American Journal of Networks and Communications
2017; 6(4): 67-73
http://www.sciencepublishinggroup.com/j/ajnc
doi: 10.11648/j.ajnc.20170604.12
ISSN: 2326-893X (Print); ISSN: 2326-8964 (Online)

Review Article

Comparison of Energy Efficient Routing Protocols in Wireless Sensor Network

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To cite this article:

Abdul Ahad, Zakir Ullah, Bahrul Amin, Atiq Ahmad. Comparison of Energy Efficient Routing Protocols in Wireless Sensor Network. *American Journal of Networks and Communications*. Vol. 6, No. 4, 2017, pp. 67-73. doi: 10.11648/j.ajnc.20170604.12

Received: May 12, 2017; **Accepted**: June 1, 2017; **Published**: July 17, 2017

Abstract: The life of Sensor Network (SN) is mainly dependent upon power consumption. If the power dependence is managed efficiently, the network can go on for longer. Different protocols have been developed for power reduction of the sensor networks which have greatly minimized the power consumption of the said networks. Analysis of different routing protocols in WSN, and the results show major advancement in the life span of wireless sensor networks. In this paper classification and comparison of routing protocols in reduction of power consumption in wireless sensor networks will be present.

Keywords: Wireless Sensor Network (WSN), Base Station (BS), Sensor Node (SN), Cluster Head (CH), Quality of Service (QoS)

1. Introduction

According to Wikipedia.org the definition of wireless Sensor Networks is "Wireless sensor networks (WSN), sometimes called wireless sensor and actuator networks (WSAN), are spatially autonomous distributed sensors networks to analyse environmental or other physical conditions, such as sound, pressure, temperature etc. and to pass data cooperatively through the network to a main location."

The first ever efficient wireless sensor network was Sound Surveillance System (SOSUS), which was used by the US Military in the 1950s to track and analyse the Soviet submarines. This network used hydrophones – which were submerged acoustic sensors, distributed in the Atlantic and Pacific Oceans. Besides war, this technology has served greatly in analysing and studying the wild life and volcanic activities undersea. A project of Integrated Wireless Sensor Networks was initiated in 1966 at the Science centre of Rockwell at Los Angeles which produced Integrated Wireless Micro sensors. Then at the University of California, a project for designing very tiny sensor networks, called motes, was started. The purpose of this project was to produce such tiny wireless sensor network system (WSNS) which can be integrated, literally, into anything. It should be so small like a speck of dust or a grain. Despite the tiny size, the WSNS should be able to efficiently sense, compute and communicate data to a base station.

The sensor networks can be used for many purposes which include detection of temperature, motion of objects, pressure of air, amount of certain gasses in the air, vibration of molecules, or even the presence of pollutants in some medium. Now, for communicating the collected information back to the base station (BS), the WSN utilizes its small nodes which carry the data from hope to hope towards the BS. It is known as that the WSNs are usually deployed in unattended and solitary environments, therefore, these Networks are composed of small sized nodes which communicate with each other to pass on information to the BS.

2. Related Work

In order to operate, the WSs need power, therefore, the WS Nodes are built with tiny size batteries which are capable of

storing only a limited power capacity. These small networks with numerous WS Nodes together compose a WSN. Because of the limited power capacity of the WS Nodes, the WSN will soon be non-functional as the nodes will get out power. Hence it shows that routing in a WSN is the most challenging part, for which many researches have been carried out. Numerous algorithms are proposed to minimize the amount of total energy consumed. One such algorithm proposed is that data should be transmitted through the shortest paths in order to use minimum distance to reach the BS. But by doing so, if all the network traffic starts using the shortest path, the nodes over that path will get out of power, rendering those nodes non-functional.

Here the objective is to sustain the network life time by maintaining power on the nodes. If the power over the WSN is managed properly, the network will go on for longer. Therefore, the network needs to use such nodes which are significantly smaller, having the size lesser than a cubic centimetre, have less than a hundred grams' weight and most importantly use ultra-low power to avoid frequent use of a power substitute. When these micro nodes, get below a certain threshold of power, they would use the surrounding environment to refill their power bank through a technique known as Energy Scavenging or Harvesting.

Following are some of the terminologies used in WSNs:

Sensor Field: It is the region in which the sensors are deployed and are inter connected to pass the sensed data to the base station.

Sensor Nodes: it is the main component of the WSN, which senses, collects and forwards the information to the base station.

Sink: it is that important node of the WSN which receives data from the WS Nodes, process it, store it and then communicate it to the task manager. It is also known as the data aggregation points because they reduce total number of communications over the network, thus reducing the power consumption significantly.

In figure 1, All the technologies which are needed to run WSN are shown.

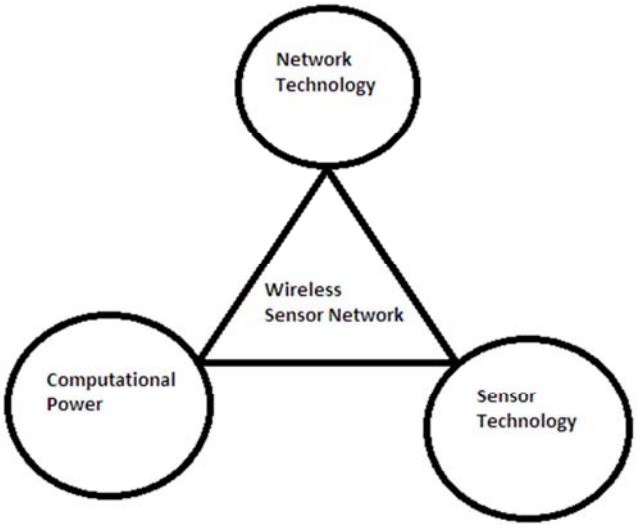

Figure 1. *Technologies involved in WSN.*

Task Manager: it is also known as the Base Station. It collects the data over the network and stores it for further needs. Also it can send commands to the network for retrieving specific type of information or any other commands. It also acts as a gateway to other networks and an interface for humans. Mostly this could be a laptop or workstation.

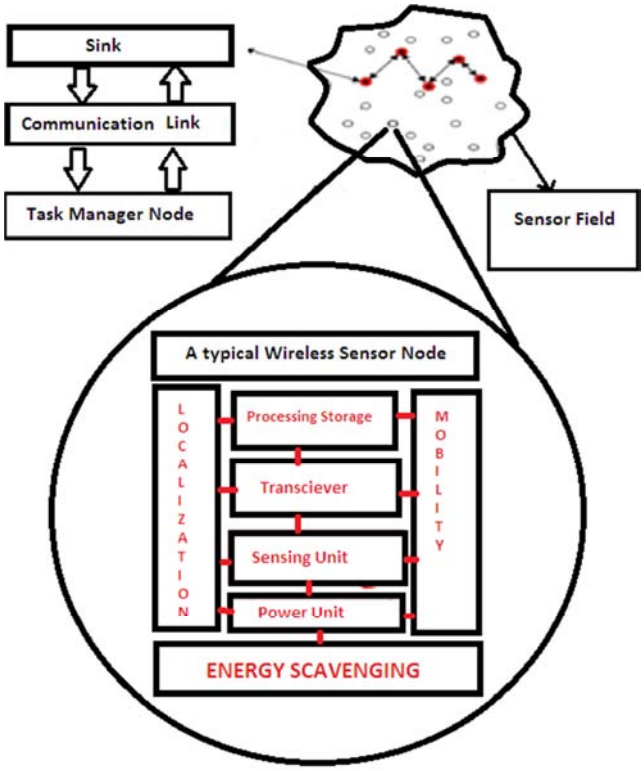

Figure 2. *The Sensor networks communication architecture.*

In figure 2 the sensor network communication architecture is shown. In this structure of joint sensor nodes, all the sensor nodes are connected with each other to pass on the information to the BS. The pivot component of this joint network is the sensor node. A sensor node consists of the following components: processing storage, transceiver, sensing unit and power unit. The sensor unit consist of an Analog to digital converter (ADC) which senses the data and passes it on to the processor. Whereas the communication unit carries out the commands/ queries of the processing unit to the outside network. The processing unit is the most complicated unit of the wireless sensor node. It controls almost all the components of the node. It computes the power consumption of delivering information from one node to another, monitors ADC, processes the received information etc. The power unit is responsible for provision of power to the rest of the components. Some optional components also may be included in this structure: Localizing unit and mobilization unit. A vital advantage of the mobilization unit is that it provides mobility. Each node within the vicinity of the network can move freely. It senses, collects, processes and forwards the collected information to the base. It also provides localization to the collected information. Other nodes that send information to a node, it processes it and then forwards it to the nearest node, so that little power be consumed in this process. Besides these, the sensor

node also collects energy from its surrounding. It may be in the form of sun light, heat or vibrating bodies. This phenomenon is called energy scavenging. As the nodes are very tiny in size and they need very less energy to survive, they also have limited energy storage. Therefore, the energy scavenging method saves a lot of energy for the node. Lots of researches are being carried out to further enhance the energy scavenging method in WSN nodes and also to devise alternative such methods.

In [1], sensor field is the area where the sensor nodes are placed. These sensor nodes collect data such as temperature, pressure, humidity, sound, vibration, motion etc. This collected data is then passed on to the sink either directly or through other communicating sensor nodes. The sink then passes on the collected data to the task manager or base station where it is further processed for elicitation of information.

3. Routing Protocols in WSN

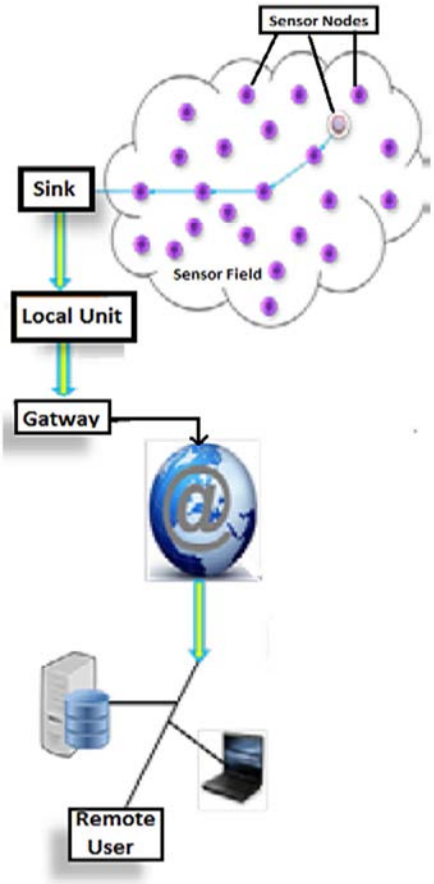

Figure 3. *The communication between sensor nodes with sink in WSN.*

As the main goal of this paper and WSN, the energy reduction is very necessary for the life span of WSN. Energy is largely consumed in computational processing and communication which can be controlled by designing an energy efficient and multi-hot algorithm. The energy can also be saved by limiting the size of the packets and the numbers packets that are being routed in the network. If the number of tasks, a node has to perform, is limited, can also reduce the power consumption of the node. Besides, if idle states of the node are controlled properly by implementing specialized algorithm can significantly increase the power consumption of WSN. As the nodes are very tiny in size and they need very less energy to survive, they also have limited energy storage. Therefore, the energy scavenging method saves a lot of energy for the node. Lots of researches are being carried out to further enhance the energy scavenging method in WSN nodes and also to devise alternative such methods. Energy awareness is an integral part of the routing protocols in WSN [2].

Based on the network structure, the routing in a WSN can be divided into the following categories:

(1) Flat Based Routing
(2) Hierarchical based Routing
(3) Location based Routing

3.1. WSN Architecture

There are further two types of WSN architecture.

3.1.1. Layered Architecture

The main advantage of the layered architecture is that each node communicates within a low power and short distance with nodes of the other layers. Below in figure 4, a layered architecture of a WSN is shown. In this architecture, a powerful base station (BS) is installed at the core of the layered network. Each sensor node in their respective layer has the same hop-count to the base station. The BS is connected to a wired medium as backbone whereas the WSNs provide remote connectivity. In clustered architecture the WSNs are arranged in clusters or groups. Each group has a dedicated Cluster Hop (CH). The nodes communicate with their respective CH, which collects the information from all its surrounding nodes, processes it and transmits the resulting information back to the BS. The formation of cluster and CHs should be a self-governing and distributed process.

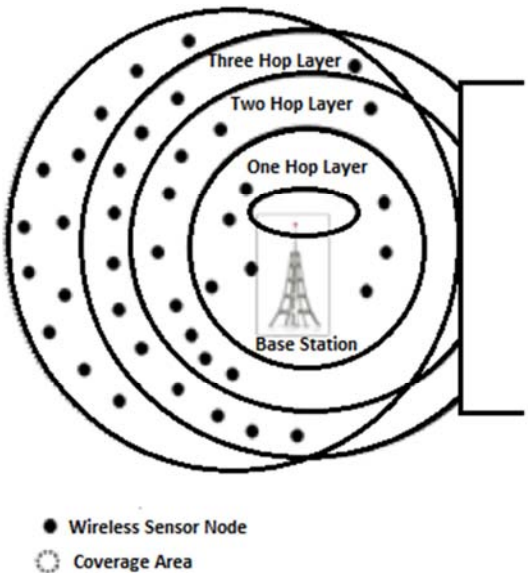

Figure 4. *The Layered architecture in WSN.*

3.1.2. Clustered Architecture

In clustered architecture the WSNs are arranged in clusters

or groups. Each group has a dedicated Cluster Hop (CH). The nodes communicate with their respective CH, which collects the information from all its surrounding nodes, processes it and transmits the resulting information back to the BS. The formation of cluster and CHs should be a self-governing and distributed process.

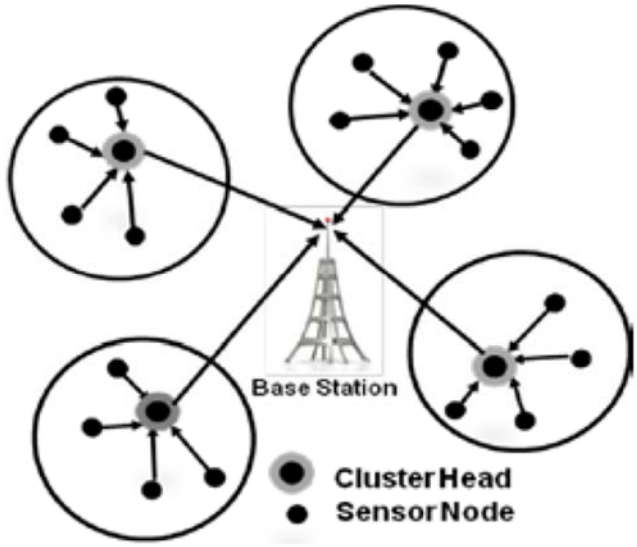

Figure 5. *The Clustered Architecture in WSN.*

3.2. Classification of WSN Protocols

There are two types of sensor nodes: homogeneous and heterogeneous. So the protocols can be classified whether they are being operated on flat topology or hierarchical. Protocols in WSN can be categorized based on the structure of network, establishment of path and communications [3].

According to [4], the WSN protocols can be categorized as follows:

(1) Flat Routing Protocols
(2) Hierarchical Protocols
(3) Location based Routing Protocols

Among the above listed protocols, the Hierarchical protocol is the most efficient one regarding power saving. This technique works on the basis of clusters. Clusters are collection of multiple hops which are governed by CH. In this mechanism direct data transfer is not supported, rather each hope gets data from its neighbor and pass it on to another one, this process goes on until the data is delivered to the sink. Currently two energy efficient protocols are in use, namely LEACH (Low Energy Adaptive Cluster Hierarchy) and HEED (Hybrid Energy Efficient Distribution). Despite their efficiency and wide use in the WSN, there are still a few disadvantages of these protocols. Like the CHs remain active more than the other nodes, therefore, they exhaust earlier than other nodes and in such scenario the one entire segment of the network might lose. Besides, these protocols are suitable for small networks and they quite fine with them, but for large networks they have to find and pass on the data to the next CH, which they assume to be similar in energy, but they are actually not. So a sufficient amount of energy is wasted in this process. Therefore, these protocols are applied to small area networks which may be spread out in a building or couple of building. Besides, the SNs must be situated at such a place where they are more visible to light wherefrom they can regain their energy in case of energy drain out, especially the CHs. The networks based on these protocols can also deployed in dark environments, but they have to be provided with some other energy source, so they that they might regain their power easily.

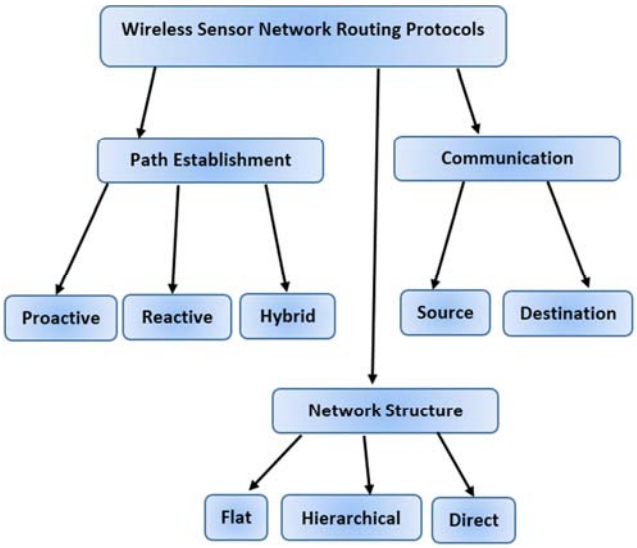

Figure 6. *Classification of WSN Protocols.*

4. Comparison of Routing Protocols in WSN

As mentioned above that according to [4], the WSN protocols can be categorized in hierarchical protocols, flat routing protocols and location based routing protocols. In the flat based routing, each node in the WSN is given the same functionality i.e. each node acts as transceiver and any node could be selected as CH based on the protocol algorithm. It means that there is no specific difference among the nodes as CHs, and common nodes but same role is played by all the nodes. In hierarchical routing protocol, as is cleared from its name, a hierarchy of nodes is formed. Each node has a separate role i.e. some are common nodes that just senses, collects and forwards data, other just listen to their neighbour nodes, receive and forwards their data. Down the hierarchy, there are other specialized nodes called CH. They act as central hops for a segment of the WSN, manages and collects data from its subordinate nodes and forwards them to the sink by communicating through other hops till the data reaches the sink. Whereas in the location based routing protocols, the positions of the nodes are used to route data. In this type of protocols, the most suitable routing path is determined by checking the positions of the nodes. In this scenario a path may be established by different algorithms, like shortest path available, but this algorithm has a prominent disadvantage such that if all the traffic is subjected to that very path, soon these nodes along the path will run out of power. Therefore,

another algorithm can be used such that, for a specific time interval, the path is to be re-established by selecting some nodes other than previously used.

Besides the above categorization, routing protocols in WSN are also categorized in node centric, geo centric, data centric and Quality of Service (QoS) based routing. In node centric communication the concentration is subjected on the node itself. Here the notion is that the routing protocol establishes routes on the basis of nodes (which includes their current status, i.e. power capacity, the distance from other nodes etc.). But there is again a disadvantage of this method that is the communication in WSN should not be bound to a specific static routes, rather it should be so dynamic that the network decides the best way for itself. Therefore, the geo centric and data centric approaches are mostly owned. In data centric approach the sink sends signals to a specific region of SNs. The nodes in that particular region respond to the sink with pretty redundancy because usually there are many sensors in the same region and they all provide usually same data which ultimately results in redundancy. Due to redundancy, not only redundant data is to be processed many times by the sink but also causes sufficient power loss. On the other hand, in geo centric approach, the positions of the nodes are exploited to form the routing to the target nodes. The location information of the nodes can be used to improve the routing protocols and devise new ways of path establishment. Another routing protocols are QoS. In these protocols the latency, and energy consumption are very low whereas the data through put is high. Here the focus is on quality which will definitely cost more than the other methods but it is comparatively better. Here the bandwidth and capacity of the network nodes are increased for better performance.

Another way of categorizing the routing protocols is reactive protocols and proactive protocols. In proactive protocols the data paths are set without sending any data. In this method the advantage is that if a node has to send data, then it will not cause any delay for establishing path rather it will quickly send the data without any latency. On the other hand, there is a disadvantage too. If the network does not send any data, then the path establishing was just a waste of time, energy and resources. Besides, if a node wants to send data to another node, whose path is not optimally routed, the network either has to make another path or may send the data through the non-optimal path, which in both cases wastes resources. Whereas in the reactive method, a node requests for data transmission. So the path establishment is started on demand till the destination node with an optimal path without consuming any extra processing time or energy but here it will increase the latency. Another similar way of categorizing the wireless protocols is source-initiated and destination-initiated protocols. Like the proactive method, in source-initiated protocols, the source announces the transmission of data and therefore establishes path from source to destination. Whereas in destination-initiated protocols, the destination makes demand of data from one or more nodes in particular region of the network and starts planning its routing path to it. Following is the Taxonomy of routing protocols in WSN [5].

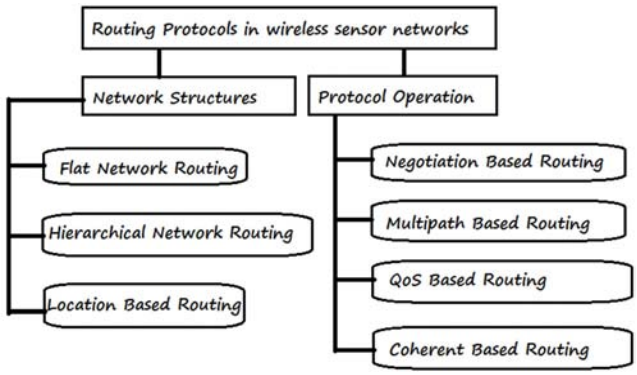

Figure 7. *The Hierarchy of Routing Protocols in WSN.*

In this paper the following protocols are compared and discussed.

Table 1. *Routing Protocols Discussed in this Paper.*

Routing Protocols	Designing Characteristics
FBR	Flat Based Routing
HR	Hierarchical Routing.
LBR	Location Based Routing.
NB	Negotiation Based.
MBR	Multipath Based Routing.
QBR	Query Based Routing.
QOSBR	QOS Based Routing.
CBR	Coherent Based Routing.
LEACH	Low Energy Adaptive Clustering Hierarchy.
TEEN	Threshold sensitive Energy efficient sensor network.
ReBR	Reactive Based Routing.
PrBR	Proactive Based Routing.
HBR	Hybrid Based Routing.

In this paper different protocols will be categorized in different ways.

Table 2. *On the basis of Structure.*

S. No	Name of Protocols
1	Flat Based Routing
2	Hierarchical Based Routing
3	Location Based Routing

Table 3. *On the basis of Operation.*

S. No	Name of Protocols
1	Multipath based Protocols
2	Query based protocols
3	Negotiation based protocols
4	QoS based protocols
5	Coherent based routing techniques

Table 4. *Classes of Routing Protocols.*

S. No	Name of Protocols
1	Location Based Protocols
2	Data-Centric Protocols
3	Hierarchical protocols
4	Mobility based protocols
5	Multipath based protocols
6	Heterogeneity based protocols
7	QoS based protocols

In table 4, the given classes are proposed by [6]. Besides the above listed protocols there are a few more protocols which,

after research and analysis of other such protocols, have come into existence. These protocols are FEAR (Fair Energy Aware Routing) [7], BEER (Balanced Energy Efficient Routing) [8] and EAR (Energy Aware Routing) [9]. In FEAR, they have adapted multipath routing protocols for the nodes to route their data to the sink. This way they fairly utilize almost all the nodes along the multipath way so that some of the nodes may not be energy scavenged. In this way the network load is fairly balanced and no nodes faces extra network overhead. In EAR, a similar mechanism is followed but each path is further sub-divided into multi paths. This way is even more efficient than that of the FEAR because almost all the sensor nodes are utilized in this way of communication and no nodes are drained out of energy due to work overload. In the BEER protocols, they have combined FEAR and EAR. Besides the multipath and sub multipath communication, a probability has been added to the network which, apart from measuring the residual energy of the network, also counts the number forwarding tables that a forwarding node has.

5. Suggestions

As for suggestions, from the detailed discussion and comparison of the protocols that geo centric communication method is the most suitable one for most of the networks. As it exploits the physical positions of the Wireless Sensor Nodes to establish the path along the network. But other algorithms are to be used to prevent the nodes from always selecting the same path otherwise all those nodes along the path will run out of power soon. Besides, other such algorithms be deployed alongside which ensures sending data through a route for specific time interval, and then the path is to be broken and re-established including nodes other than previously selected ones so that a few nodes are not drained out of power. This way the data will get transmitted continuously and network will stay live for longer.

6. Conclusion

In this paper we started with introduction of WSN and its parts, how they combine together to form a Wireless Sensor Network and how they communicate with each other to keep the network live. Then each part of the WSN was discussed with its functionalities and responsibilities. Then we presented the need of WSN technology in today's era and highlighted its burning issues and fields in which most of the researches are being carried out. Then we came down to the discussion of routing protocols in WSN. First we discussed those factors that are necessary for the long lasting of the WSN. Those were energy efficiency, less processing, and intelligent routing mechanism. Then we discussed some initial protocols that were in use and others which were later on added and deployed in WSN. Above all the energy efficiency was discussed in detail that how energy is used in WSN and how important it is to keep all the odes of WSN live all the time. Therefore, such algorithms and protocols be devised which will route the data throughout the network efficiently without losing any extra energy. After that now to discussed different architectures that are proposed and some are deployed for efficient routing protocols. Among these the two were layered architecture and clustered architecture. After that now to listed some famous WSN protocols in different categories. Some of which were flat, location based and hierarchical routing protocols. Other protocols like LEACH and HEED were discussed, their pros and cons were highlighted. In section IV, it is coming to the comparison of routing protocols. Here again we compared the functionality of flat, hierarchical, location based and hybrid protocols. From which we found that hierarchical and sometimes hybrid protocols are usually the best cases for routing protocols. After that in another categorization which discussed the Wireless protocols as node centric, geo centric, data centric and QoS based routing protocols. And from this comparison we found that geo centric routing protocols are the ideal choice for implementation. Also QoS base routing protocols are better than others to implement because it ensures secure data delivery though at the cost of some other factors. In the end it shows that all the discussed protocols in different tables, showing their acronyms and different categorizations. At the very end three more protocols which were FEAR, BEER and EAR are discussed [12]. FEAR, BEER and EAR protocols have recently been emerged and adds special functionality to the routing in WSN. BEAR is the combination of EAR [10] and FEAR [11], therefore, it is better to be implemented as compared to its companions. So, this paper presents that what are the mostly used protocols in use in WSN today, what protocols play better role than others and which protocols need modification to be efficient enough for implementation in WSN. Besides, pros and cons of each protocols are shown which helps in better understanding of each protocol.

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