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A Review of Protocols for Energy-Efficient Wireless Sensor Networks

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Abstract:- Wireless sensor networks are made up of a group of nodes that are spread out in an environment. Nodes in these networks have very limited energy sources, so they need to collect and send data efficiently. To send data in this way, energy-efficient routing protocols have to be used. The main purpose of these protocols is to save energy and make the network last longer while in routing. In this paper, we are reviewing some routing protocols that can be used to make wireless sensor networks energy-efficient. (Abstract)

Keywords:- *Energy Efficient, Wireless Sensor Networks (WSN), Routing Protocols.*

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are a rapidly expanding area of wireless communication that has seen tremendous growth in recent years. Micro-Electro-Mechanical Systems (MEMS) are improving at a rapid pace, and technological breakthroughs in the field are allowing for the deployment of small, low-cost, inexpensive, and smart sensors in physical environments that are connected via wireless links. [1]. It opens up new possibilities for detecting physical characteristics like as motion, pressure, temperature, sound, vibration, attacks, and so on in a range of civilian and military applications, but it comes with significant drawbacks. It has a finite amount of energy and does restricted computing [2]. A sensor network is a sensing, processing, and communication infrastructure [3] for acquiring local data and making global choices about a physical environment. The measured values are subsequently sent to a data collecting station to be processed further. Nodes in a sensor network are small, low-cost devices that connect together to form a heterogeneous network. The flooding strategy is used to communicate information from sensor nodes to the base system [2]. Wireless sensor networks can be classified into two types: structured wireless sensor networks and unstructured wireless sensor networks. In an unstructured wireless network, sensor nodes are deployed in an ad hoc way throughout an area. All sensor nodes in a structured wireless network are dispersed in a pre-determined pattern [4]. Wireless Sensor Network (WSN) applications adhere to the IEEE 802.15.4 specifications. With the IEEE 802.15.4 standard, the wireless medium access control layer and the physical layer of low-rate wireless personal area networks were specified for the first time. In addition to its wireless medium, WSN has several characteristics such as a small power consumption, low cost, and a low data rate. WSNs have a number of characteristics, including large numbers of sensors, collaborative signal processing, ease of deployment, self-configurability, self-organization, and the absence of an infrastructure. [5]. The implementation of these sensor network applications necessitates the use of a variety of networking approaches.

Different protocols and algorithms have been developed; however, they are not necessarily well matched to the particular characteristics and application needs of sensor networks.

Sensor networks are used in a variety of applications because of to their unique properties. Examples may include health care industry, the military, the residential industry, and the commercial industry. [1]. For setting the network and the process of collecting information from the target environment, many data collection protocols are developed. Data from the nodes must be gathered and delivered to the base station in each cycle of the data collection protocol, from which the end user may access the data. To accomplish aspects such as energy efficiency, the sensor nodes employ various data aggregation algorithms. The sensor network is mostly made up of four components. They offer communication across networks, define the cluster head that transmits information to the base station, and provide the central locations for data correlation and computational resources in the sensor network, for example [3]. Wireless sensor networks use the network layer to send and receive data. Sensors and controllers use electric and magnetic field sensors, infrared sensors, pressure sensors, and environmental navigation sensors [6]. Sensors are low-cost, high-performance devices having several integrated sensing units. The sink node is the hub of the sensor network. Sensor nodes connect with the sink directly. Motes are another name for wireless sensor nodes. A series of multi-hop, short-distance, and low-power wireless networks connect sensors to the internet. These linkages rely on another network to transport information to a certain location, after which data aggregation and analysis will take place [37]. Wireless sensor/actuator networks are a cost-effective way to avoid installing a costly cable system and deploying dispersed monitoring and control devices. The self-healing networks allow nodes to reorganise their connection ties by discovering alternate paths around powered down or failed nodes, allowing them to recover from failure. Self-organizing networks allow a new node to join the network and function without the need for human involvement [5]. Nodes in a wireless sensor network are capable of monitoring their surroundings, as well as collecting, storing, sensing, and transmitting information about their surroundings. Sensor nodes can be deployed anywhere on the network without the need for any special infrastructure. The sink can communicate with the rest of the world through the internet and gather data from the sensor node. It processes the acquired data before sending the information to the user through the internet [7].

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Ant colony optimization may be used to tackle a variety of optimization challenges in wireless sensor networks. Using optimization approaches, the network lifespan may be extended. It is made up of stable nodes that use the shortest pathways to transport data from the source to the base station. To reduce energy usage, more data packages should be sent over shorter pathways [2]. Sensor network protocols are capable of connecting to a large number of sensor nodes. By controlling the quantity of connectivity and storing the important data, these networks' battery life may be prolonged. This information is utilised in the local store for each sensor. The fundamental issue with wireless sensor networks is that battery life is restricted owing to sensor node size. All of these components, such as battery-storing memory, CPUs, and battery size, must be compact. In a wireless sensor network, energy consumption is higher than internal processing, and sensed data and routing information must be supplied so that information may be correctly utilised before any calamity arises [8].

A fundamental problem in developing large-scale sensor networks is ensuring that sensor nodes provide constant information to mobile sinks while maintaining uninterrupted connectivity. When caching is done correctly, it may cut a lot of network traffic while also increasing data availability at the sink [7]. In wireless sensor networks, caching is employed. It is a technology that allows any computing system to access data more quickly. Because cached material may be saved and accessed as needed, its accessibility is improved [8]. Multiple sinks can be found in a Wireless Sensor Network. If a system has more than one sink, the Wireless Sensor Network generates the same query. Each sink will have its own path established to the source node in such a system, which is not needed. Caching is necessary for these sorts of problems [7].

The large number of sensor nodes in the sensor network is densely distributed, and neighboring nodes are quite close to one another. Because of this, it is expected that multi-hop communication in sensor networks will consume less power than standard single-hop communication. Long-distance wireless communication suffers from signal propagation problems, which are mitigated through multi-hop communication [1]. A grid is also used to organise the sensor field. A grid of square cells makes up the grid. There are a number of sensor nodes in each square cell. The source receives a request from the sink with a sensor node. A multiple sink might be located anywhere in the sensor field, allowing a request to be sent from any point in the sensor network [7]. Sensor nodes have a finite amount of power that can't be replaced. Traditional networks strive for a high level of service offering. Sensor networks are primarily concerned with power saving. These networks must include built-in trade-off technologies that help the end consumer to extend the network lifetime in exchange for a lower throughput or a longer period between transmissions. Sensor nodes have a larger magnitude than adhoc network nodes. A sensor network's topology is constantly changing. Sensor nodes are susceptible to failure and are extensively distributed [1]. Different MAC protocols are required for different types of wireless sensor network applications [9].

In order to extend the lifespan of the network, the wireless sensor network architecture makes use of energy-conscious processing, multi-hop communication, and density management techniques. WSNs should fail for a variety of causes, including energy depletion or node destruction. In the implementation of sensor networks, there are still a few obstacles to overcome. Limited power capacity, dynamic topology, a lack of application support, manufacturing quality, service quality, and environmental considerations are among these challenges [3]. The most difficult aspect of designing a wireless sensor network is creating a protocol that allows the deployed nodes to act in a coordinated and cooperative manner. All node aspires improving the usefulness of its function. To function in a meaningful and effective manner, the entire network requires a balance in resource allocations. However, hierarchical routing systems have several advantages, including scalability, longevity, and energy economy. Weak nodes choose the cluster head using a combination of the two criteria below:

- As a general rule, the cluster's head node should have more residual energy than the other nodes.
- They are separated by a smaller distance than the others [3].

Micro sensor networks are a type of network sensor that collects data from several dispersed sensors. There is embedded computing in each sensor node, as well as a variety of onboard sensors, such as seismic, infrared (IR), acoustic, magnetic, and tiny radars and imagers. These sensors can be used to see what is going on around them. Storage, wireless connectivity to other nodes, and information about where and how they are located can all be found through local positioning algorithms or the global positioning system [10] and will be available onboard. Sensors create data, which is referred to as sources. For processing and analysis, the data is sent to one or more sinks. The measurement reaches the sink without any alterations. The transport of data might take place in either a push or pull manner. In push mode, sources continuously transfer data to a remote, which is called the sink. When using pull mode, data is just transferred if a sink request is made. Multi-hop message relay is used for the major source-sink connection. Generally speaking, sensors located closest to a sink will deplete their batteries faster than sensors located further away, whereas sensors located further away will retain more than 90 percent of their initial energy. This is because sensors located close to a sink are shared by a greater number of sensor-to-sink paths, have a greater message transmission burden, and therefore consume more energy. Energy holes are caused by uneven energy depletion processes, which affect network performance. If all of the sensors across a sink lose power, this will cause the sink to be disconnected from the network, resulting in the failure of the network. Because it is not possible to physically replace or recharge sensor batteries owing to operating constraints, it is desirable to balance and minimise energy consumption across sensors [11].

Energy consumption is a major concern in wireless sensor networks. It determines the lifespan of a battery-powered sensor network [9]. Energy consumption in a sensor network might come from either valuable or inefficient sources. The useful energy consumption may be attributed to data transmission and reception, query processing, and query and data forwarding to neighboring nodes. Hierarchical (clustering) approaches can minimise helpful sources of energy consumption, whereas numerous algorithms and protocols can reduce wasteful sources of energy usage [12].

II. ENERGY EFFICIENT ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

Energy efficiency is a critical issue in wireless sensor networks (WSN). As networks grow in size, the amount of data generated grows as well, all of which uses a significant amount of energy, leading in a node's earlier expiration. Some energy-efficient routing protocols are as follows:

A. Leach

LEACH is an acronym for "Low-Energy Adaptive Clustering Hierarchy." Most nodes connect with the cluster heads (CH) in this form of hierarchical protocol [13][14]. It has two phases:

First is Setup Phase: The clusters are grouped and the Cluster Head (CH) is identified in this phase. CH's job is to collect, wrap, and forward information to the BS [15]. The Second is Study State Phase: The nodes and CH were created in the previous stage; however, data is sent to the Sink in second state of "LEACH". This usually lasts a little longer. The period of this process has been enhanced to reduce overhead. The cluster head will be contacted by each node in the network, and the data will be transferred to it. The CH will then initiate a schedule for data flow from each node to the BS [14][15].

B. Pegasis

PEGASIS is an acronym used to present "Power-Efficient Gathering in Sensor Information Systems." It's a chain-based protocol that builds on the "LEACH." To direct and obtain information, each node in "PEGASIS" only transfers to a close neighbour. It takes turns talking with the BS, which saves energy used in each time [16]. The nodes are organised in a chain that is completed by sensor nodes and an algorithm. The BS may compute this chain and communicate it to all sensor nodes [17]. This is believed that every node in the network has global information about the network and that a greedy approach is utilised to construct the network's chain of nodes. As a result, the chain's construction will start at the farthest node and work its way closer. To avoid the inactive node, the chain is reconstructed in a similar manner whenever a node expires [18].

C. Teen

TEEN stands for "Threshold Sensitive Energy Efficient Sensor Network Protocol". The TEEN protocol is a hierarchical rule is created to meet the situations like as abrupt modification in sensed variables like temperature. TEEN [19] was the first protocol created for a reactive network. In order to decrease the number of times of data transfer, hard threshold is used to enable nodes to communicate only when the detected attribute is within the limit. A soft threshold decreases number of transmissions with the help of omitting any broadcasts that might occur when the observed property is modified little or not at all. In terms of energy saving and reaction speed, TEEN is suited for time-sensitive applications. It also gives the user the ability to regulate the amount of power used and the accuracy of the measurement to fit the application [20].

D. Apteen

APTEEN is an acronym for "Adaptive Threshold Sensitive Energy Efficient Sensor Network." APTEEN is a development of "TEEN" that intends to collect episodic data as well as respond to time-constrained occurrences. Almost immediately after the base station builds the clusters, the cluster head. sends out all of the nodes' parameters, threshold values, and transmission schedule [19]. This is followed by a period of knowledge accumulation, which has the effect of sustaining power. In comparison to "TEEN," the key advantage of "APTEEN" is that nodes consume fewer power. The key disadvantages of APTEEN, on the other hand, are the complexities and the longer deferment latencies [21].

E. Directed Diffusion

A data-centric routing technique called directed diffusion collects and distributes data in wireless sensor networks [22]. For example, when the sink requests certain sensor data, it was built to satisfy this requirement. Goal is to reduce energy usage and hence network life. To accomplish this purpose, it uses message exchange to keep node interactions restricted. This protocol has a one-of-a-kind feature: a localised interaction that allows for multipath delivery. This one-of-a-kind feature, along with the nodes' ability to answer to the sink's queries, leads in significant energy savings [13][22].

F. Eesr

A flat routing technique [23] known as EESR (Energy-Efficient Sensor Routing) is meant to improve power consumption and data delay in wireless sensor networks while still allowing for scalability. The Gateway, Base Station, Manager Nodes, and Sensor Nodes are the primary components of a network infrastructure.[24][38]. Their responsibilities are as follows: The gateway relays signal from management nodes or establishes new networks for the base station, which has more features than standard sensor nodes. It communicates with the Gateway by sending and receiving messages. It also communicates with sensor nodes, sending and receiving queries and data. Both the Manager Nodes and the Sensor Nodes collect information from their surroundings and transmit it to the base station in a single hop. [23].

III. LITERATURE SURVEY

W. R. Heinzelman et al. [25] proposed Sensor Protocols for Information Through Negotiation in a 1999 paper, which uses meta-data as a marketing tool before transferring actual data. When a node receives data, it broadcasts it to its neighbours (ADV), and only those who are interested may respond with a request message (REQ). The data-carrying node may then transfer data (DATA) to the nodes that have requested it. It eliminates flooding issues such as duplicate information transmission and sensing area overlap, hence increasing energy efficiency. The inability of SPIN data advertising to assure data transfer, specifically in the context of remote nodes, was its primary shortcoming.

In their study C.Intanagonwiwat et al. [26], investigated at Direct Diffusion like a data-centric protocol, with the main objective of diffusing data among sensor nodes utilising a method for information depending on communication preference. The sink sends out an inquiry to its neighbours. Data may be sent by nodes who are interested in replying to the query. Additionally, the entry for interest comprises numerous gradient fields. A gradient was a response connection to the neighbour who generated the interest. It was defined by the data rate, duration, and expiry time extracted from the fields of the received interest. Thus, routes between sinks and sources were built using interest and gradients. Numerous pathways can be built in such a way that one of them is reinforced. Thus, the most efficient method was chosen, consuming the least amount of energy. If the link among the origin and the sink fails, another path is used to connect the two points. As a result, the overhead was raised by retaining the alternate pathways. As a result, it may be impossible to apply it to huge sensor networks.

Lindsey et al. (2002) defined the "Power Efficient Gathering in Sensor Information Systems" (PEGASIS) protocol as an upgraded version of the LEACH protocol in their paper [27]. This chain-based technique outperforms LEACH algorithms in a number of ways. Every node combines the acquired information and then transmits it for further node in the sequence for submission of it to the sink. Grouping of nodes in a chain is obtained using a greedy method; the base station then computes the chain and broadcasted it for other sensor nodes. PEGASIS saves power over LEACH in a variety of ways: To begin, the distances travelled by the majority of sensor nodes during local data collection were significantly fewer than those travelled when sending to a cluster head in LEACH. On the other way, each cycle of communication involves only one node transmitting to the Base Station. Additionally, the number of broadcasts to the BS has been decreased. It makes use of multiple hop transmission and selects just one node to transfer data to the sink or BS, whereas LEACH makes use of one hop transmission. Due to the elimination of the overhead associated with dynamic cluster creation.

PEGASIS introduces excessive latency for remote nodes in bigger networks. And the one designated node may act as a bottleneck by being responsible for data transmission to BS. It was predicated on several assumptions that rendered solutions impractical in the actual world, such as any node transmitting data straight to BS. All WSN nodes are aware of the sensor nodes' positions.

Younis et al. (2002) introduced an Energy Aware Routing method named EAR [28]. In their paper energy-aware routing nodes were grouped into Cluster heads and gateways. Gateways preserve the nodes' statuses and establish multi-hop paths. The sink communicates exclusively with the gateway. The gateway notifies other nodes of the slot in which they should listen for other nodes' transmissions and the slot in which they should transmit collected data. The nodes may operate in these modes: sensing-only, sensing-relaying, sensing-relaying-only, and inactive. A cost function was constructed between any two nodes in energy utilization, latency minimization, and other evaluation metrics, and it could be applied between any two nodes. Based on the value of this cost function, the shortest route between sensor nodes and the gateway was identified.

F. Akyildiz et al., (2002) provided electro-mechanical systems technology in their article [1]. Additionally, sensing tasks and prospective sensor networks were investigated, as well as the factors affecting the design of sensor networking. Different sorts of applications are possible because to the high sensing, fault tolerance, flexibility, and cheap cost properties. Additionally, they discussed pre-defined and development phases, as well as the re-deployment of additional phases.

Chee-Yee Chong et al. (2003) provided a history of sensor network research, technology trends, novel applications, and technical issues in sensor network development in their paper [10]. Small, affordable, and powerful sensors based on microelectronic system technology, wireless networking capabilities, more reliable communication, and a low-power CPU enabled the implementation of wireless ad hoc networks for a variety of applications.

Limin Meng et al., (2008) described energy-aware quality of service protocols for routing that were also efficient for best effort traffic in their study [29]. They demonstrated how to increase first-order energy efficiency via the use of dynamic clustering and how to boost service quality through the use of multi-objective programming models.

As stated in their study Xu Li et al. (2007) demonstrated how to gather data from sensor nodes for the purpose of research and processing in a predetermined field.[11]. Additionally, they used sink mobility to minimise and balance energy usage across sensors. They examined the theoretical promise of the uneven energy reduction phenomena in a single sink wireless sensor network and addressed the issue of energy-efficient data distribution to mobile sinks.

Basilis Mamalis et al., (2009) examined clustering nodes, hierarchical routing, and data collection algorithms that facilitate scalability in their paper [30]. Hierarchical clustering minimises energy use and communication. It enabled rapid convergence while consuming the least amount of energy possible. Nodes in the clustering algorithm make rapid decisions. Additionally, they discussed multi-hop communication and multi-level clustering.

Sudhanshu Pant et al. (2010) discussed data caching strategies in wireless networks in their study [8]. To improve the performance of wireless sensor networks, caching strategies were deployed. Energy may be made more cost-effective in case sensors in networks are spread evenly and utilize the same amount of energy, and the network is kept functioning for as long as feasible.

WSN has been studied by Saravana Kumar R. et al. (2010) [31]. It has a huge number of sensors, and because each sensor has a restricted power source, it's difficult to come up with an energy-efficient routing protocol that can reduce latency along with delivering great energy efficiency and extending the network's lifetime. A novel routing and data consolidation method is proposed which work without re-clustering, and the node re-scheduling scheme based on the residue energy of each node. When compared to the LEACH protocol, the suggested routing strategy uses significantly less energy and extends the overall lifespan of the wireless sensor network.

Jang, Seongsoo Ho-Yeon Kim et al. (2011) [38] worked on the WSN technique, that will become main technology in the upcoming. A fundamental problem that must be overcome in the WSN is improving the overall energy efficiency of the entire network. Energy efficiency can be improved by a variety of approaches, including clustering. A new approach called "Energy Efficient Clustering Scheme with Concentric Hierarchy (EECCH)," was proposed which is a centralised clustering scheme that aims to overcome the flaws of both LEACH and LEACH-C. The base point divides network nodes into layers by forming circles with the base station as the centre. Through this procedure, it is now possible to improve energy efficiency.

Mehrdad Ahad et al. (2012) studied communication in Wireless Sensor Networks in their paper [32]. The information gathered by WSN nodes should be sent to the base station. It assists in conducting computations and making sound judgments. Near the sink, the density of data packets rises. This was dubbed the Energy Hole scenario. The problem of energy leakage should be minimised in Wireless Sensor Networks. It was a critical aspect in the design of large-scale wireless sensor networks. They developed different sink models that mitigate the energy gap issue. This was accomplished by increasing the number of nodes located near the sink. This model is composed of several sink intensities. Sensor nodes were tasked with the responsibility of analysing their environment. It forwards the acquired data to a node designated as the sink. Energy management is critical for the continuity of these networks.

On a wireless sensor network, Lohan, P. et al. (2012) [33] introduced the Geography-Informed Sleep Scheduling and Chaining Based Routing (GSSC) algorithm. Because detector nodes are power constrained, the system lifespan can be extended efficiently utilising node energy. GSSC saves energy by detecting similar nodes from a routing standpoint based on their geological information. It identifies data that is virtually identical and shuts down unnecessary nodes to minimise data duplication, thereby reducing costs. The results show that GSSC increased the network lifespan significantly more than LEACH and PEGASIS.

The clustering process, which is the most well-known guiding strategy in WSNs, was researched by Ahmad, A., et al. (2013) [34]. Because of the many requirements of WSN applications, the utilisation of productive vitality in directing conventions remains a promising study area. In this study, the scientists presented a new energy-efficient guiding technique. This method is employed to address the core issues of energy and coverage gaps. They have used density to control these challenges in their plan. This resulted in an optimal selection of cluster heads within every cycle and uniform hub circulation.

Gherbi Chirihane et al. (2015) [35] suggested a distributed energy-efficient adaptive clustering strategy for WSN This technique uses less energy and extends the network lifetime, according to Gherbi. Clustering techniques work well with distributed cluster heads. In order to reduce the cost function, the node's ratio is disabled for a period of time. Nodes are randomly deployed, and resource reserves are exploited to shorten the simulation time. The distributed energy efficient adaptive clustering protocol (DEACP) with data gathering reduces total network energy consumption, balances energy consumption among sensors, and increases network lifetime. Distributing cluster-heads uniformly across the network reduces transmission power, cutting energy usage.

The PDORP protocol, which is a transmission-based energy-aware routing system, was proposed by G. S. Brar et al. (2016) [36]. Both a power-efficient sensor information system (PEGASIS) and a DSR routing protocol are represented by the proposed protocol PDORP. A proposed routing strategy to differentiate energy-efficient optimal paths is linked to a hybridization of genetic algorithms and bacterial foraging optimization. The execution examination, which uses a hybridization technique to correlate the proposed routing convention, yields a better result with a lower piece error rate, less delay, lower energy consumption, and improved throughput, resulting in improved QoS and extending the system's lifetime.

Sabri Y. et al. (2019) [39] in their paper, developed a unique method for realising energy consumption in WSNs and analysed the DSR routing protocol in the prescribed network scenario. The authors measured the power consumption of the dynamic source routing protocol in sending, receiving, and idle modes. The generic model consumed the most power in transmitting and receiving modes, while the mica-mote type consumed the least.

Hussein A. A. et al. (2020) [40] investigated the performance of many chain-based routings protocols, one of the hierarchical routing protocol types, by exploring thoroughly the technical aspects and models of these protocols. Examined the behaviour of the PEGASIS protocol from its origin to its later upgrades based on number of nodes that have expired and how this affects the network lifetime.

On the other hand, Ibrahim et al. (2021) [41] published a survey on critical topics in the WSN domain, illustrating the main problems and their solutions, as well as key obstacles in WSN technology. Their study's major goal is to help scholars comprehend numerous areas and fields, as well as shortcomings and strengths.

IV. COMPARISON OF VARIOUS PROTOCOLS

An evaluation based on class, lifetime, energy efficiency, throughput, and scalability of some energy efficient routing protocols is given in table 1.

The comparison of energy-efficient wireless sensor network protocols is based on the evaluation parameters like class, lifetime, energy efficiency, throughput, and scalability. A suitable protocol for the wireless sensor network may be selected in comparison to the other available protocols. Energy efficiency is crucial because the sensor nodes are tiny and have limited power resources. In order to increase the lifespan of a reliable WSN, it must be energy efficient. Among the various parameters in WSN, throughput is also a critical parameter. As a result, the throughput value must be optimised for improved WSN performance. Scalability is a critical factor in the design of a routing algorithm. An efficient routing protocol must be scalable and adaptable to updating network topologies, as well as perform well as the network's size or workload grows. It is well known that wireless sensor networks (WSNs) are very energy-constrained, and each network's lifespan is strongly dependent on the nodes' battery capacity. WSN research is still very much focused on ensuring the network's long-term viability.

TABLE I. COMPARISON OF PROTOCOLS

	Classification	Lifetime	Energy Efficient	Throughput	Scalability	Data Aggregation	Over head
LEACH [15]	Hierarchical	Very Good	High	Very High	High	Yes	High
TEEN [20]	Hierarchical	Good	Good	Satisfactory	Good	Yes	High
APTEEN [21]	Hybrid	Very Good	Good	High	Good	Yes	High
DIRECTED DIFFUSION [22]	Flat	Good	High	Satisfactory	Restricted	Yes	Low
EESR [23]	Flat	Very Good	High	High	High	Yes	Low
PEGASIS [27]	Hierarchical	Very Good	High	Very High	Good	No	Low

V. CONCLUSION AND FUTURE SCOPE

It is critical in wireless sensor network applications to transmit data efficiently in terms of power efficiency and network longevity with the utilisation of limited resources available with the network. The most difficult part of such networks is routing and delivering data to the target node while being energy efficient. Energy-efficient routing protocols play a significant role in wireless sensor networks as they minimise the energy utilised in the network. Due to the large range of WSN applications, routing issues in WSNs are among the most active and challenging research topics. This study presents an overview of some energy-efficient WSN routing protocols. An evaluation based on class, lifetime, energy efficiency, throughput, and scalability is given in table-1. Therefore, the energy-efficient routing techniques used in wireless sensor networks are reviewed. Although the protocols presented here are energy efficient, quality of service (QoS) should also be addressed to ensure that the most energy efficient data transfer mechanism is implemented, including a promised data transfer rate or latency. In addition, one important issue in routing is that most routing protocols presume that the sensor nodes and sinks are fixed in their locations. However, in a real-world scenario may be totally different. In such cases, new routing strategies are necessary to account for the overhead concerned with portability and topology changes under such power-constrained conditions. By employing smart and efficient strategies, we can extend the network lifespan and perhaps improve sensor coverage. Researchers can create more smart and secure routing protocols by analysing routing attacks and security measures in WSNs in the future.

REFERENCES

[1.] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: a survey", Computer Networks (Elsevier), vol. 38, 2002, pp. 393-422, 2002.
[2.] S. Okdem, and D. Karaboga, "Routing in Wireless Sensor Networks using on Ant colony optimization (ACO) Router chip. Sensors", 9, 2009, pp. 909-921.
[3.] A. A. Kharazian, K. Jamshid, and M. R. Khayyambashi, "Adaptive clustering in wireless sensor network: considering nodes with lowest energy", International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC), vol. 3, no. 2, April 2012.
[4.] K. Maraiya, K. Kant and N. Gupta, "Application based Study on Wireless Sensor Network", International Journal of Computer Applications, vol. 21, no. 8, May 2011.
[5.] J. Tillison, "An introduction to wireless sensor network concepts", pp. 1-6, August 08, 2011.
[6.] P. Kumar, M. P. Singh and U. S. Triar, "A Review of Routing Protocols in Wireless Sensor Network", International Journal of Engineering Research & Technology (IJERT), vol. 1, Issue 4, June 2012, pp. 1-14.
[7.] N. Chauhan, L. K. Awasthi, N. Chand, "Cluster Based Efficient Caching Technique for Wireless Sensor Networks", International Conference on Latest Computational Technologies (ICLCT'2012) Bangkok, 17-18 March 2012.
[8.] S. Pant, N. Chauhan, P. Kumar, "Effective Cache based Policies in Wireless Sensor Networks: A Survey",

International Journal of Computer Applications, vol. 11, no. 10, December 2010.

[9.] S. S. Kumar, M. N. Kumar, V. S. Sheeba, K. R. Kashwan, “Power Management of Hybrid Scheduling Routing in Cluster Based Wireless Sensor Networks”, Journal of Information & Computational Science 9:6, pp. 1555–1575, June 2012.

[10.] C. CHONG, and S. P. KUMAR, “Sensor Networks: Evolution, Opportunities and Challenges”, Proceeding of the IEEE, vol. 91, no. 8, August 2003.

[11.] X. Li, A. Nayak, and I. Stojmenovic, “Sink Mobility in Wireless Sensor Networks” pp.1-32. 2007.

[12.] O. Younis, and S. Fahmy, “Distributed Clustering in Ad-hoc Sensor Networks: A Hybrid, Energy-Efficient Approach”, 23rd Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2004), 2004, pp. 629-640.

[13.] Kazem Sohraby, Daniel Minoli and Taieb Znati, “Wireless Sensor Networks”, ELSEVIER Inc., 2007.

[14.] J. N. Al-Karaki, and A. E. Kamal, “Routing Techniques in Wireless Sensor Networks: A Survey,” IEEE Wirel. Commun., vol. 11, no. 6, pp. 6-28, 2004.

[15.] N. A. Pantazis, S. A. Nikolidakis, and D. D. Vergados, “Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey,” IEEE Commun Surv Tut, vol. 15(2), pp. 551-591, 2013.

[16.] S. Lindsey and K. M. Sivalingam. “Data Gathering Algorithms in Sensor Networks Using Energy Metrics.” IEEE Transactions on Parallel and Distributed Systems, 13(9): 924-934, 2002.

[17.] Holger Karl and Andreas Willig “Protocols and Architectures for Wireless Sensor Networks.”,2005 John Wiley & Sons, Ltd. ISBN: 0-470-09510-5

[18.] Jayashri Deb Sinha and Subhabrata Barman, "Energy Efficient Routing Mechanism in Wireless Sensor Network", IEEE conference on Recent Advances in Information Technology,2012.

[19.] Roseline, R.A., Sumathi, P, Local clustering and threshold sensitive routing algorithm for Wireless Sensor Networks, Devices, Circuits and Systems (ICDCS), 2012 International Conference, IEEE, 2012.

[20.] A. Manjeshwar and D. Agrawal,” TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,” In Proc of 15th International Parallel and Distributed Processing Symposium (IPDPS’01) Workshops, USA, California, 2001, pp. 2009-2015.

[21.] A. Manjeshwar, D. Agrawal, ”APTEEN: A Hybrid Protocol for Efficiency Routing and Comprehensive Information Retrieval in Wireless Sensor Networks,” In Proceedings of International Parallel and Distributed Processing Symposium, Florida, 2002, pp.195-202.

[22.] K. Sohraby, D. Minoli, T. Znati "Wireless Sensor Networks, Technology, Protocols, and Applications" Published by John Wiley & Sons, Inc., Hoboken, New Jersey. 2007.

[23.] H. Oh and K. Chae, “An Energy-Efficient Sensor Routing with low latency, scalability in Wireless Sensor Networks", IEEE 2007 International Conference on Multimedia and Ubiquitous Engineering, pp 147-152, May 2007.

[24.] H. Oh, H. Bahn and K. Chae, "An Energy-Efficient Sensor Routing Scheme for Home Automation Networks," IEEE Transactions on Consumer Electronics, Vol.51, No.3, pp.836-839, Aug.2005.

[25.] W. R. Heinzelman, J. Kulik, and H. Balakrishnan, “Adaptive Protocols for Information Dissemination in Wireless Sensor Networks”, 5th Annual ACM/IEEE

[26.] International Conference on Mobile Computing and Networking (MobiCom '99), pp. 174-185, August 1999, Seattle, WA.

[27.] C. Intanagonwiwat, R. Govindan, and D. Estrin, “Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks”, 6th Annual IEEE/ACM International Conference on Mobile Computing and Networking (MobiCom'00), August 2000, pp. 56-67, Boston.

[28.] S. Lindsey, C. Raghavendra, and K. M. Sivalingam, “PEGASIS: Power-Efficient Gathering in Sensor Information Systems”, IEEE Aerospace Conference, vol. 3, 9-16 March 2002, pp. 1125-1130.

[29.] M. Younis, M. Youssef, and K. Arisha, “Energy-Aware Routing in Cluster-Based Sensor Networks”, 10th IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS 2002), pp. 129-136, January 2002. Fort Worth, TX.

[30.] L. Meng, K. Zhou, J. Hua, Z. Xu, “A Dynamic Clustering-Based Algorithm for Wireless Sensor Networks”, International Symposium on Computer Science and Computational Technology, 2008.

[31.] B. Mamalis, D. Gavalas, C. Konstantopoulos, and G. Pantziou, “Clustering in Wireless Sensor Networks”, Zhang/RFID and Sensor Neyworks AU7777_C012, pp. 323-354, 2009.

[32.] Saravanakumar R, Susila S.G. and Raja J., "An energy efficient cluster-based node scheduling protocol for wireless sensor networks," Computational Intelligence and Computing Research (ICCIC), 2010 IEEE International Conference on, vol.1-5, pp.28-29 Dec. 2010.

[33.] M. Ahadi and A. M. Bidgoli, “A Multiple-Sink Model for Decreasing the Energy Hole Problem in Large-Scale Wireless Sensor Networks”, 2012.

[34.] Lohan P. and Chauhan R., "Geography-informed sleep scheduled and chaining based energy efficient data routing in WSN," Electrical, Electronics and Computer Science (SCEECS), 2012 IEEE Students' Conference on, vol., no., pp.1,4, 1-2 March 2012.

[35.] Ahmad A., Latif, K., Javaid, N., Khan, A. and Qasim U., "Density controlled divide-and-rule scheme for energy efficient routing in Wireless Sensor Networks," Electrical and Computer Engineering (CCECE), 2013 26th Annual IEEE Canadian Conference on, vol., no., pp.1,4, 5-8 May 2013.

[36.] Gherbi Chirihane & Aliouat Zibouda, "Distributed energy_x0002_efficient adaptive clustering protocol with data gathering for large-scale wireless sensor networks", Programming and Systems (ISPS), 12th International Conference, IEEE,2015.

[37.] Brar G. S., Rani S., Song H. and Ahmed S. H., "Energy Efficient Direction-Based PDORP Routing Protocol for

WSN", IEEE Special Section on Green Communications and Networking for 5g Wireless, Vol. 4, pp: 3182-3194,2016.

[38.] Seongsoo Jang, Ho-Yeon Kim, Nam-Uk Kim and TaiMyoung Chung, "Energy-Efficient Clustering scheme with Concentric Hierarchy," RF and Microwave Conference (RFM), 2011 IEEE International, vol., no., pp.79,82, 12-14 Dec. 2011.

[39.] K. Sohraby, D. Minoli, and T. F. Znati, Wireless sensor networks: technology, protocols, and applications. Wiley-Interscience, 2007, pp. 1-4

[40.] A. Norouzi, M. Dabbaghian, A. Hatamizadeh and B. Berk Ustundag, "An Improved EL Gossiping Data Distribution Technique with Emphasis on Reliability and Resource Constraints in Wireless Sensor Network," IEEE international ISBN: 978-1-4673-5613-8©2013 IEEE Conference on Electronic Computer Technology, Kuala Lumpur, 7-10 May 2010, pp. 179-183.

[41.] Sabri Y., El Kamoun N., Lakrami F, "Investigation of Energy Efficient Routing Protocols in Wireless Sensor Networks on Variant Energy Models", Proceedings of the 4th International Conference on Big Data and Internet of Things (BDIoT'19) October. 2019 Pages 1–5, https://doi.org/10.1145/3372938.3372989.

[42.] Hussein A. Ayad., Khaled R. Abd., "Performance Analysis of Chain-Cluster based Routing Protocols in WSN", IOSR Journal of Electronics and Communication Engineering (IOSRJECE), Volume 15, 2020.

[43.] Ibrahim D. S., Hussein A. Ali, Zaidan F. K., "Routing Protocols for Energy Efficiency in WSNs: A review", SAR Journal. Volume 4, Issue 1, Pages 29-33, ISSN 2619-9955, DOI: 10.18421/SAR41-05 March 2021.