LRC: Novel Fault Tolerant Local Re-Clustering Protocol For Wireless Sensor Network

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Abstract - One of the most important and efficient factors in longevity of wireless sensor networks is their energy consumption. Therefore; the less energy consumption, the more networks lifetime. On another hand, fault tolerance and avoidance of Repeating operations, which are because of faults should be re-done will reduce energy consumption and cause the longevity of these networks. In this paper, we will review and introduce the fault tolerant clustering protocols like: Leach and DSC and also fault tolerant clustering protocols like: FT – LRC together with their weak points. Furthermore, by taking the advantage of these protocols, we'll introduce a new protocol named FT-LRC, which has the whole benefits of previous protocols and has the least Energy Consumption Level. In this regard, fault tolerant is better than other previous protocols and other main advantages of these clustering protocols, which make them distinguished among the others is that it does re-clustering phase locally. While other protocols to do this matter globally, which cause procrastination and more energy consumption and reduction of network's total efficiency.

Keywords: Wireless sensor network, Clustering, Fault Tolerance, Network lifetime.

1 Introduction

Wireless sensor networks consist of a lot of sensor nodes. Each node consists of sections such as processing unit, memory unit, sending unit, receiving unit, Gps, mobilizer and power unit. Size is one of the issues in designing and making these devices. Technological developments have resulted in minimizing the size of these nodes that now their sizes are much smaller than a thumbnail.
Considering the specifications of WSN, combined of supervisory, computational and communicational technologies- many Applications have been made for these kinds of networks. We will introduce some of the main applications of these networks as below:

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Environmental control: The above mentioned networks can be used for environmental supervising and control. For instance, they can be used for controlling soil drifting or environmental pollution substances.

Military and security systems: The major usage of these networks is in military. Being fault tolerance, self-organized and wide spreading cause these networks will be used in target detection, communication, control and military tracing.

Hygiene and medical care: Moreover, the nodes of these networks can be used for supervising and controlling disabled people's and patient's vital signs. Control parameters like body temperature, blood pressure, blood oxygen etc., are within the domain of such control.

Smart houses: Another amazing application is using these networks for controlling mechanical pressure of the buildings situated in earthquake-prone regions. In this Application, sensor nodes will be installed on the columns right before the building construction procedure is over so that these sensors will be able to measure different mechanical parameters. The safety level related to the different

parts of a building can be measured through this pre-completion installation.

The other applications of these networks are: controlling of water consumption, smart control of traffic and recognizing the kind of vehicles for avoiding car accidents.

These networks are divided into two major parts: homogenous and non-homogeneous. In homogeneous WSN networks, hardware structures of all nodes are the same, and any difference or advantages can be observed among nodes. In contrast, in non-homogeneous WSN networks, nodes in terms of hardware structure are divided into some parts. Some of them are the same, but the others have some special advantages in their units. For example, some nodes will be chosen to be cluster head, which has a different and stronger power unit than the other nodes. WSNS has different ranges some of which include routing, clustering, security, fault tolerance, network's life time, energy consumption and so on[1,2,3]. This paper aims at declaring the ideas and viewpoints correlated to the clustering and fault-tolerance which are efficient in better progress and effectiveness. First of all, we explain two different domains of these networks; namely, the concept of clustering and fault tolerance.

1.1 Clustering

In a WSN, nodes sense the data from the environment concerning the type of their sensors (temperature, humidity, pressure and mobilization) and send the data to their central station. As these network nodes are widely spread in the environment, hence some of which are outrange from the central station, they are not able to communicate accordingly. Secondly, similar data will be broadcasted from a specific area; that is, all sensors close to each other send the same temperature. For avoiding of sending repeated data, clustering of these networks is considered. One of the limitations of these networks which have an amazing effect on network's life time is the battery and power units. Regarding the most energy consumption related to data transferring among nodes, if data transferring repetition is avoided, it's normal to have the reduction in energy consumption in these networks and as a result network's life time will be increased. Therefore, clustering is one of the methods regarding data transferring repetition. The implementation of different clustering algorithms in WSN can divide nodes into two main parts: Cluster head node, Non-cluster head node and base station of receiving information that is called base station or briefly BS. Different protocols and algorithms have been used for clustering of nodes, each of which has its own advantages and disadvantages.

1.2 Fault tolerance

The conception of fault tolerance occurs when a system or a network faces a problem (every system, no matter what secure nodes it contains, will become faulted in long run) so that it will be able to continue its normal operation in a way that the fault cannot have any effect on the system's final output. It is obvious that this important subject only be able to continue when, first of all, fault and error be detected and secondly, according to special related mechanism that resource and effect is recovered. The main point is that detection and recovery process must not impact on the system normal operation.

In the following pages, this paper introduce some of the mentioned protocols in the field of WSN clustering. In section 2, then in section 3, the suggested protocols are explained. In the fourth section, the suggested protocols are analyzed and compared with other protocols and the weak and strong points of protocols are evaluated. In conclusion, all the matters that can be discussed and researched is are declared[4,5].

2 Related works

One of the mentioned protocols for WSN clustering is LEACH; low energy adaptive on homogeneous WSN networks- this algorithm will be applied on homogeneous WSN. It is an alternate algorithm, and each alternation period has two phases: cluster formation phase and stability phase. In the formation phase of a cluster, commencing amount of CH like T(n) will be specified by BS then each node gets an amount between 0 to 1 randomly. Each node with the random number less than T(n) can be proposed as CH. In the stability phase, every round will be divided into time sections and in each time section node will transfer its related info to CH.

Leach protocol has different types, three of which will be pointed out here [6,7,8,9]: LEACH–C, there is a central cluster in this algorithm, which only connects to central cluster via BS. LEACH–F; in this algorithm CHs are fixed and won't change. SEC-LEACH; each of CHs and NCHs have a specific id. Their relationship is based on a series of special mathematical relationship so that they can form a cluster. Meanwhile, some of the nodes which have no parent that will be connected to the BS directly.

DSC is another type of leach protocol. This protocol has two parts: dynamic and static. Dynamic one has two phases: installation & formation phase and stability phase BS. In installation and formation phase CHs are chosen based on energy level and situation. Second, it broadcasts related id to CHs. Each node can be a member of CH when a harmony exists among ids of CH and NCH. In stability phase, first, data transferring from NCHs to

related CHs will be accomplished according to its dedicated time and in the form of TDMA. second, each CH aggregated the receiving data from NCHs and then propagation and transferring from CH to BS. Third, at the end of each round CH will introduce the node, which has the most remained energy as a new CH. Static section has only one phase, and it is similar to the previous static phase. The difference is that specifying of new CH won't occur at the end of each round. However, specifying of new CH will be after some round.

As mentioned before, this protocol has a strong dependency on BS and CH but no fault tolerance is defined or considered for them. Therefore, if CH makes fault in its operation, all parts of a protocol will have problem and there will be no difference between a CH with correct operation and faulty CH. Consequently, the other protocol named FT-DSC presented which fault tolerance FT-DSC is like DSC. The difference is that each node in specified time or out of it sends a request based on sensor data, which is transferred, so two possibilities can occur: in the first one data, packet is read and sent together with a specific packet that shows healthiness of the node. In second way, when it does not have any ready packet to send, it sends a specific packet (showing correctness and aliveness of it). In addition, BS has a timer, if it doesn't get any response from CH, it sends a hello message to the CH in order to have an acknowledgement from CH. If it does not get any response, CH is out of order, then BS will choose the node, which has the most remained energy as a new CH. In our view, this protocol has some weak points that we are going to point out some of them, and we offer two proposals in the form of a new protocol that will cover those problems. Weak points of those protocols are as following:

- In these algorithms, focus regarding clustering and CH is on BS. Therefore; the protocols security will be low.
- This protocol will make fault tolerance for NCH and CH, but it has not provided any mechanism for BS.
- The other problems of those protocols (FT-DSC, DSC, LEACH) are that clustering will be accomplished generally, which causes more energy consumption and less network longevity. Besides, the network will face more procrastination. However, in the suggested protocol (FT-LRC) this clustering will be accomplished locally and in parts. Therefore, there is less energy consumption in the whole network, and there won't be any procrastination or network down in the network concerning clustering.
- As the clusters and the value of sensor transferred data in the whole network are different, this local clustering will be more efficient and better whenever is needed rather than involving the network in installation and formation of clustering occasionally.
- The other important factor is why and how BS should know about the energy level of all nodes so that it can decide about clustering in the second phase. In the first phase, all nodes have the same energy and there is no problem in which BS, so they cannot make a right decision in this regard, because all nodes are not in the BS radio range, and some of the nodes will be out of BS range. Secondly, regarding nodes, which are n BS radio range, first these nodes should send their energy level to the BS. This issue causes the reduction in energy consumption in the level of all nodes and decreases the longevity of network accordingly. As you know, most energy consumption is when a node wants to connect to the BS and send data to it.
- By considering the focus on BS for choosing CHs and as there is no any fault tolerance mechanism for BS; therefore, focus on choosing of CH should be decentralized or should provide a mechanism regarding BS fault tolerance.

3 Proposed FT-LRC protocol

Concerning suggested protocols, we have tried to get all advantages from offered protocols besides by covering all weak points of the protocols we can provide special advantages for our protocols, and we will be able to reduce energy consumption. In this case, we have noticeably increased fault tolerance. The first stage of our suggested protocols is choosing of CHs like other algorithms. In the first place as all nodes have the same energy, BS will choose round CH based on the situation. this level is named primary choosing or initializing. Each node has a unique id. In each CH node's array will define which id and energy level of each related NCH will be kept in it. And in each NCH nodes array is going to be defined. So, it keeps id and energy level of all nodes which are in the range of node's radio frequency in a sorted way.

It is obvious that two criteria are considered in NCH arrays:

- Energy level according to sorting operation.
- Frequency range that means not only all neighboring nodes of a cluster will be maintained, but also it may maintain all neighboring nodes from other clusters in NCH arrays, for example, in Figure_1. In an array related to NCH7 & NCH8 energy level, the energy level of NCH_6 will be maintained too, whether this NCH_6 is related to CH_b or not.

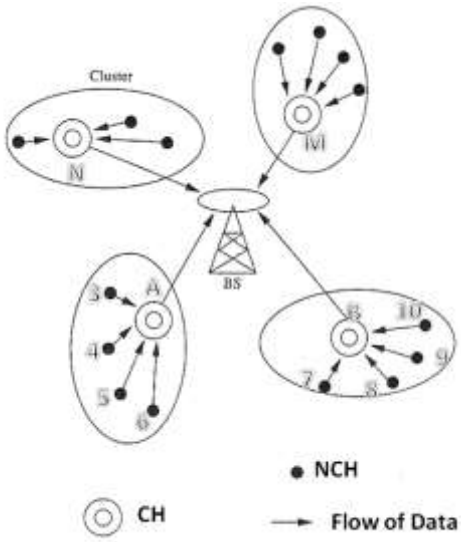

Fig.1: local re-clustering in the wireless sensor network

With respect to the above-mentioned matters, the procedure in our suggested protocols is as follows: whenever a CH wants to communicate with one of its NCH, it sends an energy packet with its energy level to NCH. According to distance and energy level, NCH will sort its array vector and in response it can send data packet including sensor data with one controlling packet to CH.

If $E_{NCH} < E_{CH}$, then data packet will be transferred and CH after aggregation will send aggregated data to the BS right away. Then it broadcast its reduced energy level to its NCH. By this method, NCH'S find out that the CH is faultless and sending data to BS will be accomplished. Afterwards, they can decide if the node can be a CH or should be replaced with the other NCH. The important factor is if energy level of CH to its NCH won't change in 2 times, NCH'S find out the CH has faced a problem and its relationship with its BS is disconnected. Therefore, they will be replace with a new CH from CH array.

If $E_{NCH} > E_{CH}$, then NCH sends a data packet to CH and then sends its id and energy level to its neighboring array related to NCH node. So, it broadcast its energy level to all NCH that NCHs will be able to update their CH array. Then, both BS and all NCHs know that the CH of this cluster is replaced. It's normal when a NCH broadcast its energy level, maybe the energy level goes to a neighboring cluster in this case and node will be separated from its cluster and will join to its neighbor cluster accordingly. For example, suppose that CH_B broadcast their energy level to the nodes of each related clusters. Whether the energy level is high or lower from CH energy, they should acknowledge so this is the fault tolerance of NCHS which is designed and provided in this protocol. If energy level of a node will be lower, it sends sensor packet to the CHS, but if energy level of a NCH like nch_7 is higher after sending data packet to CH, it broadcasts its energy level, too. Since nch6 is in the radio range of NCH_7 & NCH_2, the energy level is higher than the energy level of ch_a; as a result a small and local re-clustering will be done, so nch_6 put nch_7 before ch_a as a new CH in its CH array. In this way, a hierarchical clustering with no procrastination exists and whenever needed a small and local repairing can have noticeable effect on the whole network performance and its energy consumption. Consequently, we have increase network longevity because of fault tolerance in NCH level and CHs and decentralization on BS.

4 Analysis

By considering the above-mentioned matters, the procedure in our suggested protocols is as follows: whenever a CH wants to communicate with one of its NCH, it sends an energy packet with its energy level to NCH. According to the distance and energy level, NCH will sort its array vector, and in response it can send data packet including sensor data with one controlling packet to CH.

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By providing BS and CH relationship as mentioned in [10], it's said: if we consider data with n as size of the packet and P_{DATA} as a possibility of dispatching and P_{SPEC} as a possibility of sending specific packet and e_{DATA} as energy consumption for sending specific data packet, we will have:

$$E_{SPEC} = n_{SPEC} \cdot \epsilon_{SPEC}$$
$$E_{TX} = (P_{DATA} \cdot E_{DATA}) + (P_{SPEC} \cdot e_{SPEC})$$
$$E_{TX} = (P_{DATA} \cdot N_{DATA} \cdot \epsilon_{DATA}) + (P_{SPEC} \cdot N_{SPEC} \cdot \epsilon_{SPEC}) \quad (1)$$
$$N_{DATA} = K \cdot n_{spec} \quad ; K: Constant \quad (2)$$
$$P_{DATA} = L \cdot P_{SPEC} \quad ; \ 0 \le L \le 1 \quad (3)$$

So from the combination of relationships (1) & (2) & (3) We will have:

$$E_{DATA} = \frac{1}{\left(\frac{1+LK}{LK}\right) \cdot P_{DATA}} \cdot E_{TX}$$

$$E_{DATA} = m \cdot E_{TX} \quad ; m > 1$$

$$E_{TX} = e_{FT-DSC} = e_{FT-LRC}$$
$$E_{DATA} = e_{DSC}$$
$$E_{FT-DSC} = e_{FT-LRC} = \frac{1}{m} \cdot E_{DSC} \quad ; m > 1$$
$$\rightarrow (E_{FT-DSC} = E_{FT-LRC}) < E_{DSC} \quad ; \boldsymbol{BS \leftrightarrow CH}$$

On the other hand, in relationship between CH & NCH related to FT-LRC the procedure is different from another algorithm and make their relationship, on the contrary, of another algorithm, NCHS gets related to CHS in the form of TDMA. Our offered protocol will establish a fault tolerance relationship by energy level between CH and NCH. The other important factor about our offered protocol is the relationship between CH and NCH, which are not in the form of TDMA, but whenever a CH wants to get connected to one of its NCH, sends a message containing its own energy level to NCH. NCH acknowledges to the data packet, and if it does not have a ready packet, it only sends its energy level to the CH. This matter is provable as follows:

If we consider P_{DATA} as a possibility of packet sending and P_{ENERGY} as a possibility of energy level and e_{PD} as energy consumption for sending data packet and e_{PE} as energy consumption sending energy level and n_D which n as packet size and n_E as energy level with size of n. ϵ_D as energy consumption for sending each data packet and ϵ_E as energy consumption level for sending each packet of energy, then we will have:

$$E_{PE} = n_E \cdot \epsilon_E$$
$$E_{NCH} = (P_{DATA} \cdot E_{PD}) + (P_{ENERGY} \cdot E_{PE}) + e_{PE}$$
$$E_{NCH} = (P_{DATA} \cdot n_D \cdot \epsilon_D) + (1 + P_{ENERGY})(n_E \cdot \epsilon_E)$$
$$N_D = K \cdot n_E \quad ; K: Constant \ \& \ K \ge 1$$
$$P_{DATA} = L \cdot P_{ENERGY} \quad ; 0 \le L \le 1$$
$$E_{NCH} = (P_{DATA} \cdot E_{DATA}) + \left(\frac{1}{K} \cdot e_{PE} \cdot \left(1 + \frac{1}{L} P_{DATA}\right)\right)$$
$$E_{NCH} = e_{PD} \cdot \left(P_{DATA} + \frac{1}{K} + \left(\frac{1}{K.L} \cdot P_{DATA}\right)\right)$$
$$; \ K \ge 1; \quad 0 \le L \le 1; \quad 0 \le P_{DATA} \le 1$$
$$E_{NCH} = m \cdot E_{PD} \quad ; \ 0 < m \le 1$$
$$\rightarrow \ E_{NCH} \le E_{PD} \ \rightarrow \ E_{FT-LRC} \le E_{FT-DSC} \quad ; \boldsymbol{CH \leftrightarrow NCH}$$

5 Conclusion and Future works

In this essay while we offered some clustering protocols of a new protocol named FT-LRC, in all levels, researches done and axis of our focus is on reduction of energy level and network longevity and making the higher fault tolerance for this kind of networks. We considered offered algorithms by focusing on clustering in rounds and non-rounds, which take away dependencies from base station and provided re-clustering in order to have less energy consumption and network longevity and to have noticeable reduction in clustering procrastination. Because of this, we did not provide a fault tolerance mechanism for BS, but in the near future we can offer other algorithms like previous protocols for clustering by concentration on BS, but we should design a mechanism for fault tolerance related to BS accordingly. By considering the basis of fault mechanism, all relationships regarding offered protocols to have designed and provided. However, contradicted expectations and number of relationship between BS and CH and non CH is increasing, but the energy level is reduced in two phases dramatically. In the first phase, energy reduction in relation of BS and CHS and in second phase in relationship of CHs with NCHS. In the Table.1 Summary of this efficiency, differences and advantages of FT–LRC can be observed.

Table.1
Comparison of protocols specifications

Features	Leach	DSC	FT-DSC	FT-LRC (Proposed)
Fault Tolerance on BS	–	–	–	–
Fault Tolerance on CH	–	–		√
Fault Tolerance on NCH	–	–	–	√
Centralization on BS for choosing CH		√	√	–
Re-clustering	GLOBAL	GLOBAL	GLOBAL	LOCAL
Network energy consumption based on Re-clustering.	HIGH	HIGH	MEDIUM	LOW
Relationship between BS and CH	TDMA	PACKET	PACKET	PACKET
Relationship between CH and Non-CHs	TDMA	TDMA	TDMA	PACKET

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