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Review on LEACH Protocol

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***Abstract*-- As a result of the development and improvement in communications and information technology, and the need to monitor specific fields, wireless sensing nodes appeared. It is low-cost, multi-purpose, small in size, but also low-power. In wireless sensor networks, the most significant points worth exploring are how to increase the lifetime of the network. Several routing protocols have been proposed such as those based on homogeneity and heterogeneity, or that rely on a hierarchical or hybrid approach, etc. As it is possible to rely on routing protocols to determine the best communication path among the transmitter and the receiver in general, therefore it is considered better for low energy and increased network lifetime. In this research, we aim is to discuss several of the routing protocols and their merits and misfortunes.**

***Index Terms*-- Energy efficiency, Hierarchical routing protocol Residual energy, Wireless sensing nodes, LEACH.**

I. Introduction

Wireless sensor networks (WSN) made up of a big number of small size autonomous sensing nodes that work together to collect information about the surrounding environment and deal with it and then send it to the central station, its idea depends on dispensing with the human factor [1]. sensor nodes are randomly deployed to areas that are not usually easy to reach by aircraft. As most of the applications on this network are the management of battlefields, wars and disasters, earthquake and fire detection, and there are many peaceful applications also: air navigation control, health care, multiple commercial purposes electronic selling points and many more as well [1]. Routing is the process of determining the appropriate pathway among the source and the final destination. This is done in the network layer to guide and transfer data, as it must be achieved with high reliability and fast performance.

As we mentioned earlier, it is difficult to reach the places of publication of the sensor nodes, so it must remain alive as long as possible to be able to carry out the monitoring effectively. As those nodes contain batteries, the batteries are known to have a limited life span. Therefore, one of the most important and critical points are related to extending the lifetime of the network as a whole and appropriately distributing the total energy to prevent sensor nodes energy depletion in the early stages. In the past few years, many different routing protocols have been introduced and have been categorized into several levels based on more than one parameter, including its geographic-based routing protocol, clustering-based routing protocols, data-centric routing protocols and hybrid routing protocol [3],

according to [2][4], there are other categories as follows (according to the initiator of communications, according to the operating mode, according to the protocol operation and according to the design of network flow). As for the rest of the research, it is divided into section II. The topics of routing challenges, Section III. WSN routing methods and explanations of common routing protocols, section IV. Low energy adaptive clustering hierarchy (LEACH), the penultimate section V. various routing protocols of type LEACH, the last VI. Conclusion and then references.

II. Topics of Routing Challenges

According to [2] we consider the most important features of the appropriate the routing protocol that we consider good in WSN are scalability, awareness, and knowledge of energy level, and simplicity due to limited energy, arithmetic and basic units such as memory and others, the design of this network is affected by many difficulties, including:

A. Deployment of the sensor node

Deployment of the sensor nodes depends on the type of the application which significantly affects the performance of the routing protocol. deployment of the sensor nodes is either random (self-organizing) as we mentioned earlier, or it is manually and specific in its place. The location of the sensor nodes, especially the cluster head and base (monitoring) station, plays a very important role in energy efficiency.

B. Network traffic status

Ordinary sensing nodes other than the head of the group (cluster) or monitoring station are preferable to be (static) non-moving due to the ease of controlling them and determining the appropriate routing protocol, but in some applications, it requires a moving sensor node.

C. Tolerance of Faults

In the event that one of the sensing nodes dies, the routing protocol should create new links to avoid a lack of information about the monitored environment.

D. Scalability of the WSN

The number of sensor nodes may reach thousands and even tens of thousands in the area to be monitored, so the routing protocols must be able to handle with this high density of nodes.

E. Constraints on hardware

All units that make up the sensor node must be present as small as possible and consume the lowest possible power and examples of these units are: GPS, communication, sensor, power, memory, etc.

F. Information Transfer

Normally, the data transmission method is wireless, which is easily affected by the obstacles and weakens the signal more than the wire transfer and greatly affects the proper operation of the network.

G. Conservation of energy

During the building of the network, the process of establishing routes is strongly influenced by energy considerations. given the radio transmitted power on which the network is based is inversely proportional to the square of the distance or more with interference and obstacles. So logically, that the multi-hop directive will drain less energy than single-hop but increasing the network troubles, generally single-hop works well in small networks with nearby sensor nodes.

H. Models for data delivery

Delivery of data to the monitoring station may be continuous, or related to an event, directed to the inquiry, or mixed between them as required by the application. if it is continuous, each sensor node sends data periodically. On the other hand, in the second and third type of delivery, the node is activated when an event occurs or when the data source needs certain information, respectively. The routing protocol is affected in this type of delivery, especially the issue of reducing energy consumption.

I. Aggregation / fusion of information

It is the method of collecting data from different sensor nodes in order to remove the duplicates. The network works to collect packets from multiple sensor nodes to reduce the data needed for delivery and thus reduce the energy needed for that.

III. WSN ROUTING METHODS AND EXPLANATIONS OF COMMON ROUTING PROTOCOLS

Based on the direction of routing paths that are established, which can be one of these three reactive, proactive or mixed, the reactive paths calculate the paths when the real need is only. While proactive calculates all paths in advance before the real need for them and stores these paths in a routing table for each node, it is therefore useless because the network usually consists of thousands of sensing nodes, and finally, the mixed protocols combine them.

Based on the design of network flow, the routing protocols are split into flat-routing, hierarchical and location-based routing. the first one (in flat-based routing) all of the nodes perform the identical function so data is transmitted from each sensor node with a high redundancy of data [2].

Hierarchical Protocols, this type of protocol is intended to raise the efficiency of the network, extend its lifetime, increase the scalability, and cover a larger field of sensor nodes based on two steps: the first is to select the head of the cluster and the second for routing. Clusters are created in this type of protocol [2].

Location-based protocols, there is a correlation between the distance between two sensing nodes and the energy needed to transfer data between them, so sometimes we need to know the location of the node and we can do this either through GPS or other methods [2]. See Figure 1

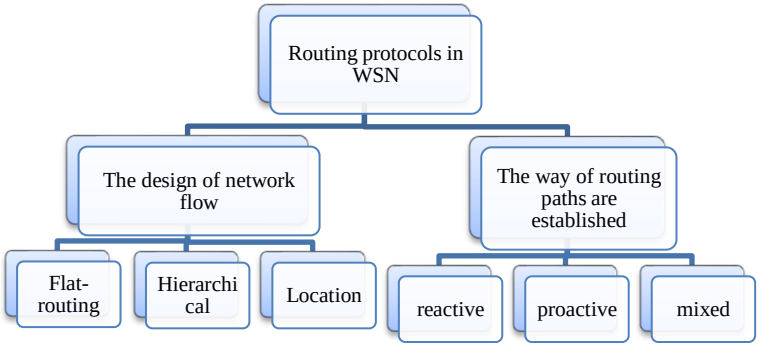

Fig. 1: Types of routing protocols.

The first thing that comes to mind when transferring data from one sensor node to another is that each node transfers its data to the base (monitoring) station, and its known as Direct Transmission (DT), but it does not ensure the balanced distribution of the energy spent between the nodes and leads to the rapid death of the nodes and such a protocol Minimum Transmission Energy (MTE). Therefore, it was directed to hierarchical protocols that outperform flat routing, especially on the topic of energy conservation.

In the clustering methods of WSN, the sensor network is split into various groups identified as clusters, one of the cluster nodes is selected by the sensor nodes and is better known as the cluster head, function of the cluster head will rotate between all other cluster nodes based on the algorithm chosen by the routing protocol. The cluster header in the current round sends one signal packet instead of many packets to the base

(monitoring) station and it also combines and collects data before sending [5].

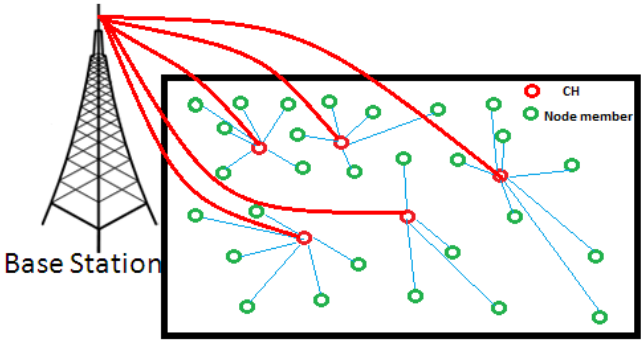

Fig. 2: Creation of clusters. [5]

In clustering routing, the node is either the cluster head and has to gather data and send it to the base (monitoring) station or it is a normal node, elections are split into multiple rounds; to balance energy consumption of wireless sensor network, adjustments may be made to each round. Clustering decreases, the size of the network by splitting the clusters into different sub-networks.

Advantages of the Cluster Process are discussed below [6]:

- Easily control network size: in clustering, the nodes are split into clusters, the head of the cluster is the one who deals with the base station because of the presence of a receiving and sending device. Therefore, the base station receives information from a few nodes compared to other routing protocols and the rest of the nodes that are not the head of the cluster do not deal with the base station and thus the network is easy to control.
- The allocation of loads should be regulated: the result of dividing the wireless sensor network into groups is the final functions are spat, which ultimately helps to ensure the same power dissipation between all sensor nodes. Consequently, every sensor node has a specific work to do at a specific time, while the nodes that fall away from the monitoring station die faster in flat routing protocols, losing their energy faster than the nearby nodes and thus increasing the energy consumption of the entire network.
- Aggregation / Fusion of information: Nodes send data signals to cluster headers, and data is collected there to either reduce the amount of redundant information or merge it to merge information signals into one.
- The network life is stable and longer: by rotating the head of the cluster and reducing the likelihood of death of the distant nodes as much as possible.
- Preventing collision: since the head of the cluster is only the one dealing with the base (monitoring) station, the rate of collisions is less than it was when each sensor node sends its data to the base station as in the flat model mentioned previously.

IV. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

It has been suggested by W.B.Heinzelman in [3], LEACH is the original hierarchical routing system for sensor networks, LEACH is an adaptive clustering method which uses randomized cluster head rotation to evenly distribute the energy load between the sensor nodes in the network. It is a very flexible and random (self-organizing) protocol. LEACH utilizes a one-hop routing.

Every WSN is split into clusters and each cluster consisting of a cluster header and normal cluster nodes. In this protocol, the head of the cluster is randomly chosen and this role revolves around the rest of the sensor nodes to check the power balance of the network. The head of the cluster is directly connected to the monitoring station and stops the rest of the nodes as much as possible to reduce energy use, as stated in this protocol, Operation LEACH is split into various rounds, and each of these rounds consists fundamentally of two phases: one is the Setup phase and the next is the Steady phase.

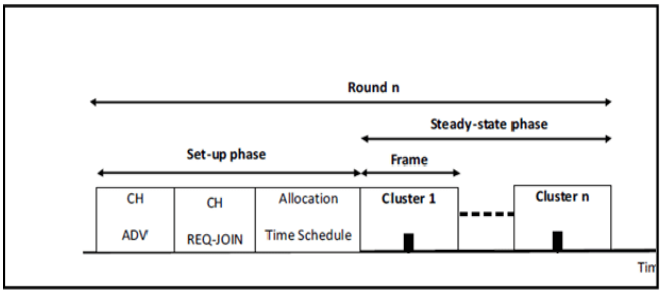

Fig.3: Operation of LEACH [12].

Initially, the node will choose a random number (n). Whether this number (n) is less than the threshold defined in the first equation T(n), then the node is chosen as the header of the cluster.

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \frac{1}{p}\right)} & if\ n \epsilon\ G \\ 0 & otherwise \end{cases} \qquad (1)$$

While p is the likelihood of the cluster head, G is the collection of nodes that will never be selected as cluster-head nodes before 1/p round.

After the heads of the cluster have been chosen, each cluster header node will send its data to the other nodes via CDMA (Code Division Multiple Access), and the normal nodes will connect the closest head to it. Then the cluster head nodes use TDMA (Time Division Multiple Access) to provide time for the transmission of data for each node attached to them.

In the second stage, data is transferred from the normal nodes to the head attached to it and processed (combined and assembled) at the head of the cluster, and then the head of the cluster sends it to the monitoring station.

According to [7][3], the most prominent disadvantages of LEACH are:

- Unbelievable selection of cluster head: The LEACH protocol does not take into account the starting energy of each node and therefore all nodes have an equally likely to become a cluster head. Assuming that a node with little energy is chosen it will quickly die and the network as a whole will fail.
- Unbelievable distribution for cluster heads: as a result of the random, non-studied choice of the head of the cluster, it causes an imbalance in the network load, the distance between the head of the cluster and the main station is not taken into account when building the clusters and thus lack of optimization of network energy, and this is a really problem.
- Further obligation on the node of cluster head: the head of the cluster is the one who collects data from the normal nodes and sends them to the monitoring station in one jump (hop). As we know, it will exhaust its energy more quickly than the normal nodes. In the event of the death of the head of the cluster, the entire cluster will die.
- It cannot be related to the time-compulsory application as it results in latency.
- It cannot be linked to a large network of sensors.
- As we mentioned previously, there is a delivery of data to the monitoring station may be continuous, it may be related to an event, directed to the inquiry, or mixed between them, the LEACH protocol is suitable for the continuous and not for anything else.
- Different size for each cluster: as it is possible that some clusters formed based on randomness contain a large number of sensing nodes while others contain a small number.

As a result of these disadvantages of the LEACH protocol, we will show in section five some of the protocols that have been found in order to solve these issues.

V. VARIOUS ROUTING PROTOCOLS OF TYPE LEACH

A. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY CENTRALIZED (LEACH-C)

LEACH-C is based on the LEACH basic protocol and also made up of rounds and is split into two-phase, it is a centralized protocol, this protocol assumes the following:

- Each sensor node can compute its energy level and send it to the monitoring station.
- Each sensor node can send its location exactly monitoring station.

Information about the location and energy of each sensor node is sent to the monitoring station by the nodes. Then the station chooses the nodes to have more energy than the average total power of the network as a cluster head, and create the best clusters depending on the minimum distance [6].

B. LEACH-Balanced(LEACH-B)

LEACH-B this revised version of the LEACH protocol gives a second choice for cluster heads at the Setup stage in each round in order to keep the cluster heads number constant and closer to optimal (Based on what was mentioned in [10] the optimal value for the number of cluster heads ranges between 3 percent and 5 percent) and thus reduce energy consumption, it is decentralized protocol, LEACH-B has improved energy efficiency compared to the original LEACH protocol [3].

C. Advanced Low Energy Adaptive Clustering Hierarchy (A-LEACH)

We also know that the head of the cluster is the one what collects data from the normal nodes and transfers them to the monitoring station so that its energy is quickly drained relative to the normal nodes, in the Advanced-LEACH protocol increases the period of stability (The time previous to the demise of the first node) and reduces the probability of death of the head of the node, each sensor node the beginning of each round is known by a synchronized clock.

We assume that (n) is the full number of nodes while (m) is the number of nodes that carry more energy than normal nodes name CGA nodes (nodes chosen as cluster heads or gateways) and the rest is (n)*(1-m) represents normal nodes, and these nodes remain sent to the monitoring station even after the normal nodes fails [4].

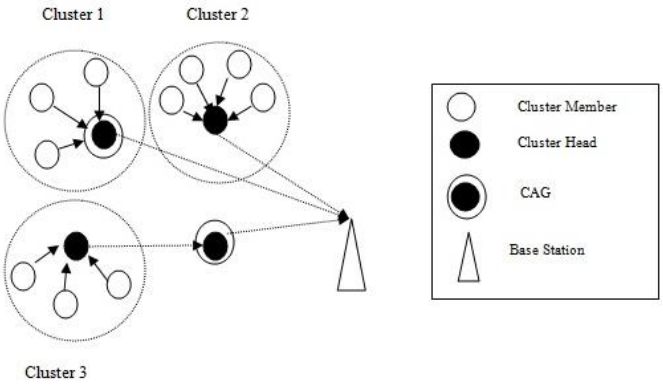

Fig.4: LEACH -A system [4].

D. Energy Low Energy Adaptive Clustering Hierarchy (LEACH-E)

E-LEACH relies on the basis of the LEACH protocol to balance energy consumption of all nodes, in hierarchical routing protocols as the number of cluster heads plays an important role in the functioning of the protocol correctly, since when the number of heads is large it consumes excessive energy and shortens the network life the whole of the network, and when the number of heads is few, each head is required to deal with a larger area and in the event that there is a normal node far from the head of the cluster, it will consume more energy than its counterparts in the same cluster and therefore the number of heads of the optimal cluster heads must be determined to reduce energy consumption the minimal spanning tree of cluster heads is used in the E-LEACH [4].

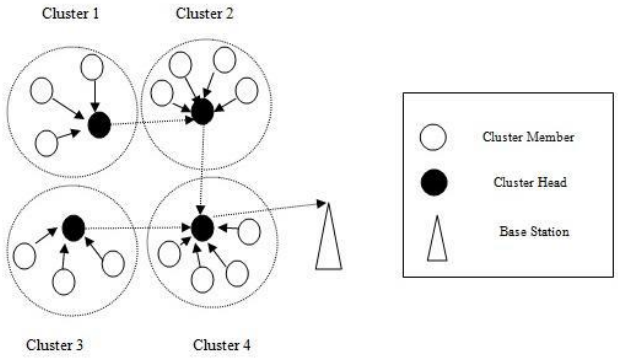

Fig.5: LEACH -E system [4].

E. Fixed Number of Clusters LEACH (LEACH- F)

Like the LEACH-C protocol, this protocol is a centralized approach, the clusters are fixed and the rotation is only for the header of the cluster within the same cluster. The steady-state is identical as the original LEACH since the number of clusters has been determined in advance, the energy required for re-clustering is provided, but it is not flexible in the event of adding, removing or dying a sensor node [4].

F. Vice Cluster Head LEACH (V- LEACH)

V-LEACH this revised version of the LEACH protocol, we also know that the head of the cluster is the one that collects data from the normal nodes and transfers them to the monitoring station so that its energy is quickly drained relative to the normal nodes, Thus, you will die before the other nodes, and when it dies, the whole cluster becomes not important because it does not communicate its information to the base station, so this protocol was created to avoid that is possible. There is a vice-CH in the function of the CH that is activated when the CH dies. Consequently, all data will reach the monitoring station and consequently the life of the network as a whole will increase, and the problem remains in the event of the death of the vice-CH, this protocol is unable to solve this problem [7].

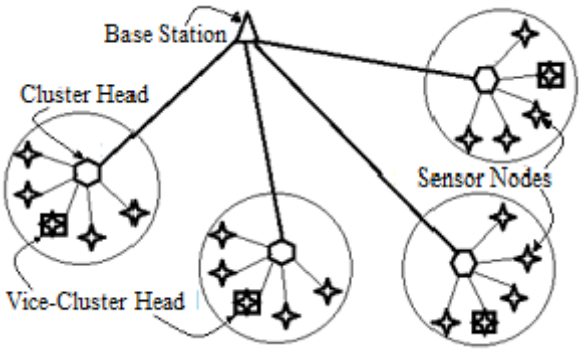

Fig.6: LEACH -V system [13].

G. Cell Low Energy Adaptive Clustering Hierarchy (Cell-LEACH)

This is a revised protocol from the original LEACH protocol, the entire network is split to several clusters and each cluster is split to seven sub-clusters called cells and each cell has a head whose task is to collect data from the normal nodes (it is chosen randomly at the beginning and in the later stages each old cell head makes calculations dependent on the remaining energy, a new cell head is selected) and the heads of the cells and the heads of the clusters are contacted directly [8].

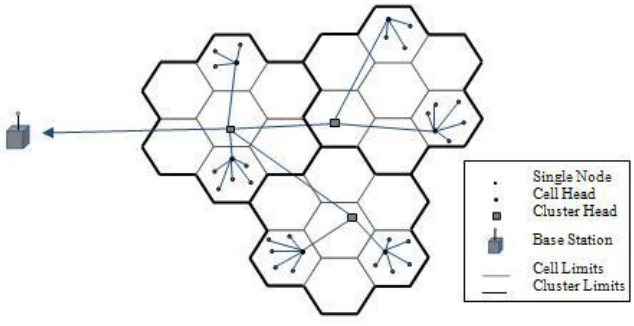

Fig.7: LEACH -Cell system [2].

H. Multi-Hop LEACH

In LEACH protocol, the sensor nodes which represents the head of the cluster send the data that is collected from the normal nodes to the monitoring station, and if the distance between them is large, it requires a lot of energy, so we wanted to have a cluster head of a middle cluster to reduce the distance between them, which is known as multi-hoping communication.

The head of the cluster closest to the monitoring station receives data from the rest of the cluster heads and sends it to the station, thereby reducing the energy needed for that and also adopts the optimal path between the head and the station [9]. As we know in the original LEACH protocol, any sensor node begins to be a cluster head regardless of its energy, and it may become a low-energy node of a cluster head and that signs the entire network in the probability of death so an adjustment was made to the choice of the head of the cluster based on its energy and extending the life of the network as a whole, we will add term to the original equation to raise the chance of the sensor with the most energy to become a cluster head to raise the efficiency of the network [9].

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \frac{1}{p}\right)} * \dfrac{E_{rem}}{E_{totnet}} & if\ n \epsilon\ G \\ 0 & otherwise \end{cases} \qquad (2)$$

While p is the likelihood of the cluster head, G is the collection of nodes that will never be selected as cluster-head nodes before 1/p round.
E_{rem} is remaining energy level of the node, E_{totnet} is total energy network. This happens in the setup phase.

To get the best exploit of the free TDMA, TDMA schedule is improved in the steady state. In some protocols for a specific event to happen, some sensing nodes may not have data that you want to send so the TDMA slot is lost. Each sensor node looks at its role in the current round if the node has data to send then send it and if it does not have data, the TDMA slot is given to another sensor node as Fig 8 [9].

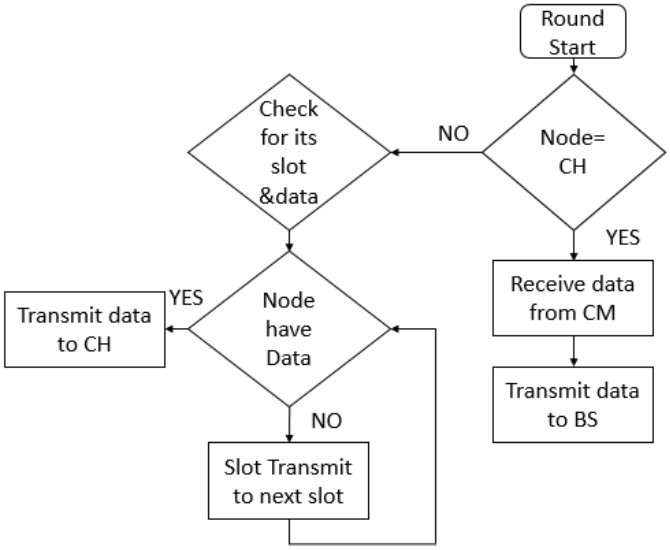

Fig 8: The new revised TDMA outline [9].

VI. Conclusion

Because of the continuous and high growth of the fields of multiple computing, new nanotechnology, and various modern applications, such research remains an open field. In this research, we have presented a part of what is related to the different routing protocols and try to demonstrate what improves the energy consumption of the whole network. We concluded that in the Multi-Hop LEACH, three amendments are made to LEACH to make this protocol great more energy efficient, the first one is more than one hop, the second is a careful choice of the head of the node with a term increase over the original equation and the last one is allocation of the inactive TDMA node to the next node if the preceding node has no data to give. Hopefully, in future work, we will introduce protocols other than LEACH.

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