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Survey on Energy Efficient LEACH Routing Protocol for Wireless Sensor Network

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Abstract: *Wireless Sensor Networks (WSNs) are decentralized networks of sensors that can measure variables like temperature, wetness, humidity, and more. Applications for WSN can be found in a number of fields, including engineering, medicine, environmental monitoring, industrial automation, and military surveillance. WSN gathers data, processes it, and communicates with the base station via data transfer. Due to the extremely low battery capacity of WSN, energy efficiency is a constant problem. The life of a WSN shortens as a result of the energy consumption required to send a single piece of data from one node to another. Finding a way to lower energy consumption is thus difficult. Routing protocol then enters the picture. This paper discusses the Low Energy Adaptive Clustering Hierarchy (LEACH) routing system, which is a hierarchical-based routing mechanism that uses less energy and is regarded as the first energy-efficient routing protocol. Discussion also includes an analysis of LEACH's energy efficiency. In this paper, comparison of several energy efficiency techniques is also investigated.*

Keywords: Wireless sensor network, Routing Protocol, Energy efficiency, Hierarchical- LEACH.

Introduction

A developing area in electronics and computer engineering is wireless sensor networks (WSN) [1]. It is a group of nodes that are linked together by a wireless channel to form a network, as the name would imply. These nodes are unique in that they can detect physical and environmental parameters in a network; as a result, they are referred to as sensor nodes [2]. For network application purposes, this sensed parameter (such as temperature, humidity, pressure, etc.) is transferred over wireless medium [3]. Processing and communication to the base station of the detected data (BS). Even while this notion is employed in projects for smart cities, it can also be used in other fields including agriculture and military applications [4].

A wireless sensor network (WSN) is made up of a sizable number of small, reasonably priced computational nodes that communicate important data to the base station (BS) for appropriate processing. Figure 1 depicts a typical WSN [7] structure. Sensor nodes in a WSN are spread randomly. All information gathered from the environment and from users who used the internet to gather information is received by a base station (BS) [8].

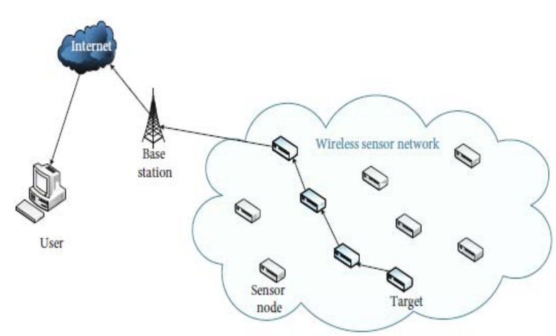

Fig. 1: Structure of WSN.

The WSN is composed of a significant number of low power micro sensor nodes spread across a sizable area with at least one BS [8]. Each micro-sensor collects data on environmental or physical parameters like pressure, temperature, humidity, and others before sending it back to the BS. Due to the fact that the nodes' placements in a WSN are not preset, the network can be organised independently. Figure 2 illustrates a basic WSN structure that consists of a sensing unit, power supply unit, processing unit, and communication unit.

Sensing Unit: It is made up of different sensor nodes that are in charge of sensing environmental and physical parameters. Analog to digital conversion of the sense data is performed. The processing unit goes on to further process this data.

Processing Unit: This unit is made up of a microprocessor that can process data from sensors and regulate the performance of other units. The capacity or quantity of detected data determines how well this unit works.

Transmitter and receiver used in data transfer from source nodes to base station make up the communication unit. This unit uses a lot of energy. The number of intermediary nodes and the distance from the source to the base station are the major factors affecting how it functions.

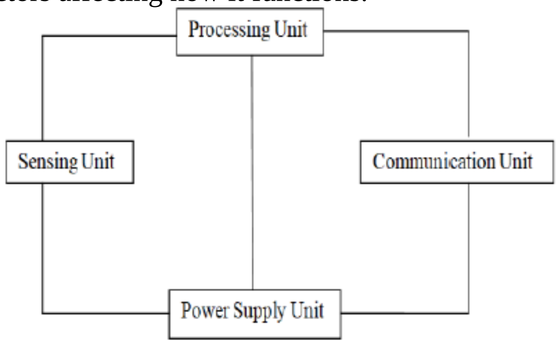

Fig. 2: Basic Architecture of WSN.

Power Supply Unit: Unreplaceable batteries are used in the power supply unit. As a result, they have a limited ability to operate. Power distribution to other units is its purpose.

Wired conventional and ad hoc networks and WSNs differ from each other in key ways. The differences are mostly caused by resource limitations in WSNs relating to energy, communication range, bandwidth, processor, and memory capacity. Specific design issues for protocol advances in WSNs are unavoidable due to the severe resource restrictions. The design of WSNs is entirely based on the application, other from that. The requirements of the application determine the size, shape, and deployment method of the network. Because of its unique features and application dependency, WSNs cannot utilise the algorithms and protocols employed in conventional and ad hoc networks. Ad hoc networks and sensor networks differ significantly in the following ways [4]:

- In contrast to previous networks, WSNs will have a relatively large number of nodes.
- The deployment of sensor nodes will be dense.
- The severe environment and energy depletion make sensor nodes vulnerable to disasters.
- In WSNs, topology changes will frequently occur.
- Sensor nodes typically use broadcast communication, whereas ad hoc networks use point-to-point communication.
- Because of the enormous number of sensor nodes and the overheads, sensor nodes typically lack global identification. Sensor nodes have stringent limits in power, processing capacity, and memory resource.

II. Energy Efficient Techniques in WSN

While sensing, processing, transmitting, or receiving data from sensors in a WSN to complete the task required by the application, energy is lost. Other causes of energy waste include interference, overhearing, control packet overhead, collisions, and idle listening. As shown in figure 3, there are five basic categories of energy-efficient approaches.

Data Reduction- The goal of data reduction is to produce, process, and send less data overall.

Techniques based on sampling and predictions are suggested in order to decrease the amount of data produced. Data compression and data aggregation are used to decrease the amount of data during processing and transmission.

Protocol overhead reduction- Reducing protocol overhead helps to improve protocol effectiveness by lowering the overhead. Utilizing cross-layering and adaptive transmission period will reduce the overhead.

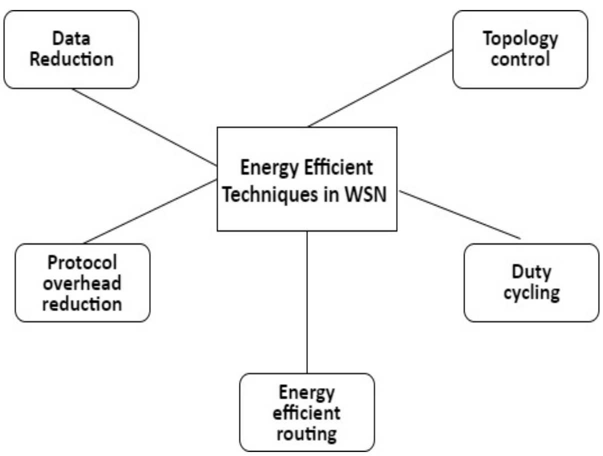

Fig. 3: Types of energy efficient techniques.

Energy efficient routing - The goal of routing protocols should be to maximize network lifetime and reduce energy usage during end-to-end transmission. Opportunistic, data-centric, hierarchical, geographical, multipath routing, etc. are some of the popular routing systems.

Duty cycling is the percentage of a node's lifetime that is spent in active operation. Duty cycling with fine-grained selection focuses on choosing active nodes out of all the sensors installed in the network. Duty cycling with low granularity is the process of turning off active nodes' radios when no communication is necessary.

Topology control: It focuses on lowering energy usage while preserving network connectivity by altering the transmission power. The goal of this research is to extend the network lifetime through the use of energy-efficient routing and aggregated data.

III. Routing Challenges in WSN

The extensibility, understanding, and understanding of energy level, as well as simplicity owing to limited energy, basic units like memory, and others, are the most crucial elements of the right routing protocol in WSNs. However, the design of this network is affected by several challenges, such as:

Deployment of the sensor node- The application type has a substantial impact on the routing protocol's performance, which is dependent on how the sensor nodes are deployed. Energy efficiency is greatly influenced by the position of the sensor nodes, particularly the cluster head and base (monitoring) station.

Network traffic status- Ordinary sensing nodes, excluding the head of the group (cluster) or monitoring station, are preferable to be (static) non-moving because it is simpler to control them and choose the proper routing protocol, but in some applications, it is necessary to have a moving sensor node.

Tolerance of Faults- To prevent a loss of information about the monitored environment in the event that one of the sensing nodes fails, the routing protocol should establish new linkages.

Scalability of WSN- In the area to be monitored, there may be thousands or even tens of thousands of sensor nodes, so the routing protocols need to be able to manage such a high node density.

Hardware restrictions- All of the components that make up the sensor node must be as compact as possible and use the least amount of power. Some examples of these components include GPS, communication, sensor, power, and memory.

Information Transfer- Wireless data transmission is typically used, which is more susceptible to interference from barriers than wired data transfer and has a significant negative impact on a network's ability to function properly.

Energy conservation- Energy-related factors have a big impact on how routes are established during network construction. Therefore, it seems sense that the multi-hop directive will use less energy than the single-hop directive while also exacerbating network issues. Single-hop often works well in small networks with proximate sensor nodes.

Models for data delivery- In accordance with the needs of the application, data delivery to the monitoring station may be continuous, associated with an event, targeted at the enquiry, or a combination of these. Each sensor node sends data regularly if the process is continuous. Contrarily, in the second and third delivery types, the node is engaged when an event takes place or when the data source requires specific data, respectively. In this kind of distribution, the routing protocol is impacted, particularly the problem of lowering energy use.

Information fusion or aggregation- It is the process of gathering information from various sensor nodes in order to eliminate duplicates. The network gathers packets from various sensor nodes to minimise the amount of data required for delivery and, as a result, minimise the required energy.

IV. Routing Protocols in WSN

In the area of wireless sensor networks, key research problems include network longevity, routing schemes, and sensor node energy consumption. WSN routing protocols are created based on actual applications and network architecture [14]. The classification of different routing protocols is depicted in figure 4 [18].

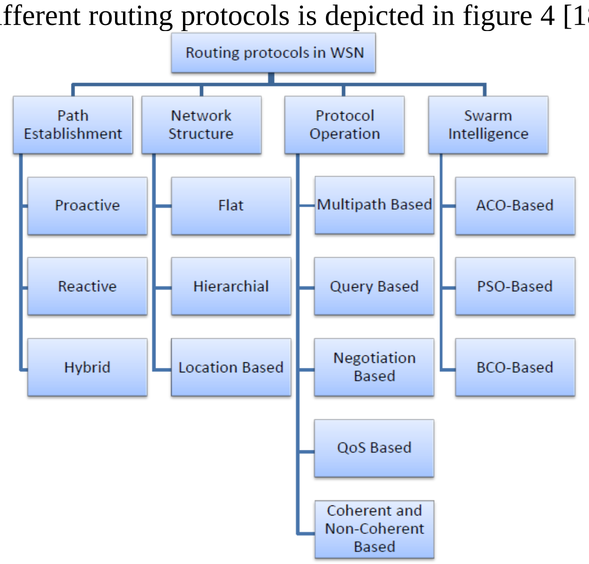

Fig. 4: Classification of WSN Routing Protocols.

(1) Based on the establishment of the path

The basic objective of routing protocols in a network is to create the best possible path between a source node and a destination node with the least amount of overhead and bandwidth usage. Path-based protocols can be divided into the following categories:

(a) Proactive Routing Protocol- It creates a route even in the absence of traffic. LEACH [1] is one illustration of it. When a node needs a path to a sink node, it may locate it in its routing table because in proactive ones, sensors regularly relay data, making it possible to know in advance each way to each sink node by storing routing information in routing tables in each node. An illustration of a proactive routing method is shown in Figure 5.

(b) Reactive protocol- It creates a route based on demand. A prime example of it is PEGASIS. When a node needs to discover a route to a sink node, reactive routing protocols do not use routing tables; instead, a request is sent to determine the best path to that sink node. An illustration of a reactive routing scheme is shown in Figure 6.

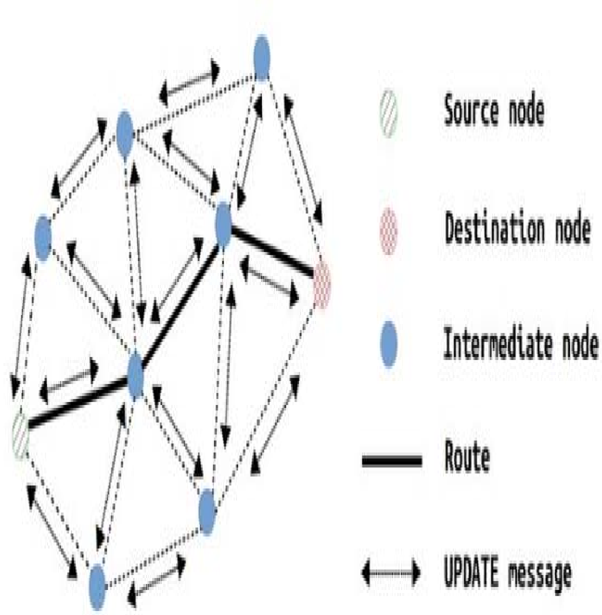

Fig. 5: Example of proactive routing scheme.

(c) Hybrid Protocol: The hybrid routing protocol combines the reactive and protective routing protocols to establish the path between the source and the destination

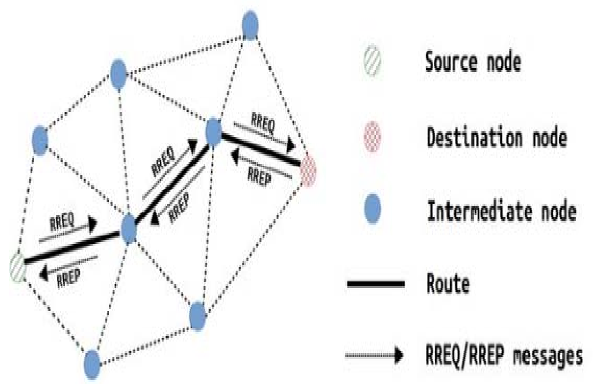

Fig. 6: Example of reactive routing scheme.

(2) Based on the network structure

Figure7 illustrates how routing protocols can be characterised as follows based on network structure.

(a) Flat - Each sensor node in flat routing completes the same tasks using the multi hop technique [7]. The cooperation of the sensor nodes with one another allows for the accomplishment of the sensing mission.

(b) Hierarchical- Information processing and transmission are carried out by sensor nodes with greater energy levels via hierarchical routing, which divides network space into clusters. The most energy-efficient routing protocols are those that are hierarchical [7]. LEACH (Low Energy Adaptive Clustering Hierarchy) is an illustration of this type wireless routing protocol. It groups sensor nodes based on the RSS (Received Signal Strength) and employs regional cluster heads as routers to send data to the base station.

(**c) Location-based routing**: Instead of sending data throughout the whole network, location-based routing uses sensor node position information to distribute data to a particular area [7]. The placement of the nodes helps location-based protocols route messages to their intended locations.

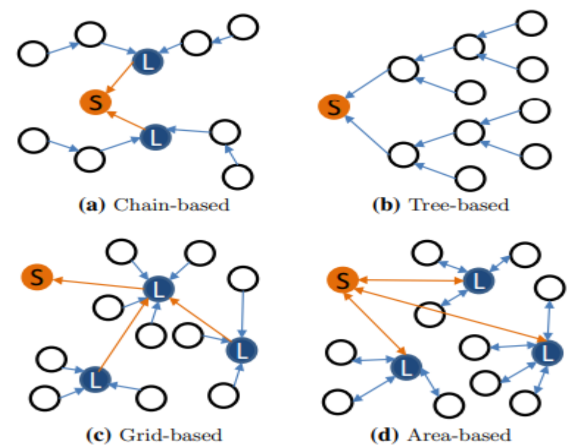

Fig. 7: Example of various network structures routing scheme.

(3) Based on protocol execution

The operation of the protocol is another reason for categorising routing protocols. Several of the routing protocols that rely on protocol operations include:

(a) Routing protocols based on multiple paths- The capacity of the multihop pathways is constrained due to the high dynamic nature of wireless communications. In order to transmit high-speed data effectively and reliably, multipath routing protocols were implemented. Following are a few multipath-based routing protocols:

(1) N-to-1 multipath routing protocol
(2) Multipath Multispeed (MMSPEED)
(3) Braided Multipath Routing Protocol

(b) Energy-Efficient On-Demand Multicast Routing Protocol (EMP)- It extends the network lifetime by introducing a strategy of energy critical avoidance in the process of on-demand construction of multicast routing trees. (b) Pure Energy Aware Routing Protocols – Pure Energy Aware Routing Protocols are designed for WSN in order to minimise the power consumption. Low energy nodes are discouraged from participating in a multicasting task.

(c) Query-based routing protocols- In these protocols, the target node propagates a data request (sensing task) from one node to another over the network, and a node that has the requested data transmits the data back to the node that sent the request.

(d) Routing protocols based on negotiation – This type of protocol uses high level data descriptors to negotiate the removal of redundant data transmissions. Decisions about communication are also made in light of the resources at hand.

(e) QoS-based routing protocols- Additional classification is taken into account based on the QoS (Quality of Service). Finding the route with the lowest energy, processing, and routing overhead costs is the goal of QoS. SPEED protocol employs geographical forwarding to determine each path and ensures a constant delivery speed across the network. To estimate the end-to-end delay, each node needs geographic information about its neighbours.

(f) Coherent based routing protocols- Coherent routing forwards data to aggregators with the least amount of processing. Time stamping, duplicate suppression and other duties are frequently included in the minimum processing. Normal choices for coherent processing involve energy-efficient routing.

(g) Coherent and non-coherent based routing protocols– In non-coherent data processing routing, nodes first perform local data processing before sending the results to other nodes for additional processing. The aggregators are the nodes that carry out further processing. Normal choices for coherent processing involve energy-efficient routing.

(4) Routing protocols based on swarm intelligence

Swarm intelligence is a meta-heuristic approach that replicates the swarm behaviours seen in nature to tackle numerical optimization problems. These methods show how interpretability, scalability, efficacy, and resilience are desirable qualities. Algorithms based on swarm intelligence may be able to solve problems in the actual world at their best. The following are some of the most often used swarm intelligence frameworks:

(a) Particle Swarm Optimization (PSO)- The network is made more efficient by (a) particle swarm optimization (PSO), which uses this technique to find the ideal sink position in relation to the relay node. Since PSO communicates with the sink via the relay node rather than the sensor nodes, each sensor node's battery life is preserved. Each solution in PSO is thought of as a particle. PSO uses many particles to represent each solution and looks for the best particle position based on the supplied fitness function.

(b) Artificial Bee Colony (ABC)- This system was developed to improve processes. In order to preserve network energy, it employs the clustering technique. It is a swarm intelligence technique that draws inspiration from honey bees' foraging habits. It is of three types: Employed, Onlooker and Scouts bees

(c) Ant Colony Optimization (ACO)- This optimization approach is likewise based on swarm intelligence. It makes advantage of distributed calculations and positive feedback. In order to choose the best route between a food source and their nest depending on the level of pheromone concentration, it involves the study of collective foraging activities of ants.

Table 1 shows many routing protocols along with their corresponding protocols.

Table 1: Routing Protocols for WSNs

Sr. No.	Category	Representative Protocols
1	Location-based Protocols	MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaF
2	Data-centric Protocols	SPIN, Directed Diffusion, Rumor Routing, COUGAR, ACQUIRE, EAD, Information-Directed Routing, Gradient-Based Routing, Energy-aware Routing, Information-Directed Routing, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination
3	Hierarchical Protocols	LEACH, PEGASIS, HEED, TEEN, APTEEN
4	Mobility-based	SEAD, TTDD, Joint Mobility and Routing, Data MULES,

	Protocols	Dynamic Proxy Tree-Base Data Dissemination
5	Multipath-based Protocols	Sensor-Disjoint Multipath, Braided Multipath, N-to-1 Multipath Discovery
6	Heterogeneity-based Protocols	IDSQ, CADR, CHR
7	QoS-based protocols	SAR, SPEED, Energy-aware routing

V. Low Energy Adaptive Cluster Hierarchy Protocol (LEACH)

LEACH is based on hierarchical protocol. The sensor nodes can convey information to the cluster heads of the cluster to which they belong thanks to this protocol. The data from the other cluster nodes is gathered and aggregated by the cluster heads before being forwarded to the base station, which serves as the sink. The purpose of this protocol is to prolong the life of wireless sensor nodes. The LEACH protocol's overall operation is built on rounds, each of which has two stages: the first is the "set up stage" and the second is the "stationary state." Figure 8 depicts the LEACH protocol's design. LEACH aids in balancing the sensor nodes' energy usage [4–9].

Based on the approved signal force, the sensor nodes will be grouped, and local group heads (CHs) will act as routers to the sink. Because only CHs will be used for transmissions as opposed to all sensor nodes, energy will build. The ideal number of CHs will probably be 5% of all the nodes. All data processing, including data union and aggregation, takes place only within the cluster. For the purpose of balancing the nodes' energy loss, CHs change at random over time.

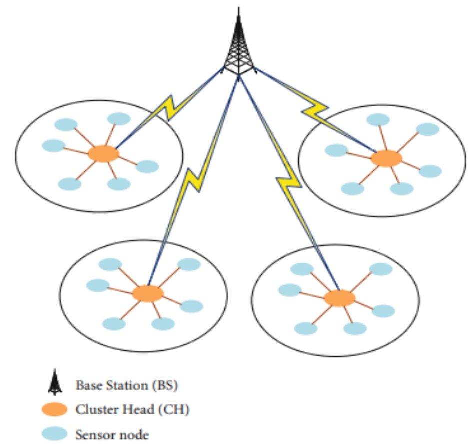

Fig. 8: LEACH Architecture.

There are several crucial aspects of LEACH, including:

(1) Local coordination and management of cluster setup and management.
(2) The corresponding clusters and the cluster "base stations" or "cluster-heads" rotated at random.
(3) Local resolve to lessen communication on a global scale.

LEACH is used to construct the cluster by choosing the cluster head (CH) from a variety of sensor nodes. Based on the strength of the received signal, the clusters are produced. As a result, WSN uses less energy because just cluster heads will be used for transmission. By decreasing the communication cost between sensors and their cluster heads and turning off non-head nodes as much as feasible, it lowers energy usage [18].

Since LEACH is entirely distributed, it doesn't call for extensive network knowledge. It does so by

(1) Minimising the cost of communication between sensors and their cluster heads and
(2) Turning off non-head nodes as much as feasible, it lowers energy usage.

Additionally, LEACH clustering assumes uniform energy consumption for CHs and terminates after a certain number of iterations, neither of which are guarantees of good CH distribution [20].

There are numerous rounds involved in the LEACH's operation. The LEACH rounds are divided into the following two phases:

- Set up phase
- Steady state phase

(A) Set up phase- Clusters are organised during this phase, and CHs have been chosen. Continuous state phase is used for data transmission and aggregation [16]. The setup phase is less time-consuming than the steady state phase in order to achieve minimal overhead. Each sensor node decides whether or not to act as a CH for the current round after the formation of clusters. The determining factors for whether or not to designate a sensor node as a CH are the proposed ratio of CHs in the network (determined a priori) and the number of times that node has been chosen in that capacity. A node "z" chooses, for instance, a random number between 0 and 1. The sensor node will only be referred to as CH. T(z) is formulated by

$$T(z) = f(z) = \begin{cases} \dfrac{P}{1 - P * (r \bmod (1/P))}, & \text{if } z \in G, \\ 0, & \text{otherwise,} \end{cases}$$

P is the preferred proportion of CH, r is the current round, and G is the set of node energy required for communication, where z is the total number of sensor nodes in the network area.

After being chosen, the CHs start broadcasting commercials. Each non-cluster head node selects its CH for that round based on the received signal intensity if it can hear more than one broadcast message. Each non-cluster head uses a CSMA to send a join request message to its selected CH that includes its ID. Following the setup step, each CH is familiar with its members and their unique IDs.

The process of choosing cluster leaders, forming clusters, and creating schedules are all happening during setup phase. We talk about these procedures as:

Election of cluster heads- For the current round, each node chooses whether or not to act as the cluster leader. This choice is based on both the node's prior experience as a cluster head during previous rounds and the recommended pace of cluster heads that should be deployed toward the network (determined from the earlier).

Cluster formation- Every node that has selected a cluster head for the current round talks with the other nodes and sends them advertisements to build a cluster. This period is also known as the "cluster-head advertising phase." Non-cluster-head nodes decide to establish a cluster based on the signal strength of the cluster head's advertisement message if they receive it with a high signal strength since this means that they will use the least amount of energy possible to transmit data with that cluster head.

Schedule creation- As was mentioned previously, the cluster head creates time slots for each node. Nodes can only send data to the cluster head during that time period. The total number of nodes in the network is used as the basis for creating the schedule. When a node transmits data to the cluster head is decided by TDMA (Time Division Multiple Access) [16].

(B) Steady state phase The CH distributes its TDMA schedule to its member nodes during the (B) steady state phase after the clusters have been created. Each member node transmits the sensed data to its CH in accordance with the timetable. The CH communicates the aggregated data [11] together with its own data to the BS after collecting all the data from its members.

The steady state phase lasts longer than the setup phase does. The network resumes setting up for a new round after a predetermined amount of time. The CHs are once again chosen to form new clusters after each round. As a result, the number of rounds can be used to estimate the network's lifetime. The LEACH protocol's time line of operation, which consists of the setup and steady state phases, is depicted in Figure 9.

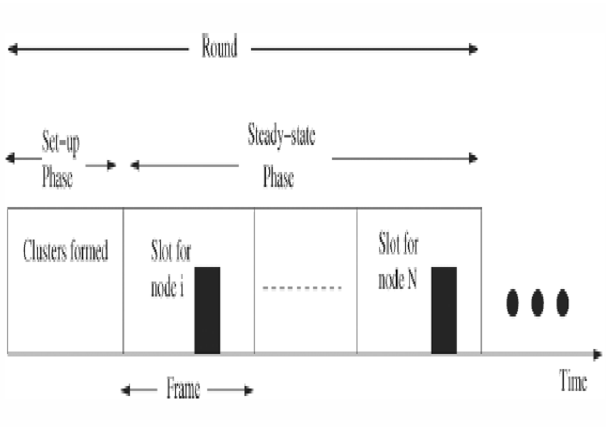

Fig. 9: Time-line operation of LEACH

VI. Analysis of Energy Efficiency in LEACH

(1) The energy of the network is good if the distance between the BS and SN is modest (S) and the average residual energy of the SN is low (L) (G).
(2) The energy of the network is good if the distance between the BS and SN is small (S) and the average residual energy of the SN is medium (M) (G).
(3) The energy of the network is excellent if the distance between the BS and SN is small (S) and the average residual energy of the SN is high (H) (E).
(4) The energy of the network is bad if the distance between the BS and SN is medium (M) and the average residual energy of the SN is low (L) (P).
(5) The energy of the network is good if the distance between the BS and SN is medium (M) and the average residual energy of the SN is medium (M) (G).
(6) The energy of the network is good if the distance between the BS and SN is medium (M) and the average residual energy of the SN is high (H) (G).
(7) The energy of the network is bad if the distance between the BS and SN is considerable (L) and the average residual energy of the SN is low (L) (P).
(8) The energy of the network is bad if the distance between the BS and SN is great (L) and the average residual energy of the SN is medium (M) (P).
(9) The energy of the network is good if the distance between the BS and SN is great (L) and the average residual energy of the SN is high (H) (G).

When the distance between the base station and the sensor nodes is short and the average residual energy of the sensor nodes is high, we conclude from fuzzy analysis that the energy of the network is outstanding.

VII. Review of Energy Efficient (EE) Routing Protocols used in WSN

Table 2 shows that the LEACH algorithm actually has the advantage of giving every other node a reasonable chance of being a CH, leading to fairly controlled energy dissipation. When the LEACH protocol is used, a certain number of rounds are used, and throughout each round, all nodes compete to become the cluster leader. Along with not requiring additional control packets, saving energy, and simply being entirely decentralised, it has a number of noteworthy advantages.

Table 2: Summary of energy efficient routing protocols used for WSN

Authors and Year	Routing Protocols used	Working Principal
Anik Kumar Saha et al. in 2019 [1]	Region based (R-LEACH) protocol	The cluster heads are still chosen using the standard Leach protocol.
Arnab Nandi et al. in 2019 [2]	Centered Sink-LEACH protocol	The LEACH protocol is used to send the data that has been collected from all nodes to the CH, which subsequently sends the data to the sink node. Single static node placement is the main focus. To extend the network's lifespan, the

		sink is positioned in the centre of the system.
Zhen Zhao et al. in 2019 [3]	Modified LEACH (M-LEACH	To enhance network performance, it obtains the ideal number of cluster heads. Then, while choosing cluster heads, it takes the weight of energy into account. In each round, it reasonably solves the quantity of cluster heads. The cluster head election is given an additional weight due to the energy component.
Sneha Kamble & et al. in 2016 [5]	Velocity Energy-effective and Link-mindful Cluster-Tree (VELCT)	Within the first fixed stage of cluster formation as well as the construction of the information aggregation tree, intra cluster and DCT communication are started to determine the best path between the cluster members and sink node.
Gopi Saminath an Arumuga m et al. in 2015 [7]	Energy-efficient LEACH (EE-LEACH)	By efficiently aggregating data and clustering nodes, it offers EE WSN routing. Every cluster is given a CH to help optimise resource usage by lowering the energy consumption of the sensor nodes. For efficient coverage of the sensing network region, the Gaussian distribution model is employed.
Payal Khurana Batra et al. in 2015 [8]	LEACH-MAC	For clustering, the dynamic, distributed, and randomised (DDR) algorithms have been utilised. Energy consumption analysis has made use of the first order radio model.
Awangga Febian Surya Admaja et al. 2021 [9]	Modified routing model based on LEACH	To stop the occurrence of a neighbouring cluster head, it distributes the cluster head.
Minglan Yuan in 2020 [13]	Energy LEACH (E-LEACH protocol)	It created a new threshold judgement formula and chose the cluster head node in accordance with it, increasing the likelihood that the cluster head will be a node that is close to the base station, has more residual energy, and experiences less energy change.
Haibo Liang et al. in 2019 [23]	WSN Routing Dense LEACH based routing protocol	It creates an unstable network operating problem by picking CH nodes at random in a loop to balance network electricity usage. An inter-routing protocol is improved by using an ant colony approach.

VIII. Performance Evaluation Metrics of Routing Protocols in WSN

In order to assess performance, this section discusses various routing protocol performance measurements. The parameters are selected to allow for a thorough assessment of the performance traits of routing protocols.

Throughput- Bits transported per second are used to measure throughput. Kbps is the throughput measuring unit (Kilobits per second). This measurement provides an instantaneous impression of how productively each group supports system activities. A higher throughput shows that the steering for information and control messages was maintained by the framework.

End to end delay- A standard system's end-to-end delay is the amount of time needed to transmit packets from a sender node to a destination node.

Normalized routing overhead- It is defined as the quantity of routing packets transmitted for every data packet.

Packet delivery ratio is calculated as the ratio of packets transmitted to packets received by the destination node. Percentage (%) is the unit of measurement for it.

Latency- The time delay that occurs during data transmission from the sender to the destination is referred to as latency. It's timed in seconds.

Success rate- It is the proportion of whole packets received at the receiver divided by the total number of full packets of data created by the nodes in the network. It is expressed in percentage (%) terms.

Energy Consumption- It is the overall amount of energy used by network nodes during the experiment. Joules are used to measure it (J).

Energy efficiency- It is calculated as the amount of packets sent to the destination node divided by the amount of energy used by the sensor nodes. Kilobits per Joule (Kb/J) are the unit of measurement.

Standard Deviation- The standard deviation measures the typical fluctuation in energy levels over the whole network of SNs.

IX. Conclusion

In order to recognise the efforts of academics working on routing protocols for wireless sensor networks that are energy efficient, this study presents a thorough overview of the various routing methods. LEACH is the most straightforward yet effective of the various hierarchical routing techniques. Because of LEACH's simplicity and adaptability, it may be used as a foundation for many other procedures, which is what motivated us to investigate it in the first place. In terms of longevity, throughput, and energy consumption, we can say that LEACH is more effective than conventional routing protocols [4]. The energy consumption of each sensor node is uniformly distributed and decreased as cluster heads are chosen from the sensor nodes. The vitality and effectiveness of LEACH's cluster-based hierarchical approach are thereby increased.

References:

[1] Arnab Nandi, Akshay Vaibhav Bengaluru, Baishalee Sonowal, Dimbeswar Rabha, “Centered Sink LEACH Protocol for Enhanced Performance of Wireless Sensor Network”, 2019 International Conference on Automation, Computational and Technology Management (ICACTM) Amity University, pp 436-440.

[2] Zhen Zhao, Guangming Li, Menghui Xu, “An Improved Algorithm Based on LEACH Routing Protocol”, 2019 IEEE 19th International Conference on Communication Technology, pp 1248-1250.

[3] Akanksha Vyas, Sachin Puntambekar, “Cluster Based Leach Routing Protocol and Its Successor: A Review”, Journal of Scientific Research, 2022, pp 326-341.

[4] Pratiksha Mishra, Satish Kumar Alaria, Prakash Dangi, “Design and Comparison of LEACH and Improved Centralized LEACH in Wireless Sensor Network”, International Journal on Recent and Innovation Trends in Computing and Communication, 2021, pp 34-40.

[5] YiLin Chen, Lingyun Jiang, Yanru Mu, “A LEACH-based WSN Energy Balance Routing Algorithm”, Association for Computing Machinery, 2019, pp 37-41.

[6] Anas Ali Hussien, Shaymaa W. Al-Shammari, Mehdi J. Marie, “Performance evaluation of wireless sensor networks using LEACH protocol”, Indonesian Journal of Electrical Engineering and Computer Science, 2020, pp 395-402.

[7] Muhammad K. Khan, Muhammad Shiraz, Qaisar Shaheen ,Shariq Aziz Butt, Rizwan Akhtar, Muazzam A. Khan, and Wang Changda, “Hierarchical Routing Protocols for Wireless

Sensor Networks: Functional and Performance Analysis", Hindawi Journal of Sensors 2021, pp 1-18.

[8] Ikram Daanoune, Abdennaceur Baghdad, Abdelhakim Ballouk, "An enhanced energy-efficient routing protocol for wireless sensor network", International Journal of Electrical and Computer Engineering, 2020, pp 5462-5469.

[9] Adnan Yousaf, Faiza Ahmad, Shahzaib Hamid and Fahad Khan, "Performance Comparison of Various LEACH Protocols in Wireless Sensor Networks", International Colloquium on Signal Processing & its Applications, 2019, pp 108-113.

[10] Miss. Noor Qubbaj, Dr. Anas Abu Taleb, Prof. Walid Salameh, "Review on LEACH Protocol", IEEE 202, pp 1-8.

[11] Amrutanshu Panigrahi, Bibhuprasad Sahu, and Sushree Bibhuprada B. Priyadarshini, "Hetero Leach: Leach Protocol with Heterogeneous Energy Constraint", Springer, 2021, pp 21-29.

[12] Bhagyshree Pawde and Bharathi Shetty, "Heterogeneous LEACH Protocol with sink node protection in a Wireless Sensor Network", ICTACT Journal on Communication Technology, 2019, pp 1999-2007.

[13] Seham Nasr, Muhannad Quwaider, "LEACH Protocol Enhancement for Increasing WSN Lifetime", International Conference on Information and Communication Systems, 2020, pp 102-107.

[14] Rehab Sattar Motlag Alyousuf, "Analysis and Comparison on Algorithmic Functions of Leach Protocol in Wireless Sensor Networks [WSN]", International Conference on Smart Systems and Inventive Technology, 2020, pp 1349-1355.

[15] Xiaojun Ren, Jiaqing Li, Yongtang Wu, Yuanfang Chen, Hongwei Sun, Zhichen Shi, "An enhanced energy optimization routing protocol for WSNs", Springer 2021, pp 1-12.

[16] Akash Chandanse, Pratik Bharane, Sujoy Anchan, Hemlata Patil, "Performance Analysis of LEACH Protocol in Wireless Sensor Network", International Conference on Advances in Science & Technology, 2019, pp 1-5.

[17] Haibin Sun and Dijing Pan, "Research on Optimization of Energy Efficient Routing Protocol Based on LEACH", Research Square, 2021, pp 1-27.

[18] Anu and Silki, "Energy Efficient Routing Protocols for Wireless Sensor Networks–A Review", International Journal of Computer Networks and Wireless Communications, 2018, pp 15-23.

[19] Christos Nakas, Dionisis Kandris, and Georgios Visvardis, "Energy Efficient Routing in Wireless Sensor Networks: A Comprehensive Survey", Algorithms 2020, pp 1-65.

[20] Shio Kumar Singh, M P Singh, and D K Singh, "Routing Protocols in Wireless Sensor Networks – A Survey", International Journal of Computer Science & Engineering Survey, 2010, pp 63-84.

[21] Ravi Kishore Kodali and Naveen Kumar Aravapalli, "Multi-level LEACH Protocol model using NS-3", IEEE 2014, pp 375-381.