A New Clustering Technique with Improved Fault Tolerance in Wireless Body Area Networks

Hajar Shabani
Department of Mathematics,
Yadegar-e-Imam Khomeini (RAH)
Shahre Rey Branch, Islamic Azad University, Tehran, Iran

Sara Najafzadeh
Department of Computer
Yadegar-e-Imam Khomeini (RAH)
Shahre Rey Branch, Islamic Azad University, Tehran, Iran

Abbas Arjomandfar
Department of Mathematics
Yadegar-e-Imam Khomeini (RAH)
Shahre Rey Branch, Islamic Azad University, Tehran, Iran

DOI: 10.23956/ijarcsse/SV7I5/0149

Abstract—Recent advances in wireless networks on the one hand, and increasing application of sensors in the medical field, On the other hand, have led to extension of studies on wireless network and their applications in treatment of patients. Sensor data and their nature, are of great importance in terms of timely response in wireless sensor networks. Employment of consistent Clustering techniques is one of the approaches used to reduce energy consumption and improve accessibility and fault in Body Area Networks (BAN). The present paper, introduces a new clustering technique for BANs, with improved tolerance in the face of network nodes failure. Assessment of The proposed technique using simulation, shows that this technique outperforms the previous ones in terms of cluster recovery speed in the event of node failure, the average power consumption and average network control messages.

Keywords—Body Area Networks, Self-healing Clustering, Fault Tolerance

1. INTRODUCTION
Wireless Sensor Networks consist of a large number of sensor nodes embedded in the patient’s body. The sensor nodes sense and collect the patients’ physiological parameters. This data will be sent to physicians, nurses or the hospital through network access points. These nodes organize and cluster themselves, and then begin to operate. After a while, the nodes or connection-oriented links may face hardware or software problems [1].

To improve the quality of life in hospitalized patients, they should be provided with maximum mobility chances. This means that wireless sensor networks used in the medical field, should support the movement of sensor nodes in the patient body. This support is associated with many challenges and cause problems in the evaluation of these networks, and that’s why research on wireless body sensor networks is so important [2].

In this paper, the failure of nodes refers to exhaustion of sensor node energy and their in operation. Node failure and energy exhaustion occur frequently. Such a situation may lead to breakdown of the entire network.

In addition, clustering in such networks should be associated with efficient use of energy, because sensor nodes energy is usually limited. Therefore, the network optimization techniques usually seek to increase the lifetime of the network by reducing the energy consumption of the network. Many techniques can be used to reduce energy consumption and extend the network lifetime. For example, hardware improvements in node manufacturing technology can help reduce energy consumption in these networks.

Clustering is one of the most effective techniques for dealing with faults and becoming aware of node failure in the shortest time possible. In the Clustering-based techniques, some sensor nodes as selected as cluster heads and the rest play their role as cluster members. Sensor nodes consume energy for message sending, Processing and motion purposes and will continue to operate until their energy is over [3].

In case a member of the cluster runs out of energy and stops, the failure must be detected and, communicated to the center if possible, so that it can be substituted with an alternative node. But when failures occur in this cluster heads, they lead to much more serious problems, because in this case the connection between all member nodes is lost and part of the network is virtually disabled.

In this case, the failure must be detected and a new cluster head must be selected quickly. The cluster head selection process may lead to a new clustering. The ability of the network to communicate even after a fault or damage, is referred to as reliability. This phenomenon is of great importance in BAN.

Improving network lifetime through detection of failure in sensor nodes and eliminating failures by clustering is the approach used in the present study. Development of Fault tolerance refers to a situation where a mechanism is provided for continuous operation of the network after a fault or failure has occurred, in other words, Development of Fault tolerance shows improvements in network reliability. [4, 5].

The second section provides a review of techniques used to improve the fault tolerance of BAN. The third section will describe the proposed technique and the CLBAN algorithm. Section four is dedicated to evaluation of the proposed technique, provision of simulation results and comparison of them with previous studies. Finally, Conclusions and further studies will be discussed in section 5.
II. LITERATURE REVIEW

BAN that include sensitive data should be tolerant to fault so that communication of patient data is not stopped in the event of faults. Improved fault tolerance in this type of network is associated with challenges such as high cost of control messages sent between sensor nodes and high power consumption [6].

Multi-path is one of the techniques used to increase fault tolerance in BAN. This technique is associated with high energy consumption and high traffic between the origin nodes and bus nodes, moreover, the nodes encounter disorders while sending information to each other and power consumption will increase. Node clustering and clustering-based fault detection and recovery is another technique used to improve the level of fault tolerance in wireless sensor networks. Several clustering techniques and protocols have been presented in previous studies [6,8,9].

Low energy adaptive clustering hierarchy protocol known as LEACH is the first and most commonly used clustering-based protocol in wireless sensor networks that is responsible for distributed clustering. LEACH mainly aims to use cluster heads to reduce energy consumption resulting from transition of data to a base station far away. In LEACH, some sensor nodes are randomly selected as cluster heads and assigned to the corresponding cluster heads based on proximity (distance) [7].

LEACH protocol’s performance is divided into several rounds. Each round begins with the formation of clusters. Clusters are organized at this stage. After that, the normal nodes send their data to the cluster heads and the cluster heads will transfer the data packs into the base station after aggregation and incorporation of the data, in order to reduce the amount of data that must be sent to the base station. Since CH selection is associated with probabilities, it is possible to select low energy nodes as cluster heads and the selected cluster heads can concentrate in one area of the network. Therefore, in this technique, proper distribution of cluster may not be possible.

Mina Abarna et al [8], proposed a failure detection and recovery technique known as CBFDRT in wireless sensor network. In this technique, first the sensor nodes are clustered, afterwards, the sensor nodes send some information about the status of the sensor, the situation of surrounding environment such as temperature, light, etc., and biological and physiological status of the human body, to their corresponding cluster head at alternate intervals. CH maintains this information in its data table and prioritizes them based on the information received from the nodes. The nodes with higher priority are sent to the base station faster than others. In case a cluster head fails to receive a message from its member nodes for several consecutive times, it realizes that the node has crashed, and will communicate the failure to the Centre. However, the failure may also occur in cluster head and cause the cluster head to lose its energy. This case is a little more complicated, because in this situation, the connection between all the members of the cluster is lost, the nodes must be re-clustered and assigned to new cluster heads.

In CBFDRT, all cluster heads have internal communications and send Hello messages to one another at specified times. In case a cluster head fails to receive a message from another cluster head for two consecutive times, it will communicate the problem to other cluster heads. The other cluster heads will search their table for the time of the last message received from the problematic cluster head. In case it turns out that all cluster heads have failed to receive a message from that cluster head from a specific time onwards, it means that the cluster head has crashed and its members should be re-clustered.

Akbari and Dana [9] presented another technique for fault tolerance and recovery in wireless sensor networks. In their proposed technique, first nodes are clustered and cluster heads are selected. Next, a node with higher energy level compared to other nodes will be selected as the second or alternative cluster head. Whenever the first cluster crashes, a second cluster takes its place immediately and is introduced as the primary cluster head, and another node is selected as the second cluster head.

III. A NEW CLUSTERING TECHNIQUE IN BODY AREA NETWORK

Various techniques have been proposed for improving fault tolerance in sensor networks and network applications including BAN. As mentioned in the previous section, clustering is one of the most common commonly-used techniques used for this purpose.

The proposed solution in this study is a new algorithm, known as CLBAN, for clustering wireless sensor network at the network layer, and improving the efficiency of failure detection in network nodes.

Implementation of this algorithm leads to development of a clustered BAN. In each cluster, an eligible node is selected as cluster head and the remaining nodes are considered as cluster members. Being selected, the cluster head receives and maintains some information on the remaining cluster members, including their energy, the last time a message is received from them, and other necessary information.

At certain intervals, the cluster heads control the time of last messages received from cluster members, and in case the time exceeds a specific threshold, the head cluster evaluates the proper performance of cluster members by sending a message. In case of failure, the problem is reported to the base station node or sink nodes so that the reconstruction or recovery processes can be initiated.

On the other hand, in case a cluster head crashes or there is a need to change the CH, CH change procedure is executed. Cluster change actually occurs in two cases; when the residual energy of cluster head may reach the minimum required energy of the cluster head. In this case, the cluster head node changing procedure is activated by the node itself. In the second case, the cluster head may get out of the reach of cluster members in an unforeseen way. In this case, the cluster head will be much more complicated to change.
Including the application layer, until the network state to neighbor's suggestions for joining the network. Criteria considered in applied on each layer of the network. All sensors were IEEE802.15.4–based devices.

Table 1 – standards of the evaluated network layers

<table>
<thead>
<tr>
<th>The applied standard or protocol</th>
<th>Network layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>SensorAppLayer</td>
<td>Application</td>
</tr>
<tr>
<td>CLBANNetw</td>
<td>Network</td>
</tr>
<tr>
<td>IEEE 802.15.4</td>
<td>Mac</td>
</tr>
<tr>
<td>Nic802154_TL_CC2420</td>
<td>Physical</td>
</tr>
</tbody>
</table>

The network environment was considered idea land free of the noise in real world, and only thermal noises of sensor nodes were involved in the simulation results. Table 2 shows the values of the simulation variables.

IV. PERFROMANCE EVALUATION

OMNET simulation software was used to simulate the proposed technique. To do so, a BAN with the following features was employed; the network dimensions was variable and the sensor nodes were considered mobile and variable in terms of number (22, 50, 100 and 200). According to Table 1 the following standards have been applied on each layer of the network. All sensors were IEEE802.15.4–based devices.

Pseudo-code 1 below shows CLBAN algorithm. This algorithm consists of eleven stages for clustering, failure control and network reconstruction.

1. Each node (Distributed) do:
2. Initialize (State = Un-Clustered); // The beginning of network initialization which every node reset their local variables and sets its state to un-clustered.
3. Inform Neighbors (State = Neighbor Discovery); // The node broadcasts NDETECT packet to discover its neighbors. The NDETECT packet has some basic information about the node and sets its state to neighbor discovery.
4. Collect (Neighbor-Info-Table) and send it to Neighbors.
5. Compute own Score and Neighbors Score to find CHCandidate (State = Joining).
6. If it’s CH-Score is better than Neighbors send CH-Announce message to its Neighbors (State = Cluster-Head).
7. If receive CH-Announce message and its CH not assigned yet, send CH-Announce-Ack message to sender and sets its CH to sender ID (State = Clustered).
8. If (CH = true), Finds Alternative CH and send AlterCHAnnounce. // To inform CMs about Alternative CH.
9. If (CH = true) periodically sends FAULTCHECK. // To control it CMs Health.
10. If (CH = false) and receive FAULTCHECK from its CH, sends FAULTCHECKACK to CH. // To informs CH about its healthy
11. While (state = re-Clustering) // This state happens when both CH and Alter-CH become not available to the node.

Pseudo-code 1: CLBAN algorithm

In this algorithm, first all network nodes are in the un-clustered state. Each distributed and independent node broadcasts NDETECT message in order to detect its neighbors. To prevent interference of this message that is to be broadcasted by all nodes, the broadcast plan is scheduled randomly during a given period. To reduce the overhead associated with the messages, this kind of message is considered non-response.

After receiving the message NDETECT, each node will extract information about the neighbor in question and store them in its neighbor table. In case no new information is received from neighbors after a specific period of time, each node sends its neighbor table to each of its neighbors, and uses SendNeighbors message for this purpose. After receiving the neighbor tables from their neighboring nodes, the nodes update their own neighbor tables. Neighbor table contains information about the neighboring node ID, Layer 3 address, Layer2address, neighboring CH, energy levels, number of neighbors and so on.

After gathering and updating the neighbor information, each node computes its own Score and it’s Neighbors Score to find CH Candidate. Criteria considered in CLBAN algorithm include node degree (number of neighbors) and their residual energy. In case the node in question has the highest score, it will consider itself as a candidate and will inform the neighbors by the CH-ANNOUNCE message. Otherwise, it will wait for neighbor’s suggestions for joining the potential cluster heads. After receiving CH-ANNOUNCE, if the node’s CH is not assigned yet and its score is lower than the sender neighbor’s score, the node will send CH-Announce-Ack message to the sender and sets its CH to sender ID. After receiving the CH-ANNOUNCE message, each candidate cluster head undergoes state alteration and turns into a cluster head. The next step is to determine an alternative cluster head for the cluster. This is done by the cluster head itself. The cluster head will set the neighboring nodes with the highest score as the cluster head and will inform the neighboring cluster members by sending the Alter-Announce message.

This algorithm won’t allow for sending messages to other layers including the application layer, until the network state has altered to Clustered state. This will contribute to clustering accomplishment in the shortest possible time.
Table 2 – values of simulation variables

<table>
<thead>
<tr>
<th>variable</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The network perimeter</td>
<td>300-2000 meters</td>
</tr>
<tr>
<td>Number of sensor nodes</td>
<td>22-100</td>
</tr>
<tr>
<td>Primary energy of sensor nodes</td>
<td>1000 mAh</td>
</tr>
<tr>
<td>Radio Signal transmission capability of nodes</td>
<td>100 Decibel meter</td>
</tr>
<tr>
<td>Application layer packet header</td>
<td>9 bytes</td>
</tr>
<tr>
<td>The network layer packets header</td>
<td>24 to 184 bytes</td>
</tr>
<tr>
<td>Kinematic model of nodes</td>
<td>RandomWayPoint</td>
</tr>
<tr>
<td>Application layer (source of traffic)</td>
<td>SensorAppLayer</td>
</tr>
<tr>
<td>Network layer</td>
<td>CLBANNetw</td>
</tr>
<tr>
<td>Media Access Control layer</td>
<td>IEEE802.15.4</td>
</tr>
</tbody>
</table>

To assess the overhead of clustering process control messages, the Percentage of messages exchanged by each network layer is extracted. Figure 1 shows the clustering overhead in the first 1000 s of network operation for each individual layer.

As indicated in this chart, the primary message overhead is very high during the first 10 seconds of network operation. The reason of this is predictable, this is mainly due to the fact that in early minutes of network establishment, all nodes are involved in the clustering process. The simulation results show that after completion of clustering and determination of the cluster heads, the overhead associated with this process is reduced significantly and has reached one percent.

Figure 2, shows the proposed algorithm’s packet delivery rate in a network with 22, 30, 40, 50 and 100 sensor nodes in a simulation environment of 1000 * 1000 square meters.

This chart shows that, despite clustering and tangible improvements compared to torrential procedures, in an environment with fixed dimensions, any rise in the number of nodes, leads to reduction of packet delivery rate due to interference between messages.

Figure 3, shows the number of cluster heads determined by the proposed technique and by Akbari et al [9]. It is evident that, unlike the technique proposed by Akbari et al, the proposed CLBAN algorithm has taken into account the density of sensor nodes and has selected a balanced number of cluster heads.
The efficiency of CLBAN algorithm was compared to the efficiency of Akbariet al [9] and CBFDRT technique [8] in terms of the mean energy consumption of network nodes. Figure 4 shows the result of comparison during a simulation process. This result can be attributed to the improved procedure of CLBAN algorithm in terms of fault detection and rapid replacement of the cluster head. As mentioned in the previous section, this techniques has also been optimized in terms of employment of improved clustering algorithm, and replacement of crashed cluster heads, and the simulation results confirm this.

According to the previous comparisons carried out by simulating the proposed technique and other similar techniques, algorithms presented in this paper outperforms the other techniques in terms of energy consumption and packet delivery rate and consequently in terms of fault and failure recovery.
V. CONCLUSION

In this study, a novel technique, capable of failure detection and recovery, has been proposed for clustering in BAN. In the proposed technique, a distributed clustering algorithm called CLBAN is introduced. Taking into account the characteristics and limitations of the BAN including the autonomous nature of sensor nodes, this technique clusters the network in a distributed way and uses the cluster head replacement technique to avoid the repeated execution of clustering.

To compare the proposed technique with the previous techniques, we review the strengths and weaknesses of previous techniques, providing a brief explanation of them, and use the OMNET simulation software to evaluate the proposed technique in different conditions.

Simulation results show that the proposed technique outperforms the previous ones in terms of balanced selection of cluster heads relative to density of sensor nodes. The average energy consumption of sensing devices has significantly declined and the network lifetime has consequently increased. Interference of message Packages has also declined and this has led to an increase in the delivery rate of message Packages.

In addition to improvements in the performance of the proposed technique in terms of energy consumption and quality of service, the BAN based on CLBAN algorithm, show higher tolerance to faults and failures of sensor network nodes, and this can be due to employment of improved CH replacement in these networks.

REFERENCES