Energy Efficient in Medical Ad Hoc Sensors Network by Exploiting Routing Protocols

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Abstract—The energy efficient in medical ad hoc sensors network (MASN) is one of the most important areas of researches to ensure better services for applications using such an environment. The challenge is how to use of energy of the sensors nodes in a fair way to avoid a break of connectivity in the network as long as possible. Our work focus on how to optimize the energy consumption and to increase the performance of the user applications in medical context. Our proposed approach is called M-EE (Medical Energy Efficient) which is based on the routing protocols with adding a new algorithm for energy fairness. M-EE takes into account the medical communication environment to manage efficiency the energy of the sensor nodes. With this mechanism, sensor nodes which are using image and video medical data are allowed more energy than other sensors nodes. The simulation results showed that our proposed M-EE approach allow significant energy consumption of the network, a reduction of the data loss and an increase in average working time of the sensors.

Keywords—MANET; Network Layer; Routing Protocols; Transport Protocols; Performance Improvement;

I. INTRODUCTION

Medical Ad hoc Sensor Network (MASN) is a distributed system which consists of wireless sensors for better implementation of medical applications. In order to ensure the communication, each sensor must act as a router and a terminal, and must retransmit packets from other sensors. Due their great flexibility of use, good robustness and very quick deployment, such networks can be used in many areas like medicine. The applications developed in such area use especially multimedia and real-time data (images, video, ...).

The limited sizes of the sensors make complex the support of such applications which require significant resources like the energy. An efficient consumption of the energy is very important issue in medicine ad hoc sensors networks. Significant solutions in energy consumption for such networks have been proposed and several of them use the routing protocols [1] [2]. We exploit this policy in order to propose a new approach for better energy efficient in medicine ad hoc sensors networks.

The proposed approach is called M-EE (Medical Energy Efficient), it is based on the routing protocols with adding a new algorithm for energy fairness. M-EE takes into account the medical communication environment to manage efficiency the energy of the sensor nodes. With this mechanism, the evolution of the energy of the sensors using different medical data and medical applications is equitable. M-EE associate for each data type a factor used as threshold to guarantee the fair evolution of energy of the sensors in the MASN. With this approach, sensors nodes with low energy are prevented in the routing process in order to maintain similar energy values during the running time for the medical applications. In this work, we use simulation to evaluate our proposed solution in term of data lost, total energy of the network and the lifetime of the sensors.

The organization of this paper is as follows: Section 2 we summarize some of the existing approaches for energy efficient which can be exploited in MASNs. Section 3 details the M-EE proposed solution and the different parameters used in its modeling. Section 4 offers a discussion of the evaluation results of M-EE in according to the reliability of data and the energy consumption. The conclusion is presented in Section 5.

II. RELATED WORK

The energy consumption has been since long the main concern of several researches. It is a key element in the functioning of a computer unit [3]. Like any scope of wireless networks, effective management of energy in the medical sector is undid overcome to ensure a good functioning related to this sector as applications. In this section, we present some of the proposed solutions for better energy consumption in MASN [4].

A new cluster based energy efficient routing protocol is proposed in [5]. The objective of this protocol is to sparse heterogeneous wireless sensor networks by building an optimal path for data transmission between base station and cluster heads. For the evaluation of the solution, the authors used simulations with the use of the three types of sensor nodes, primarily with different energy levels. As simulation results, they found that their solution offers better stability, network lifetime and energy efficiency in the network.

To address the problems of Gossiping and its extensions the Fair Efficient Location-based Gossiping (FELGossiping) approach is proposed in [6]. This approach is able to increases the network energy and then improve the network life time in comparison to the others solutions studied in this work. In addition, they show that the energy is balanced (fairly)
between nodes. After evaluation, the proposed approach here increases the lifetime of the nodes in the network. The propagation delay and the loss of packets are also reduced with such solution.

Optimal Energy Efficient Clustering Algorithm (OEECA) is new approach proposed in [7]. Here, a comparison made between the proposed approach and LEACH (Low Energy Adaptive Cluster Head) Routing Algorithm. The authors studied the energy consumption based on the selection of Cluster-Head node and the sending data’s to the Base-station. Based on the obtained results, they conclude that OEECA is better than LEACH in term of the energy consumption.

QCS-protocol [8] has been introduced for the intelligent energy efficient in ad-hoc sensor network. For the good functioning of the QCS-protocol, the Final Broadcast-Petrol Flow and the Irregular Information Transfer protocols are used in order to contribute in energy efficient. The challenges in ASNs are mainly the limited energy of the node, ad-hoc organization and the reliability of the network. Most of the existing approaches have done by addressing the problems separately, but not in a totality. QCS-protocol has been evaluated and could improve the duration of the network life and also made the consumption of energy less than before during the process of the data sending to the base station.

The Energy-Efficient Adaptive Protocol for Clustered Wireless Sensor Networks (EEAP) is a modification algorithm LEACH protocol [9]. EEAP lead to the prolonging the lifetime of the sensor networks with the use of balancing technique of the energy consumption of the nodes. With EEAP, only the nodes of the high residual energy can be as cluster-head. Special nodes, called “elector nodes” are used for the selection of the cluster-heads based on the collection of the energy information of the nearest sensor nodes. A simulation study showed that EEAP algorithm improves the performance of LEACH protocol.

PEACH protocol (Power-efficient and adaptive clustering hierarchy) has been proposed to increase the length of the grid in ASNs [10]. PEACH based on listening to the information exchanged between nodes in order to reduce the number of packets and using data aggregation policy. This protocol forms the clusters without additional packets related to the advertisement, announcement, joining, and scheduling process. This protocol is to be implemented on consular routing protocols using the concept of probability. This protocol can not be used on all type of WSNs. For example it is more effective in location-unaware and location-aware wireless sensor networks. The communication energy is decreased by in the network due to the reducing of the data packets. The authors showed that PEACH can increase the lifetime of the network and makes an economy in the consumption of energy by the network. With PEACH, the overhead on cluster head selection is avoided and adaptive multi-level clustering are used as compared to the existing clustering protocols.

A new algorithm is proposed in [11] called HEEP (Powered by ambient energy harvesting) for better performance network. The idea is to optimize routing algorithm by making unlimited the recharge cycles for endless deployment. Instead of batteries, the authors propose to use super-capacitors as energy storage devices. With this proposed protocol, three kinds of nodes are considered. Relay nodes which consist to forward data packet from source to sink node. They are more important when the source node is not within the sink range for the communication purpose. The second kind of nodes are source nodes, they are similar to the relay nodes except that if they does not receive any packet in the reception time, they will send their own data packet during the transmission time. The last kind of nodes is the sink nodes, such nodes have an unlimited energy and able to receives any data packet transmitted by the sensor.

ADRP (Adaptive decentralized re-clustering protocol) is an adaptive clustering protocol proposed for WSNs [12]. The residual energy of each node and the average energy of each cluster having nodes are the two parameters used by ADRP to elect cluster-heads and next heads. The energy consumed by the nodes is balanced by the cluster-heads. The proposed protocol makes the collection of the data from distributed sensor nodes to be transmitted to the base station. Due to some new functionalities of ADRP, the energy and communication overheads used are reduced. The reduction of the energy can be realized mainly by switch directly to next heads every sensors nodes without communicating with the base station. Also, the sensor nodes have the highest energy load when they are located farther away from the base station and single hop is used to reach the base station. In the opposite case, the sensor nodes closer to the base station should have higher load of relaying packets.

To increase the network lifetime of the wireless networks, a new algorithm which focuses on inter-cluster routing protocol is proposed in [13]. The principle is to balance the power of node consumption by using the fuzzy logic system to determine node’s chance of becoming cluster head. In addition to that, the authors propose to use an adaptive max-min ant colony optimization to construct inter-cluster routing between cluster heads and base station. This inter-cluster balances the energy consumption of cluster heads. A beacon message is sent from the base station to all the sensor nodes at fixed power which can compute the approximate distance to the base station using the strength of the received signal.

Based on the previous presented approaches, we can say that many researches work try to ensure better consumption energy in MASN. No proposed approaches take into account all, even some, of the communication environment parameters which participating in the degradation of the energy consumption in the network. Some works have only used existing routing protocol with adding new algorithm or function according only to the routing process. The main aim of our work is to propose a new energy efficient consumption approach for better performance of applications in MASN. The principle is to use the most important parameters in the communication environment and their behaviors in the management of the energy resource [4]. Provide an efficient energy solution increase the lifetime of the network and reduce the data lost. Due to that, the quality of service of the medical application is improved.
III. THE M-EE PROPOSED SOLUTION

The main goal of our M-EE proposed solution is how to manage efficiently the computing energy of the sensors without decreasing the quality of the services required by the medical applications in MASN. M-EE classify the data manipulated by these applications to different class according to two critical. The first critical is the type of the data: text, image, audio or video. The second critical is the priority (importance) of the application running on the sensor node. M-EE uses also another parameter which is the distance which is separating each sensor from others. M-EE should make the evolution of the energy in every sensor node according to these three critical. The result which we want reach is the service for the medical applications with less loss data especially the most important and also to keep the life of the sensors as long as possible especially the ones which are situated far from other.

In MASN, the distance between sensors can be different, some of them are close to each other while other no. Our solution takes into account this distance to know which sensors are situated in strategic places. For that, for every sensor \(i\) we need to calculate the average distance \(D_i\) as follow:

\[
D_i = \frac{\sum_{j=1}^{N-1} d_{ij}}{N} \quad (1)
\]

\(N\): the nodes number in the network; 
\(d_{ij}\): the distance between the nodes \(i\) and \(j\).

In addition to the distance \(D_i\), our M-EE uses two parameters to calculate an energy efficient threshold \(S_i\) for every sensor \(i\) in the network. The first parameter is the type of the data which is using by the sensor. In medical applications, the class of data can be defined as follow:

\[
C_k = \{\text{Text, Image, Audio, Video}\} / C_4 = \text{Video} \quad (2)
\]

The second parameter used too by M-EE is the priority of the packets treated by the sensor. The packet is more important if it used by an important medical application (emergency for example). Let \(P_m\) this priority, it is defined as follow:

\[
P_{m = 1..3} \in \{\text{low, medium, high}\} / P_3 = \text{High} \quad (3)
\]

The most important objective in this work is the energy efficient in the network. For the modeling of our solution, we need also to know the total energy \(E_{total}\) of the network and that can done with the follow equation:

\[
E_{total} = \sum_{i=1}^{N} E_i \quad (4)
\]

\(E_i\): Current energy for the node \(i\).

The threshold \(S_i\) used by M-EE is calculated according to the previous formulas as follow:

\[
S_i = \frac{(m e^k + D_i)}{E_{total}} \quad (5)
\]

Here, the constant \(\beta\) is determined according to the changes in the consumption of energy with mobility. Its value is determined according to the amount of energy consumed by the sensor during an interval of time. In our case, it will be fixed to value assumed not high and not small, just enough to achieve the objective of the function \(F_i\).

The sensors can be either statics or mobiles but the mobility is not considered here because this mobility is due to the mobility of users or the machines where the sensors are situated or integrated.

IV. M-EE PERFORMANCE EVALUATION

We evaluate in this section our proposed approach in term of packets lost, energy consumption and the life time of nodes in
the network. Such parameters are also used in some of our previous work [3][4].

A. Evaluation Environment

The performance evaluation of the routing protocols supporting the audio, video, pictures and text data will be studied using the simulator OPNET 14.5. The default simulation parameters used in the simulations are listed in the following Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position of nodes</td>
<td>random</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>70</td>
</tr>
<tr>
<td>Size of the network</td>
<td>1200mX1200m</td>
</tr>
<tr>
<td>Time of the simulation</td>
<td>1000s</td>
</tr>
<tr>
<td>Physical layer</td>
<td>OFDM</td>
</tr>
<tr>
<td>MAC layer</td>
<td>IEEE 802.11a with a transmission rate of 54Mbit/sec for the applications used (video and audio stream, pictures and text (http)).</td>
</tr>
<tr>
<td>Transport layer</td>
<td>TCP/UDP</td>
</tr>
<tr>
<td>Network layer</td>
<td>DSR, AODV</td>
</tr>
</tbody>
</table>

Table 1: The default simulation parameters

The settings for the data used in our simulations used are given in the following Table 2.

<table>
<thead>
<tr>
<th>Video stream</th>
<th>Low resolution video</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame interarrival time information</td>
<td>10 frames/sec</td>
</tr>
<tr>
<td>Frame size information (byte)</td>
<td>128*120 pixels</td>
</tr>
<tr>
<td>Type of service</td>
<td>Streaming multimedia</td>
</tr>
<tr>
<td>Audio stream</td>
<td>G.711</td>
</tr>
<tr>
<td>Encoder scheme</td>
<td></td>
</tr>
<tr>
<td>Voice frames per packet</td>
<td>1</td>
</tr>
<tr>
<td>Type of service</td>
<td>Streaming multimedia</td>
</tr>
<tr>
<td>Print (Texte File)</td>
<td></td>
</tr>
<tr>
<td>File size ( byte)</td>
<td>Normal(3000,90000)</td>
</tr>
<tr>
<td>Print interarrival time (second)</td>
<td>Exponential(90)</td>
</tr>
<tr>
<td>Type of service</td>
<td>standard</td>
</tr>
</tbody>
</table>

Table 2. The settings for the data used

B. Results and interpretations

We will evaluate three key performance metrics: Protocol reliability, power consumption and network life time.

The reliability of M-EE

As showed in the graphs of the Figure 5, the network using AODV with M-EE presents a better stability than the network using ADOV (see Figures 2, 3, 4 and 5) and this with the different data used. This better stability is due to the reduction of the links failure caused by the disappearance of the sensors with low or without energy. We note that the data loss rates for the two networks (AODV and AODV with M-EE) stills the same with the four data types used. Even there is a difference of evolution of the rates between the different types of data studied but always with M-EE the results are better. These rates become more important when the multimedia data are used. The largest value of the data loss rates is recorded with the video data and the smallest one is recorded with the text data.

Based on these results, we deduce that the reliability of the network with our solution don't decrease the performance of AODV which is, in the contrary, improved even for little.
Then our solution, although it aims to improve the energy consumption in the network, it can be also interesting for the reliability of the MADSNs.

**The energy consumption in the MASN**

![Figure 6. Evolution of number of sensors in the network (Text)](image)

![Figure 7. Evolution of number of sensors in the network (Pictures)](image)

![Figure 8. Evolution of number of sensors in the network (Audio)](image)

![Figure 9. Evolution of number of sensors in the network (Video)](image)

Figures 6, 7, 8 and 9 show the evolution of the number of working sensors in the network with the routing protocol AODV with and without M-EE. As we can see, the number of sensors with AODV starts to decrease before and quickly than with AODV using M-EE. This difference of performance between AODV and AODV with M-EE stills the same with the four data types used. But there is small difference of increasing of number of sensors between the data types, we can see that it is more important with video and less important with text. This is due to the nature of these data which need to use differently the energy.

Due to the utilization of the energy fairness threshold, our proposed approach M-EE favors sensors with a higher residual energy and carries out its equitable use. M-EE takes into account the position of sensors and the data type of the application used. All these features make the evolution of the number of working sensors in the network fairly. The results of the simulations showed that our approach allows an increase in average lifetime of sensors and avoid the stop of the network activity due to the disappearing of some sensors after ending their energy.
which concludes from the energy evolution in the previous results that proves the sensors are communicating. We network with our M-EE improvement continues to decrease, distance. During the same time interval, the energy in the network probably do not communicate because of their distance, the application priority and data types used. All these parameters make M-EE suitable for the four data types by using efficiency the energy.

The results show also that the energy level of the network AODV stabilizes at given time with the four graphs. This is due to the loss of connectivity between sensors after a no fair use of their energy. With AODV, some sensors have been solicited more than others, leading to the depletion of their total energy. This explains the failure of network connectivity, which stops the activity in the network.

For example, with video data, when $t = 600$ sec, the energy of the network stabilizes to 40 joule because the sensors in network probably do not communicate because of their distance. During the same time interval, the energy in the network with our M-EE improvement continues to decrease, which proves that the sensors are communicating. We conclude from the energy evolution in the previous results that our approach M-EE allows an efficient consumption of energy in the sensors network and then save a considerable amount of this energy.

V. CONCLUSION AND PERSPECTIVES

In this paper, we proposed a new approach called M-EE (Medical Energy Efficient) which is based on the routing protocols with adding a new algorithm for energy fairness. This new approach is essentially based on energy quality of the sensors and some parameters according to its communication like the distance, the medical application priority and the class of data used by these sensors. With this mechanism, the evolution of the energy of the sensors using different medical data and medical applications is equitable. With M-EE, sensors nodes with low energy are prevented in the routing process in order to maintain similar energy values during the running time for the medical applications. After implementation and simulation of M-EE, we obtained very satisfactory results: reduced data loss rates, significant saving of the total energy of the network and an increase in average working time of the sensors.

For the continuation of our work, we will consider first more communication environment parameters to make our proposed solution more reliable when used in real MASN. Also, we plan conduct a study on the communication environment of the MASN to better assign meaningful values to the constant $\beta$. In fact, the complexity of the MASN and the type of the medical application used in such network should be taken into account to deduce a significant value of the constant $\beta$. Finally, our M-EE protocol will be compared to others protocols proposed in the literature and tested on real MASNs.

REFERENCES


