach to schedule temperature in an implanted sensor network.

III. Proposed Lightweight Temperature Scheduling Routing Algorithm

A. Proposed Algorithm

In existing rendezvous routing algorithm [19], subscription or publish message has to encounter all broker nodes in its way to gateway node.

But, in proposed Lightweight Temperature Scheduling Routing Algorithm (LR), body sensor nodes are divided into some small clusters (Fig. 2, 3). A rendezvous node has the cluster information and publisher, subscriber or broker role of each node in any cluster. Each cluster has a single broker node and some subscriber and publisher nodes.

At first, rendezvous node notifies body sensor nodes about their cluster information and subscriber, publisher and broker role to each body sensor node (Phase 1). Then, with lightweight subscription algorithm (Fig. 2)(Phase. 2) (algorithm 2), in each cluster, subscriber nodes subscribe to a broker node. The broker node then sends subscription confirmation message (list of successfully subscribed nodes) to the rendezvous node. The rendezvous node then checks whether in each cluster if every subscriber is successfully subscribed

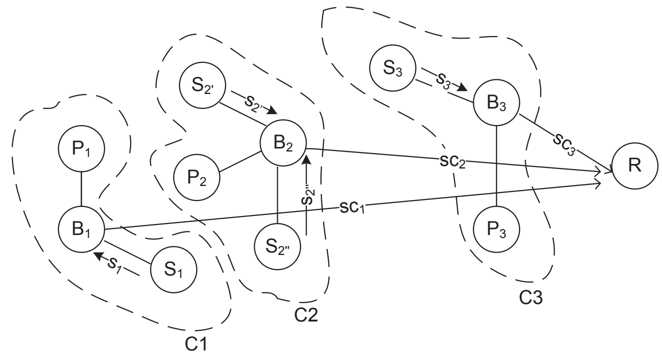

Fig. 2. Lightweight subscription is working on body sensor nodes those are divided into three clusters C_1, C_2 and C_3. In C_2, subscriber S_2', S_2'' send subscription message s_2', s_2'' respectively to the broker B_2. B_2 then sends subscription confirmation message (sc_2.) to rendezvous node R. Same operation goes for the clusters C_1 and C_3.

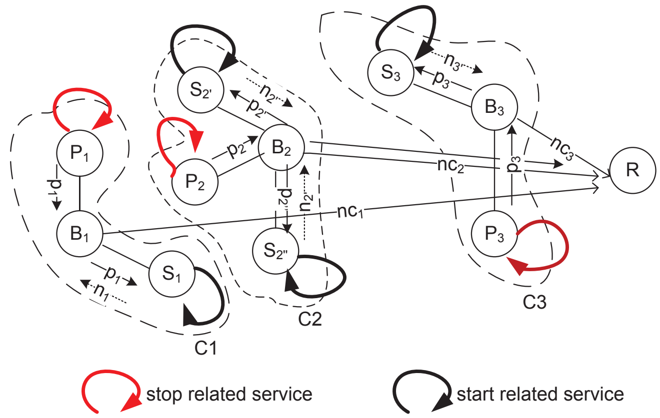

Fig. 3. Lightweight publish is working on body sensor nodes those are divided into three clusters C_1, C_2 and C_3. In C_2, when the event occurs, publisher P_2 stops related service and sends notification message (p_2) to the broker B_2. B_2 then forwards notification(p_2) to subscribers S_2' and S_2''. S_2' and S_2'' start related services immediately. Then they send confirmations (n_2' and n_2'') respectively to the broker B_2. B_2 then sends notification confirmation (nc_2) to the rendezvous node R. Same operation goes for the clusters C_1 and C_3.

(Phase 3). If not (due to packet loss from subscriber to broker or broker to rendezvous node), rendezvous node waits for the event to occur. When that event occurs, services on subscribers and publishers are started and sopped respectively.

At lightweight publish (Fig. 3) (Phase 4), in each cluster, when an event occurs, the publisher stops related service and then sends notification message to broker and broker then forwards it to subscribers. Subscribers immediately start related service and immediately notify the broker. The broker also sends notification confirmation to the rendezvous node. The rendezvous node then checks for each cluster whether all the subscribers are successfully notified (Phase 5). If not notified (packet loss from publisher to broker or from broker to subscriber or from broker to rendezvous node), the rendezvous node directly communicates with subscribers and publisher to start (if not started) and stop (if not stopped) their service immediately.

We assume that, implanted sensor nodes are divided into some clusters (C). Nodes of each cluster can have roles as publisher (P), subscriber (S) or broker (B). A rendezvous node (R) has the information regarding cluster formation and roles of cluster nodes.

IV. Performance Evaluation

A. Problem Scenario

In cancer treatment, joint operation of hyperthermia, radiotherapy and chemotherapy has become the most prominent. It depends on the temperature generated on human cells. If the temperature is below a threshold temperature, hyperthermia enhances performance of radio-therapy and chemo-therapy. But, if it is above the threshold, human cells become sensitive and it becomes dangerous to human health. We are considering implanted sensor nodes reflecting temperature scheduling in joint operation of cancer hyperthermia, radiotherapy and chemotherapy. If the temperature of a node (publisher) is increased above threshold, it will communicate broker node to disseminate temperature to subscriber node or nodes. If the temperature dissipation is not performed successfully, remote gateway node should be notified by broker node. The more the temperature is generated, the more battery power is exhibited. To extend the battery life of in-vivo sensors, energy reduction is important.

B. Simulation Results

We have performed our extensive simulation in a Java program. A set of 10 nodes are deployed in 6*6 topology. We assume that 1 and 2 unit of temperature is generated for a node's packet transmission with other node or gateway respectively.

Fig 4(a) shows total temperature among all nodes deployed in proposed LR and RR. In all cases, LR generates less temperature than RR. When, node orientation has 3 publishers, 4 subscribers and 3 brokers, LR generates the least temperature. In Fig. 4(b), 3 broker nodes of LR generate much less temperature than those of RR. Because, in LR, 3 broker nodes communicate with the rendezvous node directly. But, in RR, a broker node communicates other broker nodes on its way to rendezvous node.

Fig. 5 represents the comparison of dissipated energy on different nodes using flooding, omniscient multicast, directed diffusion and LR. In flooding scheme, sources (placed at low and top position of the square) flood all events to every node in the network. The nodes placed at the middle of the square dissipate higher energy because there is relatively higher packet transmission in that area. In omniscient multicast, each source generates shortest path multicast tree to al sinks. All multicast trees use a common interim node to make the shortest path. So, energy dissipation is huge on that node. In, directed diffusion, energy dissipation is low comparing to flooding and multicast. Interests are propagated from sources to sinks (placed at middle positions) using interim nodes (brokers) and events are propagated in the reverse path. In LR, energy dissipation is relatively very small comparing to previous three protocols.

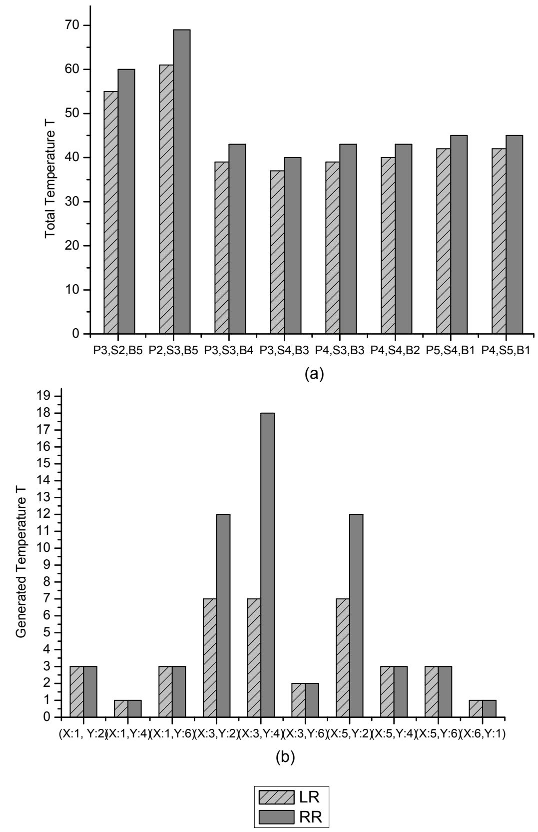

Fig. 4. Using LR and RR (a) Total temperature in different node orientations (b)Generated temperature on different nodes (with 3 publishers, 4 subscribers and 3 brokers)

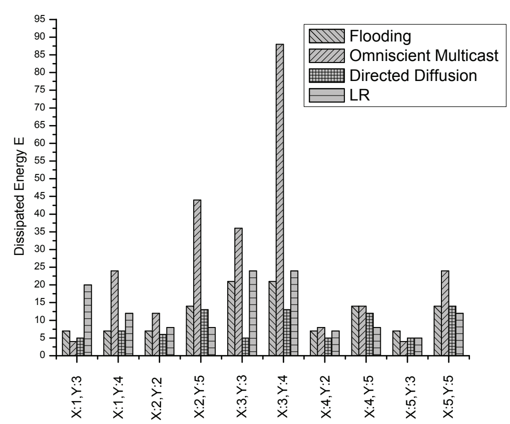

Fig. 5. Comparison of LR with flooding, omniscient multicast, directed diffusion in terms of energy dissipation

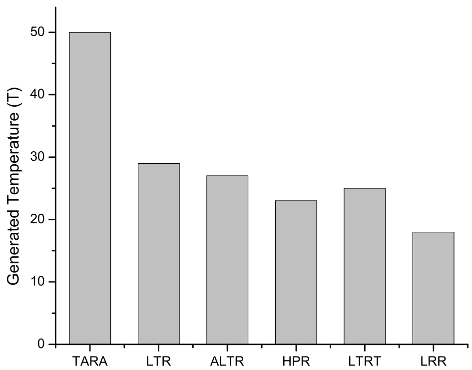

Fig. 6. Performance comparison of LR with TARA, LTR, ALTR, HPR and LTRT. LR generates less amount of temperature than other protocols. TARA generates the maximum temperature, ALTR is better than LTR for the use of hop count threshold. HPR is better than LTR, ALTR or LTRT but LR provides the least temperature.

Nodes are divided into three clusters and lightweight publish-subscribe mechanism is in action separately in three clusters. As brokers are involved in communication with rendezvous node, energy dissipation is comparably higher in those broker nodes than other nodes.

Fig. 6 describes how LR works the better than existing thermal aware routing algorithms. We assume that 10 nodes are deployed in a 6*6 mesh topology. LR generates less amount of temperature than other protocols. TARA generates the maximum temperature, ALTR is better than LTR for the use of hop count threshold. HPR is better than LTR, ALTR or LTRT but LR provides the least temperature. We consider one unit of temperature is generated for every packet transmission (send or receive) among nodes. When a node sends or receives from a gateway node, it generates 2 unit of temperature. If a node's surrounding temperature is above 7 unit, it is assumed to be in hotspot region. We assume 10 hops as max hop count for LTR and ALTR. Threshold temperature of LTRT is assumed to be 6 units. TARA generates the maximum temperature as it tries to move away packets away from hotspots and traverses more multi-hops. LTR and ALTR provide better performance than TARA by choosing the least temperature node. But, ALTR is better than LTR because when 10 hops are crossed, shortest hop routing algorithm works. HPR is far better than previous three by choosing the shortest hop with temperature parameter. LTRT is also better than TARA, LTR or ALTR but worse than HPR. LR is better than all other by creating 3 small clusters with publish-subscribe systems.

V. Conclusion

In this paper, we have proposed a lightweight temperature scheduling routing algorithm for an implanted sensor network. We have considered our proposed algorithm in a scenario of the joint operation of hyperthermia, radio-therapy and chemotherapy in cancer treatment.. In future, we will consider large experimental set, node-orientation and mobility, connected coverage in our work.

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Algorithm 1 Lightweight Temperature Scheduling Routing Algorithm

Phase 1: Installation at Rendezvous Node
for all i such that $0 \leq i \leq C$ **do**
    for all j such that $0 \leq j \leq S$ **do**
        Send cluster information and subscriber role to node j
    end for
    for all j such that $0 \leq j \leq P$ **do**
        Send cluster information and publisher role to node j
    end for
    Send cluster information and broker role to a node.
end for
Phase 2: Lightweight Subscription
for all i such that $0 \leq i \leq S$ **do**
    Subscribe i to the broker with event in that cluster
end for
Broker sends subcription confirmation to rendezvous node R
Phase 3: Post Subscription at Rendezvous Node
for all i such that $0 \leq i \leq C$ **do**
    for all j such that $0 \leq j \leq S$ **do**
        if Subscription confirmation is not found for subscriber j **then**
            When corresponding event occurs
            start related service of subscriber j and
            stop related service of corresponding publisher P.
        end if
    end for
end for
Phase 4: Lightweight Publish
for all i such that $0 \leq i \leq P$ **do**
    Stop related service
    Publish event from publisher i to broker B
end for
for all j such that $0 \leq j \leq S$ **do**
    Forward notification from broker to subscriber j
end for
for all k such that $0 \leq k \leq S$ **do**
    Start related service.
    Forward confirmation from subscriber k to broker
end for
Send notification confirmation to rendezvous node R
Phase 5: Post Notification at Rendezvous Node
for all i such that $0 \leq i \leq C$ **do**
    for all j such that $0 \leq j \leq S$ **do**
        if Notification confirmation is not found for subscriber j **then**
            start service of subscriber j (if not started yet) and
            stop service of corresponding publisher (if not stopped yet).
        end if
    end for
end for