

Overview of routing algorithms in WBAN

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Abstract

The development of wireless computer networks and advances in the fabrication of integrated electronic circuits is one of the key elements in making miniature sensors, Makes it possible to use the wireless sensor networks for environmental monitoring in and around the bodies of animals. This precinct of researches is called the wireless research around the body or WBAN and IEEE Institute has assigned two standards to this matter being IEEE.802.15.6 and IEEE.802.15.4. WBAN aim to facilitate, accelerate and improve the accuracy and reliability of medical care and Because of its wide range of challenges, many studies have been devoted to this precinct. according to IEEE.802.15.6 , the topology in WBAN is in star form and one step and two step communications are supported but Due to changes in body position and the different states of the human that body takes (for example walking , running , sitting and ...) connecting nodes in one or two step mode via sync or PDA is not always possible . The possibility of using multi-step communication and in result the existence of multiple ways between Source and destination brings up this question that in which way and by which adjoining the transmitter sends the data to the receiver. So far, many routing algorithms have been proposed to address this question in this article we are going to evaluate them.

Keywords: Routing Algorithms, WBAN

1. Introduction

According to the latest census and statistical analysis, the population of the world is increasing and on the other hand, with the development of medical technologies and social security, increased life expectancy and therefore, the aging of the population, is inevitable [1]. The aging of the population, however, causes problems such as the need for medical care for the elderly, and thus leads to

increased medical costs As research on this subject shows that medical expenses in the year 2022 will specialty 20% of America's GDP in which in its own field is a major problem for the government. As another proof of this claim, we can mention the growth of medical costs in America 85/1 trillion in 1980 to \$ 250 billion in 2004. This is despite the fact that 45 million people in America are without health insurance. Checking these statics only brings one thing to the researchers mind and that is the need of change in health systems so that the costs of treatment is lowered and the health care in form of Prevention is raised [2, 3, 4, 5, 6 and 7].

WBAN has come to increase the speed and Accuracy of health care, provide quality for human life by providing cost savings. The sensors in WBAN networks be put inside or on the body. In both ways, nodes need to wirelessly communicate with sink and as a result making radiation that can increase the temperature of nodes and its surrounding areas in long periods and as the result be harmful for body and bring serious injuries to surrounding tissues [1]. Broadly speaking, proposing any way to reduce the amount of damage to the tissues, is based on the following two rules:

1. Reducing the power of sent signals via the transmitter of sink
2. Using multi step communication instead of one step communication

It is clear that the lower power of sent signals are , the lower area surrounding node is damaged but with lowering the power of sent signals ,communications between transmitter and sink are more likely to

disconnect and in other word , Reliability link will be reduced.

Due to need of keeping the connection active due to sensitivity of its usage being so important, the need of making guarantied links is of high priority. Providing the availability of the reliability of links is needed in high levels. All of these challenges make it Inevitable to change the one step connections to sync and multi-step connections.

As mentioned on IEEE 802.15.6 standard , topologies of WBAN are in star shape motion , so that connection between nodes and sink (hub) is one or two stepped because human body experiences different motions in limited time (motions like running , walking , sitting ,sleeping , ...)there is always a chance that connection between nodes and sink to be broken and network become partition [8, 9, 10]. A solution to solve this problem is that nodes improve their signal power but as mentioned, this solution will result in nodes to have temperature rise and as the result to have tissues surrounding the nodes to injure and as the result using multi step connection is inevitable. [11, 12, 13 and 14]

Thus, for any reason and in any position to look at the relationship between wireless nodes, replacing a single communication step with the sink, the tie will be a useful step. The ability of using multi step communication and as of result being multiple ways between source and destination brings up this question that in which way and with which tool the transmitter sends its data to the receiver. So far, many routing algorithms have been proposed to address this question in this article we are going to evaluate them.

Other parts of this article have been sorted as follows:

Second part is devoted to the usage of WBAN in medical field. Third part describes the problems in navigation of WBAN and in forth section is devoted to analyzing some well-known navigation algorithms and comparison and assessment are provided in fifth Section. The conclusion is in sixth section.

2. Usage of WBAN in medical field

Due to the growth of technology, usage of medical care services will result in a Massive transformation in health field. There are expeditions that using WBAN will significantly change the systems of health care and will make doctors able to have more speed and accuracy in finding out the illnesses and to

have more initiative in times of crisis [2, 3]. Statistics show that more than 30% of the causes of death in developed countries is due to cardiovascular problems However, if monitoring technology is used it can greatly reduce the number. For example with using WBAN you can steadily monitor blood pressure, body temperature and heart rate of the patient, which are all vital signs. WBAN sensors can send amount of vital signals via a device connected to the internet for example cell phone after they are measured. Cell phone can send the data via phone's internet connection to the doctor or the medical team and at the end; medical team can decide what is necessary to do.

Ways of using WBAN in medical field is parted to three sections:

1.hideable WBANs : these clothing or in more formal way , wearable equipment , normally can be cameras , sensors for checking vital signals ,sensors for communication with a central unit and sensors for controlling the surrounding area of the person .for example for military use , with equipping soldiers with these clothes they can be tracked ,measured their activity ,tiredness or even check their vital signals and plus that if athletes use this clothes they can check their medical symptoms online and at will that will result in lowering the possibility of injuries for another example There may be cases in which a patient is allergic to substances or gases Thus, using this type of clothing, the patient may be alerted before dangerous disorders happen and will the place

2. WBANs placed inside of the body: Statistics show that in 2012, 4.6 percent of people in the world, nearly 285 million people suffer from diabetes and it is expected that in 2030 this figure will reach 438 million Research also shows that in the absence of control of the disease, many problems such as loss of vision, will threaten the patient. Using sensors and functions that are embedded in the body, such as a syringe that when it's necessary it will insert suitable dosage of insulin to patient's body can greatly facilitate the process of controlling diabetes. Plus, as mentioned, one of the leading causes of death worldwide is cancer and is predicted that in 2020, more than 15 million people will die from this disease. If the built-in WBAN is used, the ability to monitor the growth of cancer cells is provided thus Control tumor growth and reduce the death toll is easily accessible

3. control tools and medical equipment's in long-distance : the ability of WBAN sensors to connect to internet ,being able to have network between tools and medical equipment's and Provides an acceptable controlling of the equipment's from long distance that is called living with limited assist or AAL , In addition to saving time, costs are greatly reduced.

3. Routing challenges in WBAN

So far, numerous routing algorithms for ad hoc networks and wireless sensor networks have been presented WBAN networks are very much maligned to MANET in the position and motion of the nodes, of course, the movement of the nodes in the WBAN are usually grouped This means that all network nodes move with keeping their position toward one another while in MANET each node moves independently from other nodes. In addition, energy consumption is more restrictions on WBAN networks because a node insertion or replacement battery in WBAN, especially when the node is placed inside the patient's body, is much harder than replacing a node in a traditional sensor networks because surgery is usually required. Hence, it is more important to have more longevity in WBAN networks also the rate of change of topology and speed in WBAN nodes is far greater than sensor networks. Based on what was said, routing protocols designed for MANET and WSN are not useable in WBAN. Challenges that are raised in the WBAN networks, are summarized below:

1. body movements: moving of nodes because of human body position causes serious problems for providing service in WBAN Because the quality of the communication channel between nodes with each other, as a function of time and due to changes in posture of body, is not stable As a result, an appropriate routing algorithm must be able to adapt itself to a variety of changes in the network topology.

2. The temperature and interference: The temperature of a node for computing activities or relationships with other nodes, usually increases and this increase in temperature may cause damage to the human body. A good routing algorithm must manage the data sending schedule so that a specified node is not always chosen as relay node.

3. Reduce energy consumption: a good routing algorithm must be able to use intermediate nodes as the relay nodes instead of sending the data directly to a remote destination so that it prorate the overhead

power usage between different nodes and by doing this , prevent early death.

4. Increased longevity: A good routing algorithm must be able to transfer data paths selected so that the total time of network activity increases.

5. Efficient communication radius: A good routing algorithm should consider an efficient communication radius of nodes. The higher communication range of a node is the higher the energy usage will be but if communication range of a node is very low there is a chance that the mentioned node will lose communication with other nodes and network divide to several pieces. Also If the radius of communication is very low, usually a number of options for routing to the destination are reduced this results usage a same way by a node and this result in temperature rise of the neighbor node and increase of energy usage in node

6. Finite number of jumps: as mentioned before, number of jumps in WBAN standard must be one to two steps. Use of higher-quality channels can increase the reliability of packets but at the same time usually the number of steps are increased, however, despite restrictions on the number of steps in the IEEE 802.15.6 standard is intended, routing algorithms usually do not pay attention to these limitations.

7. Usage in Heterogeneous Environments: WBANs usually consists of different sensors with different data transfer rates. Routing algorithms must be able to provide quality services in a variety of different applications.

4. The routing algorithms in WBAN

So far, numerous routing algorithms for a WBAN networks have been provided and each has been trying to resolve basic variety of challenges posed in the previous section.

4.1. OFR & DOR routing algorithms

OFR routing algorithm is the same flooding algorithm used in other types of networks. As the name suggests, in this algorithm ,for sending a package between transmitter and receiver , no navigation is done but the transmitter sends the copy of the package to its neighbors .each neighbor (basically each node in network) sends the package to its neighbor after receiving it . With this method,

multiple copies of a package arrives at the receiver. Based on this, the receiver saves the first package that has less delay and sweep away other packages. OFR method is usable in different varieties, for example, it has high reliability (because it uses all the potential of the network) and has a small delay but because of using too much resources, energy usage and temperature created in it will rise and also it has low throughput.

On the opposite side of OFR method is the DOR method that its function is completely opposite of OFR method. Is routing algorithm of DOR sender only sends its data to the receiver when a direct communication link is established between them and if a link is unavailable, transmitter holds its data in the buffer until it establishes the link? In other word, there is no routing in DOR. However, unlike OFR, DOR algorithm uses fewer resources, but because it does not benefit from multi step Communication, it suffers a lot of delay and sometimes it's unacceptable, it's because of this reason that its only usage is in networks that are sensitive to delay. Plus, by increasing the distance between transmitter and receiver, even the possibility that the sender will not be able to send data to a receiver.

DOR and OFR algorithms are basically useless but low processing overhead and other benefits and features, are usually used to compare other algorithms.

4.2. PRPLC routing algorithm

In this algorithm [15] meters known as a living link factor (LLF) is defined. Each node has a duty to calculate LLF for its link to sink and other nodes and give these information to other nodes. This factor determines how the quality of the channel between the transmitter and the other nodes is. Method of calculating LLF is that higher values for a link show that link is more likely to be in next period of time. As you know, there is always the possibility that the quality of the channel between two nodes drop due to changes in the body temporarily and after a few moments revert back to normal. For example, Assume that the communication between two nodes one on the wrist and the other one on the chest is fine in normal mode but when the person puts his hand behind his back, this channel technically will have disorder. PRPLC algorithm uses time window in calculating LLF to ignore instantaneous channel changes, in other word, while calculating LLF it will

not only consider current state of the channel but also consider the state of channel in t period of time unit before current state. Obviously, the larger the value of t is the less impact on the instantaneous channel quality will be. In other word, by determining a value of t large enough, the channel quality of real-time changes will in no way affect the amount of LLF.

The quality factor of the link between node I and j at time t is shown with P_{ij}^t and it always has the amount between zero (no connection) and one (full connection) and after each time cutting , the amount will update via (1) relation :

$$P_{ij}^t = \begin{cases} P_{ij}^{t-1} + (1 - P_{ij}^{t-1}).w & \text{if } L_{ij} \text{ is connected} \\ P_{ij}^{t-1}.w & \text{if } L_{ij} \text{ is disconnected} \end{cases} \quad (1)$$

In each section satisfied between the link nodes I and j P_{ij} will increase rate of w .as mentioned , determining the amount of w will have great impacts of usage of PRPLC algorithm so that the lower the amount w is , the amount of speed of P_{ij} in having connection will reduce but if channel lose connection , P_{ij} will decrease fast.it is expected that the amount of w is in a way that for channel that have had long amount of connection P_{ij} will decrease slow and increase fast and vice versa , For channels that have been cut for a long time and have poor quality, and slowly increase and the decrease fast. In other word, the amount of w in each time cutting, must be updated, number 2 relation show the way of updating w :

$$w_{i,j}^t = \sum_{r=t-T_{window}}^t \frac{L_{i,j}^r}{T_{window}} \quad (2)$$

In this relation T_{window} is the amount of time window, also the amount of $L_{i,j}$ in r time cutting is 1 if the channel between I and j is connected, if not so the amount is 0. When node I wants to send data to node d and node j is in the neighborhood of node I , if $P_{i,d}^t < P_{j,d}^t$ node I will send its data to node j . in other word , be considering that LLF has a better position between node j and destination, node I prefers to send its data to destination via node j .

4.3. ETPA Routing algorithm

In [17] an energy-aware routing algorithm that considers measured temperature and transmitting

power at the same time has been presented as ETPA. This multi-step algorithm uses a cost estimate function for choosing best neighbor. Cost of each neighbor, is a function of temperature, energy level and signal strength received from the neighbor. In this algorithm to reduce interference and eliminating the time listening to a channel, the TDMA method is used in other word , Each time frame is divided into N slots so that N is the number of network nodes and each node to send its own time slice. At the beginning of each period (includes 4 time frames), each node for example node j sends a hello message to neighbor nodes ,then each node tries to test the signal power sent from each neighbor node and record in a table. After sending hello messages, each node will be able to calculate the cost of sending via each neighbor, and then send the data is sent through the cheapest neighbor

Equation (3) shows how to calculate the cost of sending from node j to node I

$$C_{i,j} = \alpha_1 \left(\frac{P_m - P_i^j}{P_m} \right) + \alpha_2 \left(\frac{T_j}{T_m} \right) + \alpha_3 \left(\frac{E_m - E_j}{E_m} \right) \quad (3)$$

In this equation α is the non-negative factor , P_i^j is the power of signal received in node I , P_m is highest power received , E_m is highest energy in a node (starting energy) and T_m is highest temperature permitted in a node. Each node chooses lowest costing neighbor while sending and sends the package to that node. If a suitable neighbor is not found transmitter saves the package in its buffer and calculates the possibility of sending again in time frame. ETPA suggests that the packages for more than two time frames remain in the buffer, are discarded. The simulation results show that this algorithm has good performance

4.4. BAPR routing algorithm

As we saw, PRPLC algorithm tries to minimize the effects of instantaneous channel quality vibrations in estimating function of channel quality. This way of viewing the channel, has a big problem and that is Topology changes that occur due to changes in body position, the will not affect the channel quality measurement functions in speed. In other word , although occurring things like getting blocked , does not affect the salary factor of channel in PRPLC algorithm but accruing an event for a long time will slowly effect LLF. Considering that in situations in terms of walking or running, the body is constantly changing, PRPLC algorithm will basically lose its

efficiency because in calculating LLD the inertia of the moving body is not important. Inertial measurement sensors can easily collect data on acceleration and direction of motion of the body. In addition, the sensors can lead to sudden changes in body movement that can detect sudden changes in the quality of the links.

Algorithm BAPR [16] in summary is a routing method that combines information from the relay node selection algorithms that have emerged with inertial motion (such as ETPA & PRPLC). In this algorithm, each node has a routing table. Routing table contains of records that have 3 parts. The first part of the destination node ID, second part the ID of the relay node and the third part shows the connection fee. the meaning of connection fee is a fee of connection between transmitter node and relay node, unlike routing algorithms in MANET , routing algorithms in BARR can have several records for one destination. In BAPR relay node is chosen via communication fee in this way that nodes with highest fee are in priority for selection .the reason for this kind of choosing is that based of fee calculating method in BAPR, link with higher fee has the higher reliability and from there BPR wants to improve the chance of sending the package successfully so it chooses a relay node with higher fee.

In BAPR, Information relating to motor inertia and local topology is considered in calculating the cost of connection. The cost function of this algorithm collects the data of the motor inertia to cover immediate changes to network topology and network topology history to cover long-term changes in topology. That is why in BAPR when topology changes are quick, information about the movements of the body are more valuable, otherwise the history of link is more important. In this algorithm it is assumed that the momentum vector of the body $\overrightarrow{ACC}$ can be measured via inertial measurement sensors

5. Comparison and Analysis

In this part of the article we are going to review, analyze and evaluate routing algorithms described in the previous section. The most important criteria in evaluating the performance of a routing algorithm in WBAN networks are mainly longevity and energy efficiency, reliability, successful delivery rate, packet delay. Therefore we will appraisal BAPR, ETPA and PRPLC algorithms in terms of the criteria for successful and use OFR and DOR algorithms as

Indicators to measure the performance of these algorithms.

5.1. Average rate of successful delivery

As figure 1 shows, fee of delivering the message in OFR algorithm is higher than every other algorithms and BAPR algorithm is in second place with a small difference from OFR. As you see, delivery fee price in BAPR is 30 percent higher than PRPLC algorithm that is a significant improvement

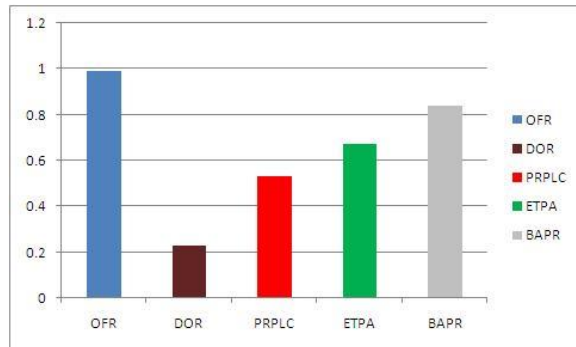


Fig1. The average rate of successful delivery

5.2. Average end to end delay

Connection in every algorithm is the same except the DOP algorithm. Since OFR algorithm uses flooding method, delay in this algorithm is a lower bound for routing algorithms. In other word, none of the routing algorithms will have less delay than OFR algorithm. Based on this, delay in all three algorithms of PRPLC, ETPA and BAPR is acceptable.

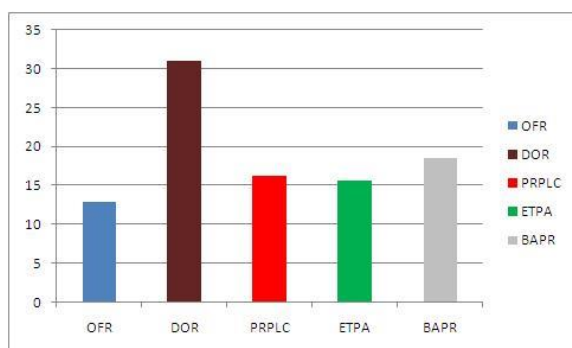


Figure 2: The average end-to-end delay

5.3. the average number of jumps

The number of jumps in a message, in a sense represents the amount of usage of resources. Thus, as

expected, the number of jumps in OFR routing algorithm is more than other algorithms while the DOR algorithm has a minimum number of jumps in between other algorithms (just one jump).number of jumps in BAPR algorithm is in better place than PRPLC and ETPR but there is not a high difference between BAPR and ETPA algorithms. Of course we need to mention that the number of jumps in just calculated for packages that have been delivered successfully thus eliminating packages in PRPLC and ETPA prevents the increase of steps in algorithms.

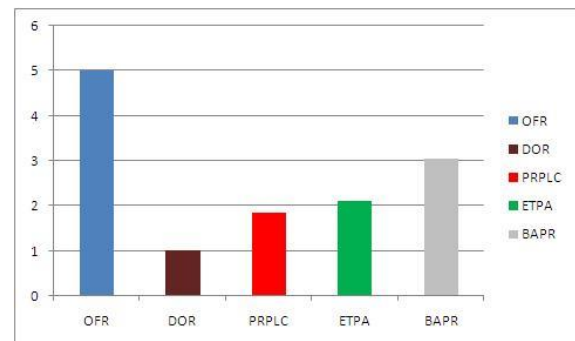


Figure 3: Average number of jumps

5.4. Other parameters

A class of routing algorithms does not pay attention to temperatures generated by the nodes, which in some cases can even cause damage to body tissues of the patient. While the ETPA pays special attention to this issue, as the temperature of the relay nodes, is being placed in fee estimate function. On the other side, BAPR routing algorithm is opposite of named algorithms and need equipment such as measurement sensor and inertial measurement. Although OFR algorithm has an acceptable performance most of the times but because of using network resources to much, is never used. Plus the overhead processing in ETPA and BARP are high compared to PFR and DOR but PRPLC algorithm has a medium overhead processing compared to other algorithms.

6. Conclusions

Due to the growing population and increasing life expectancy, the traditional methods of treatment, will not be efficient because it imposes heavy cost to the economy of a country. With regard that prevention and care, are one of the simplest ways to reduce deaths and medical costs, WBAN networks for monitoring patient's vital parameters and injection materials needed for patient's body in specific times

have been released. In the standard created for WBAN that is known with the name of IEEE 802.15.6 suggests star topology and one and multi-step communications for sending data from nodes to sink. However, due to the change in body position during the day, one step connection of nodes to the sink will not be continuously connected. To solve this problem, using a multi-step communication has been proposed. Using multi-step communication has always coincided with the concept of synchronization, for this reason, much research has been done on routing algorithms in WBAN. In this article, we reviewed some of the proposed routing algorithms within the WBAN, discussed the strengths and weaknesses of them and finally we compared them with each other.

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