Energy Efficient Wireless Sensor Network Protocols

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***Abstract*—In the last couple of years, there are a lot of new technologies developed in the area of micro-sensor devices as a result of this some new protocols designed for wireless sensor networks(WSN's). The wireless sensor network is a structure built by thousands of sensor nodes. These sensors collect various pieces of information from a desolate location and transmit it where ever we wanted. These pieces of information can be used in various applications. The main problem of these sensors has limited resources like a battery, processing power, and storage capacity. These sensors have many methods to connect with each other and this article is explaining a few of them for a better understanding of how wireless sensor networks operate.**

I. Introduction

Wireless sensor networks are built by tiny sensors. Most of these sensors built with four components, a small battery, storage with a limited capacity, a processor with low processing power, and a radio antenna. A sensor node's job is gathering information from its surroundings and reports them to the processing center. This center is usually called by 'sink'. In general, a protocol design has to be energy efficient due to a lack of battery. The battery is the main problem most of the time because embedded batteries are very hard to replace and also it's extremely hard to change all of these sensors' batteries after they take in place. Figure 1 shows us the nodes getting information from the field, generate proper data, and send them the nodes they are connected to. Eventually, all the data are collected in the sink. After performing some final task in the sink the data is sending to the user via the Internet.

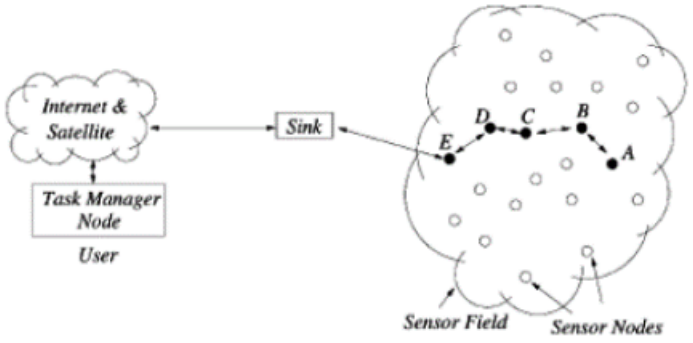

Fig. 1. Pathway of gathering data and sending to the user [1]

II. Categorization of Energy Efficient Wireless Sensor Network Protocols

There are a wide variety of sensor types for many applications. Sensors can measure moisture, temperature, pressure, movement, and so on. Wireless sensor network protocols are not only bounded by pathways and transmission speeds they should also consider energy efficiency. There are too many wireless sensor network protocols and they can be grouped hierarchically as in Figure 2.

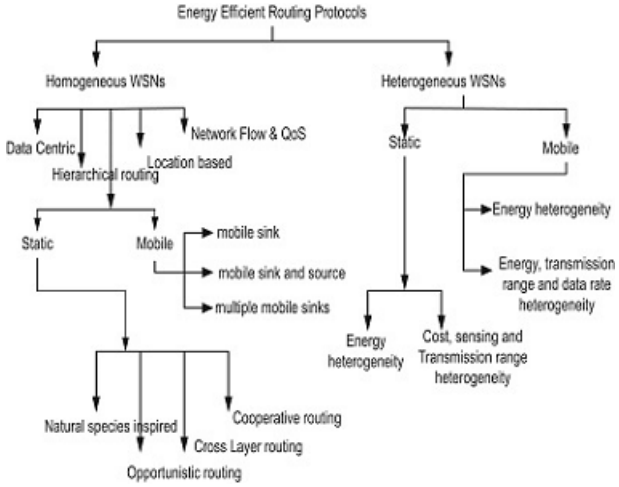

Fig. 2. Energy Efficent Wireless Sensor Protocols [2]

III. Energy Efficient Wireless Sensor Protocols

A. LEACH Protocol

LEACH protocol's main algorithms are cluster header position changing, adaptive cluster forming, and distributing cluster forming. For the target node's self-organization the protocol using the distributing cluster forming algorithm and for the energy efficiency and energy usage distribution across the nodes its using header position changing and adaptive cluster forming.

LEACH protocol works with rounds in a loop. One round has two states; cluster setup and steady-state. While the cluster setup the node is in self-adaptive mode and while the steady-state node transfers its data. Steady-state is longer than the

setup state for saving the payload. The process is demonstrated in Figure 3.

Fig. 3. Round loop in a LEACH protocol [3]

a) LEACH Protocols Vulnerabilities: Leach protocols categorize the nodes into two types powerful main nodes and poor-resourced nodes. In homogenous networks with not having enough resources generally not every node is typically connected to the main node. In most applications, these nodes most likely to have poor transmission ranges and can't reach the main node directly even if they could direct communication is generally requires more power consumption. These nodes will send the message by sending it to one another with multiple jumps. This method is useful for the nodes which are far from the main node but for intermediate nodes, it's not very effective. These nodes most likely will use more energy acting as a rooter. And their battery-life will be shortened compared with the others.

LEACH protocol also presumes every node can access the main node and while transmitting data it has enough power. Nevertheless, for saving energy LEACH uses a novel type of routing. It means routing turn over randomly among the nodes. In a nutshell, it works in rounds, and in every round, it's using a distributed algorithm to chose nodes dynamically. This equalizes the energy consumption for each node. In the example of Figure 4, there are 100 randomly distributed nodes, and the main node is located at 75m from the closest node. The simulation results show that LEACH spends up to 8 times less energy than other protocols.

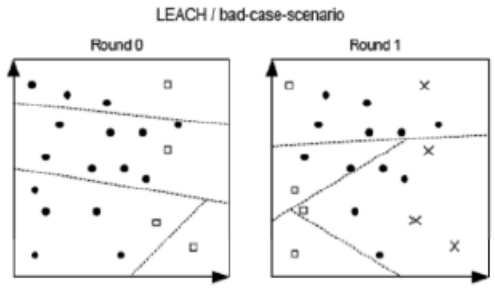

Fig. 4. LEACH Protocol's Bad Case Scenario [4]

B. Hierarchical Cluster-Based Routing (HCR) Protocol

HCR protocol is using GA(Genetic Algorithm) to build an energy-efficient system for any number of transmission. GA appoints the most appropriate node as the head of the cluster. The main station is using a minimum distance algorithm to assign each cluster to one another then the main station broadcasts full detail of the network to the nodes. The message contains, number of the head nodes, members in each cluster and which node is their head, and the number of transmissions for the connection. All nodes receive that message as a result of these clusters are formed.

a) Genetic Algorithm: After creating clusters data transfer starts. Nodes are is likened to pieces of a chromosome. The head nodes are represented as a 1 and others are represented as a 0. The fitness of a chromosome is determining by the density of the nodes and their energy usage. A population has many chromosomes but only the best ones are chosen for the next generation. At the beginning of the process, heads are chosen randomly. The frequency of survival determines the next generation. A node is presenting with 0 and 1 as mentioned. Then m number of nodes represented with m bits. The fitness of a chromosome is designed to minimize power consumption and improves total lifetime.

Fitness has 5 parameters;

- D, It is the sum of all distances from sensor nodes to the sink
- C, It is the sum of all distances from clusters head nodes to the sink
- SD, Standard deviation in cluster distances
- E, Transfer energy represents the total energy consumed while transferring the aggregated message from the cluster to the sink
- T, The number of transmissions to the main station.

$$F = \sum_{i}^{\square} \alpha(wi, fi), \forall fi \in \{C, D, E, SD, T\}$$

Fig. 5. Fitness Formula of a Chromosome

The initial fitness parameters can be set randomly weights(wi). In every generation fit chromosome is evaluated and the weights for fitness parameters are updated accordingly Figure 6.

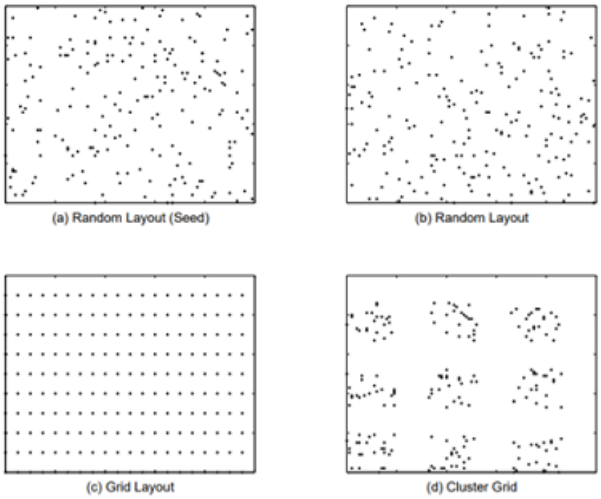

Fig. 6. Alive and Dead Node in Direct Transmission [5]

C. Stable Election Protocol (SEP)

Stable Election Protocol (SEP) is based on the remaining energy of the nodes. Each node can become the head of a cluster and it is determining by its remaining energy. This approach guarantees to keep every node at the same power level. SEP is also useful for two or three-level hierarchies. These systems have different types of sensors which are more powerful than others. Two-level hierarchies use advanced and normal sensors and three-level hierarchies use advanced, moderate, and normal sensors. In this type of system advanced and moderate nodes are more likely to be chosen for the head of the cluster due to their higher battery, transmission range, and data rate than the normal nodes. In this kind of systems, SEP is extensively prolonging the sensor network's efficiency.

D. Dissense Protocol

DISSense Protocol disseminates data and collects them. It's generally using in environmental monitoring applications which requires periodic sampling of some physical phenomenon. In short, the DISSense protocol gathers input in the desired sampling interval and computes and suitable schedule for the nodes. In that way, it generates a data collection tree. The schedule can change with transmissions. Under repetitive activities, nodes can activate more often and under long intervals, nodes can put themselves in an ultra power-saving mode. To disseminate to shared schedule DISSense protocol provides one to many backward channels.

DISSense protocol also achieves energy-efficiency by choosing which nodes must activate their radio receiver. With these methods, DISSense dramatically reducing the time the nodes activate. The main problem in DISSense is sending data at the correct time and sending reliable data. The size of the area, the density of the sensors, and transmission quality also affect the protocol. For instance, a reliable DISSense system may require retransmission several times. These transmissions should be repeated several times until at least one of them succeeds. Furthermore, in a denser network, the connection setup time can be significantly higher and the higher diameter means a higher number of jumps across the nodes and packets might corrupt during the process. Considering all of these problems we must make DISSense protocol be able to adapt all of these conditions. And also we must ensure high delivery ratios and high energy efficiency. DISSense's adaptive behavior is controlling by two metrics; Time to Resync(TTR) and Time to Recieve Data(TTRD).

In DISSense protocol the main node is responsible for the dissemination and scheduling according to data from the sensors. Figure 7 shows us the different phases of the DISSense schedule. In every period active phases are scheduling dynamically. Clock drifts and the lock inactivity periods must be synchronized in each cycle and a Guard Time Interval(GT) is predicting them at the beginning of the phase. Furthermore, a resynchronization procedure occurs periodically while the Resynchronization Interval(RI), and also this procedure realign the schedule and compensates clock drifts. Depending on the sampling period and time intervals, DISSense can be able to skip the RI procedure for few sampling periods. In that manner, it optimizes the overall protocol job cycle. The SK parameter determines the skip functionality. During the RI operation sensor, nodes exchanges routing beacons are gathering the information they needed and to build a tree which root node is sink node. Before the RI operation ends, DISSense ensures that the nodes share the same wake-up time for the next active phase, and send them their correct parent node information. After the RI operation, the Data Collection Interval(DCI) begins. In DCI each node transmits the data across the tree which is already built. Between two active phases, DISSense gets into the Ultra-Low-Power State(ULPS) by switching the transmitters to LPL mode with a 0:1 % duty cycle. Even in ULPS transmitters are not fully turned off because some nodes might be added during the ULPS and other nodes might be out of sync. While the ULPS the value of the duty cycle is very low and these cycles don't affect the overall protocol. The main schedule is only considered an active interval because it does not need to discriminate all of the phases. The active phase of DISSense operates on CSMA/CA MAC with 100 % duty-cycled radio. This has two benefits. First, it speeds up the building of the collection tree and the data collection process as a result of this it shortening the length of the active phase. Second, it reduces the inefficiencies related to broadcast transmissions under duty-cycled MAC protocols.

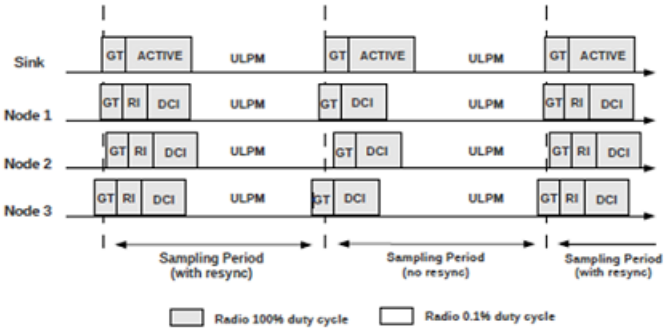

Fig. 7. DISSense Schedule Example[6]

E. Speed Protocol

SPEED protocol aims to acquire the desired speed across the sensor nodes. It has a two-tier adaptation. traffic diversion at the network layer and packet regulation in the local device then sending it to the MAC layer. It has a few components such as:

- An API.
- A delay estimation scheme.
- A neighbor beacon exchange scheme.
- A Nondeterministic Geographic Forwarding algorithm (NGF).
- A Neighborhood Feedback Loop (NFL).
- Backpressure Rerouting.
- Last mile processing.

NGF is routing the module and its purpose is choosing the next node to acquire the required speed. NFL and Backpressure Rerouting was designed to dissipate and diminish traffic load when congestion occurs. NGF can choose one of them. The last mile process provides API support and real-time communication services to the nodes. Real-time communication can be unicast, area-multicast, and anycast. Delay estimation is inspecting congestion and finds the related node. Beacon exchange is controlling location services and provides information to NGF for geographic-based routing. The details can be shown in Figure 8.

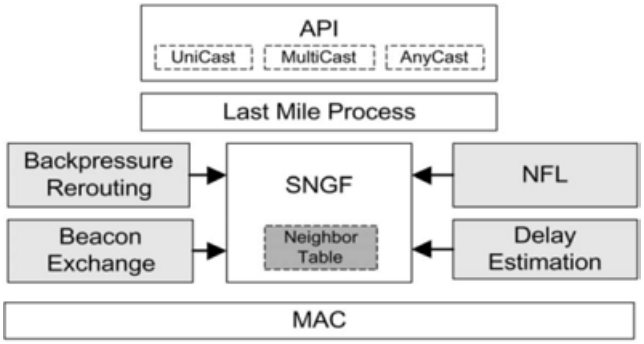

Fig. 8. Speed Protocol Design [7]

IV. Conclusion

In wireless sensors, the main problem is energy efficiency. There are a lot of energy-efficient algorithms and we explained some of them briefly. Every algorithm has advantages and disadvantages that's why there are many algorithms and most of them still developing. The technology is still new and in every case, some algorithm is much proper than the others. Figure 9 is explaining briefly the algorithm we chose.

Protocols	Comparisons
LEACH	1. The nodes organize themselves into local clusters. 2. Includes randomized rotation of the high-energy cluster-head position so not drain the battery of single node. 3. Give transmission energy homogenously.
HCR	1. Based on hierarchy of cluster head and sink. 2. One head for some nodes 3. Transmission through cluster head. 4. Work poorly because head die quickly.
GA	1. A branch of HCR is used to create energy efficient clusters for data dissemination in wireless sensor networks.
SEP	1. Increase system lifetime with increase stability. 2. Transmission energy heterogeneous.
DISSense	1. High power efficency with ultra power saving mode. 2. Synchronisation problems. 3. Poor data reliability 4. Useful for sampling a physical phenomenon
Speed	1. Faster transmissions then most of the algothms. 2. Less energy efficent.

Fig. 9. Summary of Energy Efficient Protocols

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