July 2013. Vol. 4, No. 1 ISSN2305-8269

International Journal of Engineering and Applied Sciences

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ENERGY EFFICIENT FUZZY ROUTING PROTOCOL IN WIRELESS BODY AREA NETWORKS

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Abstract:

To prolong the lifetime of a wireless body area sensor network (WBAN) is the most important concern in due to limited battery power of sensor nodes. Routing in WBAN is a very challenging problem due to the efficient utilization of energy. This paper focuses on energy efficient fuzzy routing protocol. Protocol based on fuzzy inference system computation reduces power consumption when compared to classical routing protocol. This fuzzy approach is soft and tunable and hence it can accommodate wireless body area sensor network comprising of different types of sensor nodes having different energy QoS metrics.

Keywords: *Routing ; Energy consumption; Fuzzy Inference; Quality of Service(QoS),*

1. Introduction

Wireless body area networks (WBAN) applications have emerged as one of the hottest research areas of wireless sensor networks (WSN). WBAN has the potential to greatly impact many aspects of medical care. A WBAN provides long term health monitoring of patients under natural physiological states without constraining their normal activities. It can be used to develop the smart and affordable health care systems. Routing is one of these systems in which attempts for efficient utilization of energy have been made. Routing protocols in WSN where the network comprises hundreds to thousands of nodes and great distances are covered. The exponentially increasing complexity with the number of nodes and the need to exchange large volumes of link-state information make such algorithms prohibitive. Unlike WSN, a common network architecture used in WBAN is a star-topology, where the central node gathers and records the sensing information around the human body, which can be further communications between on-body and off-body gateways. An integrated network architectures for WBAN and WSN application scenario has been shown in Fig-1. Typical application scenarios could be use of an on-body gateway. Sensor networks are being researched and deployed for monitoring of heart beats, body temperature, body positions, and location of the subject. An off-body gateway relieves the need to maintain the on-body gateways of multiple patients (e.g. service schedules, etc.), overall monitoring of healthcare patients, where the off-body gateway can be easily integrated with other information services and hardware.

Due to the direct relationship with WBAN sensors and BANs, the design of routing protocol between both of gateways intra-BAN communications is critical. Hence, implementing a global routing algorithm would require periodically gathering link-state information from nodes to gateway, optimizing all the routing paths at the gateway and sending routing protocols from gateway to all nodes. A successful WBAN design must have several unique features, which lead to a combination of interesting technical issues not found in other wireless sensor networks. WBAN mainly deployed to permanently monitor human physiological parameters must satisfy far more stringent Quality of Service (QoS) demands than those of other existing wireless sensor networks.

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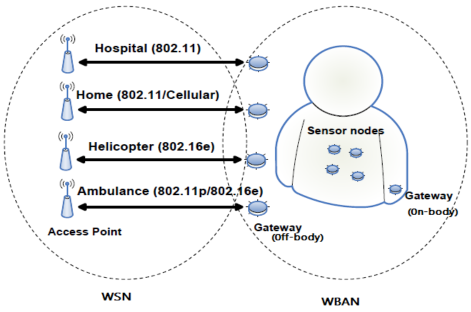

Figure 1. WSN and WBAN networks system

Among the various QoS approaches that have been proposed in literature for minimizing the energy usage between WSN and WBAN, energy efficiency routing attempts to extend the life of a WSN at network layer. Depending on how source finds a route to the destination, routing protocols in sensor networks could be either proactive or reactive. In proactive routing, routes are computed before they are needed; on the other hand a reactive routing calculates the route only when it is needed. The design constituent of the routing protocol depends mainly on the application because of the application's traffic demand and pattern may vary enormously. Power consumption and related QoS are the other most significant issues in designing routing protocols between WSN and WBAN.

Today's main challenge for the designers and developers of protocols and applications for WSN is the resource scarcity of nodes, most importantly its power availability, since in sensor networks the battery life is considered as the network life. To extend the WBAN lifetime, we utilize the fuzzy inference system (FIS) that optimizes the routing path (depending on the QoS metrics: traffic load energy, residual energy, rate of energy consumption and link cost etc.) in a distributed fashion. The remaining paper is organized as follows. Section 2, describes some related works considers the WBAN routing QoS metrics. Section 3 states the proposed fuzzy routing protocol. In section 4, we present our simulation results and finally in Section 5, the key conclusions and the future works are stated.

2. Related work

Energy efficient routes can be computed using either the minimum energy path, maximum residual energy path, path with minimum number of hops to sink etc. Sensors along paths with minimized energy link cost are repeatedly used and deplete their energy quickly, resulting in short network lifetime. Therefore, most existing routing protocols consider the lifetime of a sensor node as being dependent only on the energy resources of the node, i.e. a node is assumed to only fail when the battery is depleted. Several routing protocols have been proposed to minimize the energy consumption in order to prolong the network lifetime. Most of the proposed routing protocols uses shortest single path for data transmission. With continuously using shortest path will deplete nodes energy at a much faster rate than the other path nodes. As a result nodes in theses path will die much faster and causes network partition. Well known routing protocols such as LEACH [1], Maximum Lifetime Energy Routing [2], and Maximum Lifetime Data Gathering [3], all focus on energy as the primary objective to making routing decisions. In [4], the problem of maximizing network lifetime by energy efficient routing has been formulated as integer programming problem. Lindsey *et al.* [5] have presented an energy efficient routing protocol that keeps a set of minimal energy paths and randomly selects one of these sub-optimal paths, thereby significantly increasing the network lifetime. An energy-aware routing algorithm for cluster-based wireless sensor networks have been proposed in which a cost function is defined between two sensor nodes in terms of energy conservation, delay optimization and other QoS metrics.

From the aforementioned literatures we find some very simple QoS metrics to lengthen the lifetime of the sensor networks. These include:

- Traffic load distribution: In case, concentration of events in some particular areas is more than that of other areas, using shortest path will cause implosion along the path, so uniform distribution of traffic is needed.
- Shortest path: Shortest path from the sender to receiver is the straight line connecting the nodes. Forwarding packets along this line is more efficient than a detour.
- Small multiple hops: As the energy consumed for the transmission is proportional to the square of the distance from sender to receiver, multiple short hops is preferable instead of a single large hop.

This paper presents a solution that optimizes the routing path according to all the above mentioned QoS metrics by a fuzzy routing.

3. Proposed Fuzzy Routing Protocol

The proposed protocol assumes that the nodes can access their own battery level and transmit power can be adjusted depending on the distance of the destination. Protocol also assumes that the sensors know their location information. The objective of our fuzzy routine is to

 ISSN2305-8269

International Journal of Engineering and Applied Sciences

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determine the value of cost for a link between two sensor nodes such that the life of a sensor network is maximized. The optimal path from the available metrics are : traffic load, battery usage and number of packets forwarded previously by the same link. Optimizing the path will result in maximizing the life of the network. The protocol has the potential to be implemented in both the reactive and proactive manner. In reactive routing, when a node needs to transfer data it generates routing query and asks for its single hop neighbor's information, in order to calculate the routing path. On the other hand, proactive routing, updates the neighboring nodes by periodical broadcasting. When a data is needed to be sent the protocol selects the optimal path through the fuzzy inference system (FIS). Finally, it adjust the transmit power according to the distance of the receiver node and forward the data. By using the FIS we can integrate the different types of metrics (traffic load, battery power and link usages in our case). Therefore, the lifetime of a node depends on: (1) the traffic load the node is routing, (2) the energy consumed rate while transmitting or receiving the traffic load, and (3) the residual energy on the node. There is a correlation between the values of these parameters (traffic load, residual energy, energy consumption rate). Because these parameters have different units and their values can be defined in ranges, fuzzy logic is used to express the effect of their interaction. Our fuzzy inference system which the input fuzzy variables are: traffic load, residual energy, and rate of energy consumption. There is a single output fuzzy variable, namely link cost, the defuzzified value (using center of area method) of which determines the cost of link between two sensor nodes.

The first step of designing FIS requires characterizing the membership function (MF), which gives the input output relations. MFs are different for the different QoS metrics. In order to calculate fuzzy routing protocol, the definition of fuzzy sets, membership functions and number of rules for the inference system are needed. In determining the cost of link from node S_i to node S_j, "traffic load" represents the energy needed to transmit a data packet from node S_i to S_j (Figure 2). Lower value of traffic energy leads to lower link cost.

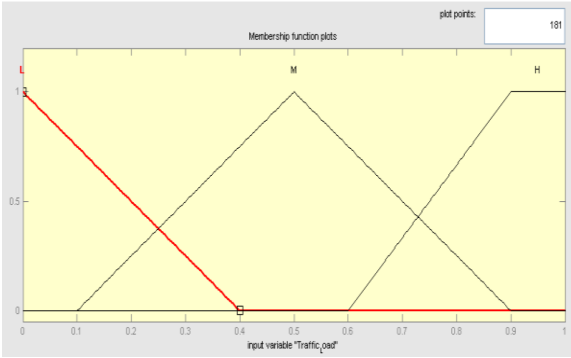

Figure 2. Traffic load fuzzy membership function

"Residual energy" indicates (Figure 3.) the energy level of node S_j. Nodes with less value of residual energy should be avoided in being selected as next-hop. Consequently, its lower value results in a higher link cost.

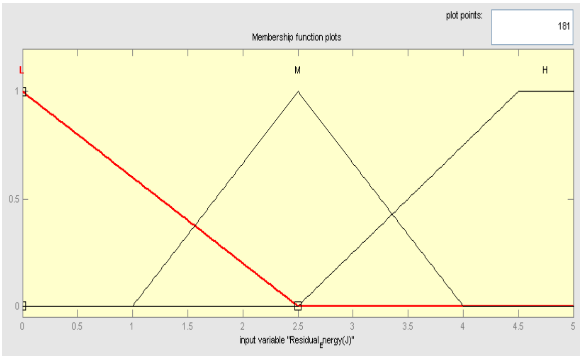

Figure 3. Residual energy fuzzy membership function

"Rate of energy consumption" of node S_j is another important parameter which represented in figure 4.

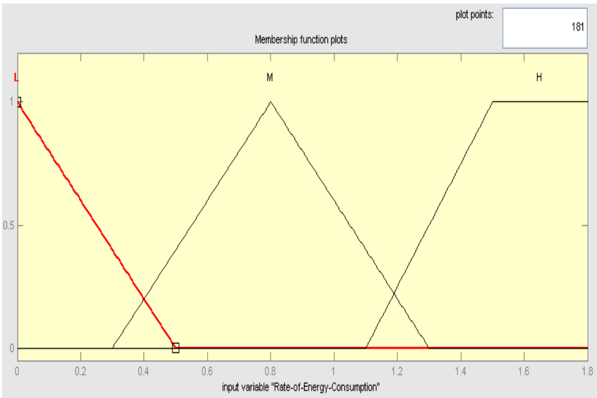

Figure 4. Energy consumption rate fuzzy membership function

July 2013. Vol. 4, No. 1 ISSN2305-8269

International Journal of Engineering and Applied Sciences

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The paths for routing that, using link cost metrics can be computed based on prevailing traffic loads to reduce energy consumption. Therefore, the selection of the link cost metrics substantially affects the performance parameters of the routing algorithms. Output FIS function of link cost ((Figure 5)) is classified into three linguistic variables: Link cost = { Low, Medium, High} which simplified as Link cost = {L,M, H}.

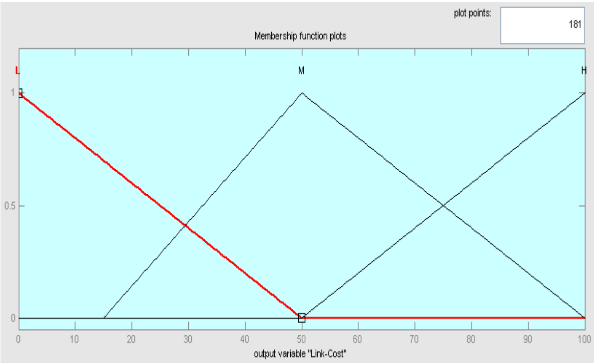

Figure 5 Link cost fuzzy membership function

The rules are created using the Fuzzy Inference System (FIS) editor contained in the Matlab Fuzzy Toolbox. Figure 6 shows a case link cost of fuzzy routing calculation based on traffic load, residual energy, and energy consumption rate.

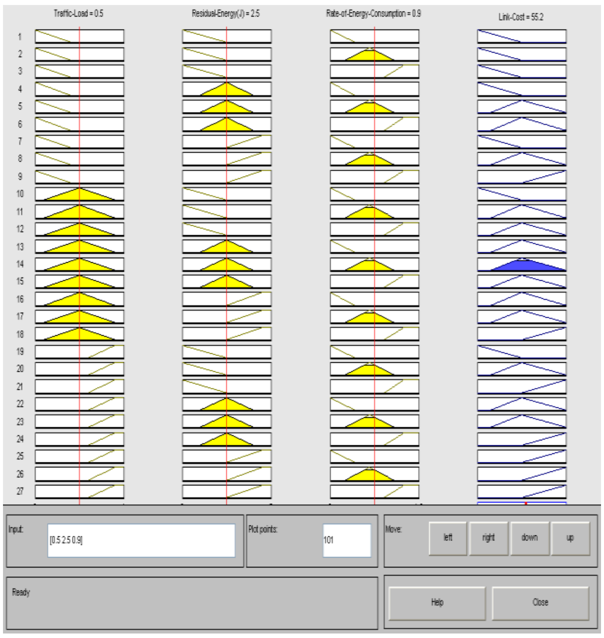

Figure 6 Fuzzy inference system for energy efficient routing calculation

4. Energy efficient routing simulations

To evaluate the performance of the protocol, we simulate the protocol shown in Figure 7. We simulate the system where the traffic loads with various pocket size, the size of each packet being 10k bits.

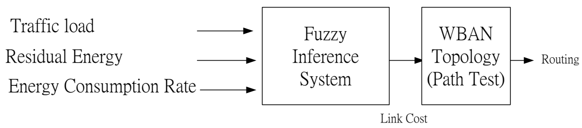

Figure 7 Energy efficient fuzzy routing simulation

For comparison with the fuzzy routing protocol, the same scenario was simulated using the shortest path method which using Dijkstra algorithm [6]. The performance of the proposed fuzzy routing protocol was compared with minimum remaining energy protocol. Each sensor generates the packet randomly with equal distribution. The simulation results in figure 8 shows the minimum remaining energy in WBAN for various pockets sensed sizes. It can be seen that fuzzy inference system performs better than the Dijkstra approach as the minimum remaining energy is significantly lower as compared to the shortest routing approach.

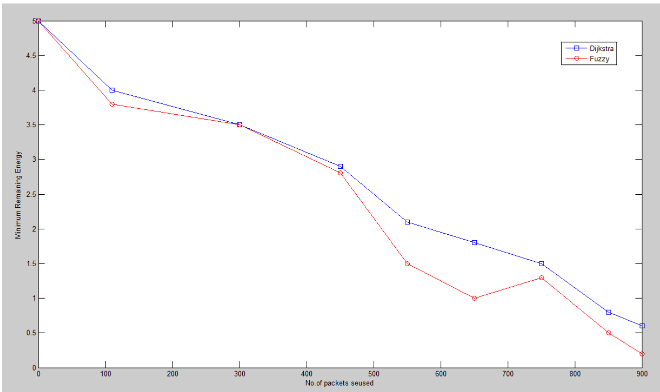

Figure 8. Energy efficient routing simulations for fuzzy vs. Dijkstra method

5. Conclusions

We have presented an energy efficient fuzzy routing protocol in wireless body area networks. Our simulation results have demonstrated the reliability and efficiency of this

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approach. Moreover, as fuzzy approach is soft it can be easily tuned for different network and node conditions simply by changing shapes of the fuzzy sets. We believe that the use of fuzzy approach provides a promising direction for devising efficient solutions to numerous related energy efficient routing problems in WBAN.

Acknowledgments

This research work was sponsored by the National Science Council, R.O.C., under project number NSC 101-2221-E-155 -032.

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