Towards Evolutionary Approach for Thermal Aware In Vivo Sensor Networks

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Abstract

Wireless sensor networks have taken immense interest in healthcare systems in recent years. One example of it is in an in vivo sensor that is deployed in critical and sensitive healthcare applications like artificial retina, cardiac pacemaker, drug delivery, blood pressure, internal heat calculation, glucose-monitoring etc. In vivo sensor nodes exhibit temperature that may be very dangerous for human tissues. However, existing in vivo thermal aware routing approaches suffer from hotspot creation, delay, and computational complexity. These limitations motivate us toward an in vivo virtual backbone ,a small subset of nodes, connected to all other nodes and involved in routing of all nodes, -based solution. A virtual backbone is lightweight and its fault-tolerant version allows in vivo sensor nodes to disconnect hotspot paths and to use alternative paths. We have formulated the problem as m-connected k-dominating set problem with minimum temperature cost in in vivo sensor network. This is a combinatorial optimization problem and we have been motivated to use evolutionary approach to solve the problem.

1. Introduction [1]

Wireless sensor network has expanded its supremacy in healthcare. In vivo sensor nodes are taking increasing interest from clinicians and surgeons of healthcare systems. Body sensor nodes [1] those are deployed in side human body and left there for long term monitoring are called in vivo sensor nodes. In vivo sensor nodes provide more accurate information, patient comfort and it is non-invasive. Therefore, since last decade in vivo sensors have been widely used in critical and sensitive healthcare applications like internal heat, cardiac pacemaker, artificial retina, blood pressure, cancer bio-market etc [1]-[4].

In-vivo sensor nodes generate temperature because of induced electro- magnetic field and power dissipation. This temperature can be harmful for biological tissues in a long term monitoring system. Thermal aware routing algorithms namely TARA[2], LTR[3], ALTR[3], LTRT[3], HPR[4] have been proposed to deal with the problem. However, these proposals suffer from problems like hotspot creation, redundant hop, maximum delay or computational complexity. These motivate us toward a lightweight, fault tolerant solution- fault tolerant virtual backbone with minimum routing cost (temperature) for in vivo sensor networks.

This is m-connected k-dominating set problem with minimum routing cost constraint. This is a combinatorial optimization problem and the problem is NP-complete.

Evolutionary computing [5] is emerging as a better approach to find approximation bound for a combinatorial optimization problem. Therefore, we are motivated to solve m-connected k-dominating set with minimum routing cost in in vivo sensors with genetic algorithm (example of evolutionary computing algorithm).

Existing approaches to solve m-connected k-dominating set with minimum routing cost problem tend to be local optimal. On the other hand, genetic algorithm can search globally. Genetic algorithm can provide robustness to fault-tolerant in vivo sensor nodes.

Therefore, our contribution in the paper is as follows (a) Discussion on limitations of in vivo thermal aware routing algorithms, (b) Explanation about why and how evolutionary computing approach can contribute to solve the problem.

2 Limitations of In Vivo Thermal Aware Approaches

[1] 본연구는방송통신위원회의차세대통신네트워크원천기술개발사업의 연구결과로수행되었음 (KCA-2011-08913-05002). Dr. CS Hong is the corresponding author.

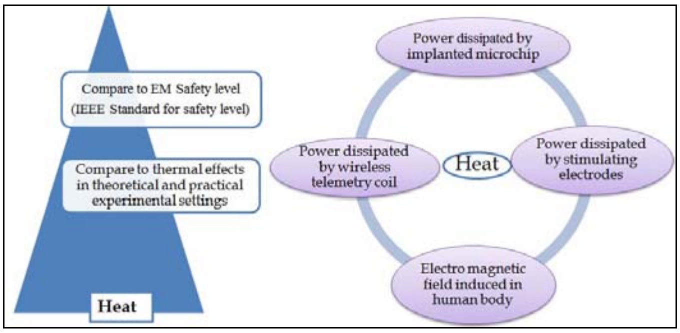

Figure 1: Heat is generated in in vivo sensor nodes for different reasons and generated heat is compared with IEEE standard for EM safety level.

Implanted biomedical sensors may effect on surrounding human tissues (Fig. 1). In vivo sensor nodes transmit data to neighboring sensor nodes and heat caused by the transmission and processing will appear in surrounding tissues. In case of long term monitoring, these generated heat can be very harmful. Heat may also have an effect in enzymatic reactions inside human body. Also, these nodes are powered by battery which is recharged by infrared ray (IR). The more the IR is exhibited, human tissue become sensitive for bacterial attack.

Existing communication protocols for wireless sensor network might not be applicable for an implanted sensor network. This type of network has to deal with some additional constraints like low power, limited computation, material constraints, continuous operations, robustness and fault tolerance, scalability, security, interference, regulatory requirements.

TARA 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, 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 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 is that temperature information has to be propagated to other nodes and it is a huge overhead. LTRT 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.

3. Problem Formulation

A virtual backbone (VB) is a subset of nodes in a sensor network. All other nodes are connected to VB and graph induced by these nodes is also connected. Only VB nodes are responsible for routing in this type of network.

So, once a VB is established, it is very easy to deploy any conventional routing protocol in that network. As the number of nodes involved in routing is reduced, less interference, collision occurs in the network. Connected dominating sets (CDSs) are frequently used to construct the minimum VB in a wireless network. A connected dominating set (CDS) of a graph G is a subset D such that every node in G is either in D or adjacent to a node in D and the graph induced by D is connected. Nodes of D and G-D are called dominator and dominate respectively in a VB. Fault-tolerance is very important for in vivo VB nodes. Because, they carry the routing information of other in vivo nodes. In an implanted sensor network, in vivo nodes may create a hotspot by continual operation for a long time. Therefore, to avoid hotspot, VB nodes can be frequently changed. However, data or link loss is a common feature for undefined physiological reasons. Therefore, to make VB nodes more resilient to volatile wireless network, fault tolerant VBs are very important in implanted sensor network. m-connected k-dominating sets are general representation of fault tolerant VBs. m-connected ensures that there are at least m different paths between any pair of dominators in a VB. K-dominating ensures that every dominate is connected to at least k dominators. Therefore, if we have a VB (constructed with m-connected k-dominating set), it is fault tolerant up-to m-1 disconnections of dominators and k-1 disconnections between a dominator and a dominate in vivo sensor nodes.

4. Why and How Evolutionary Computing Can Contribute?

In this section, we have formulated the fault tolerant virtual backbone with minimum temperature problem (m-connected k-dominating set with minimum routing cost problem) as a combinatorial optimization problem. Therefore, we have discussed why and how evolutionary computing can contribute to solve the problem.

Definition: m-connected k-dominating set in unit disk graph with guaranteed routing is a combinatorial optimization problem

Given a unit disk graph G (V, E) and two positive integers m, k.

Find a subset D *of* V (G) such that (a) each vertex v (V(G)-D) is k-dominated by at least one vertex in D such that (b)guaranteed routing is maintained (c)D is m-connected.

Every set satisfying (a), (b) and (b) are m-connected k-dominating set with minimum routing cost.

The m-connected k-dominating set problem is NP-complete. Many of existing solutions have the dis-advantage of being local optimal. Therefore, we are motivated to use evolutionary approach because of its global search ability. Evolutionary computing algorithms can handle multiple objectives (m-connected, k-dominating properties and minimum routing cost) present in problem definition. Evolutionary approach can adapt to changing environment and therefore, is robust. It is very significant in vivo sensor network because for continuous operation, hotspot may create and many routing path is to be ignored. Therefore, evolutionary approach is necessary for fault tolerant virtual backbones for in vivo sensor networks.

Genetic algorithm is an evolutionary approach to find the approximation bound for any combinatorial optimization problem. We have considered genetic algorithm to solve m-connected k-dominating set with minimum routing cost (a combinatorial optimization problem). Therefore, we have to consider Population Size, Mutation Probability, Cross-over Probability and Generation Count Parameters required for Genetic Algorithm. The parameters are formulated from information of node-orientation, temperature generation etc.

At the beginning, (a) we have to generate random population of chromosomes. (b) Then, we calculate the fitness function and sort individuals (Fitness). (c) New populations are created with mutations and crossovers are applied to current population to formulate new population. (New Population)(d) The best individual is selected and applied to current virtual with in vivo sensors (Elitism). Loop in (b)-(d) continues until termination criteria are reached.

5. References

[1] H. Cao, V. Leung, C. Chow, and H. Chan, "Enabling technologies for wireless body area networks: A survey and outlook," Communications Magazine, IEEE, vol. 47, no. 12, pp. 84 –93, dec. 2009

[2] Q. Tang and N. Tummala, "Thermal-aware routing algorithm for implanted sensor networks," in In Proceedings of IEEE DCOSS 2005, LNCS 3560, 2005, pp. 206–217.

[3] A. Bag and M. A. Bassiouni, "Hotspot preventing routing algorithm for delay-sensitive applications of in vivo biomedical sensor networks," in Inf. Fusion, vol. 9, july. 2008.

[4] D. Takahashi, Y. Xiao, and F. Hu, "Ltrt: Least total-route temperature routing for embedded biomedical sensor networks," in Global Telecommunications Conference, 2007. GLOBECOM '07. IEEE, nov. 2007, pp. 641 –645.

[5]David B. Fogel, Evolutionary Computation: Toward a New Philosophy of Machine Intelligence, Third Edition, 2006