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**A SYSTEMATIC MAPPING STUDY ON ENERGY
EFFICIENT ROUTING PROTOCOLS IN
WIRELESS
SENSOR NETWORKS (WSNS)**

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Master's Thesis

Supervisor

Asst. Prof. Dr. Ayça Kurnaz TÜRK BEN

Istanbul, 2023

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ABSTRACT

A SYSTEMATIC MAPPING STUDY ON ENERGY EFFICIENT ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS (WSNs)

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The past few years have witnessed much research interest on energy-efficient routing in Wireless Sensor Networks (WSNs). With relatively reasonable number of studies published in the research area. This growing interest has necessitated a thorough investigation that provides scholars with a thorough comprehension of this area of study. This study aims to identify the general research trend, demographics, and productivity on energy-efficient routing in WSNs. To achieve such, this study embarked on a Systematic Mapping Study (SMS) aimed at the identification and classification of relevant studies to provide the answers to the defined Research Questions (RQs). The adoption of an evidence-based systematic mapping approach in this study is to ensure an unbiased coverage, selection, and evaluation of the identified works. This mapping study led to the final selection of 120 related studies. The outcome of the SMS study showed a good level of consistency and stability in this domain in the past five years. Four research facets were identified, which are Solution proposal (90%), Evaluation research (4%), Experience paper (4%), and Investigative study (2%), with Solution proposal (90%) been the most proposed. Besides, different performance measures, validation methods, simulation tools, routing architecture (multi-hop, single hop and hybrid), and the general demographics were identified and categorized. Lastly, the trends in the research domain with the threat to validity were outlined and discussed. This study will help researchers to explore more opportunities in the research.

Keywords: Wireless, Sensor Network, Network Protocols, Energy Efficient, Leach.

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ABBREVIATIONS

LEACH	:	Low Energy Adaptive Clustering Hierarchy
MAC	:	Medium Access Control
MANET	:	Mobile Ad-Hoc Networks
OFDMA	:	Orthogonal frequency-division multiple access
PEGASIS	:	Power-Efficient Gathering in Sensor Information Systems
RREQ	:	Route Request
WSNs	:	Wireless Sensor Networks
RQ	:	Research Questions
SMS	:	Systematic Mapping Study
DARPA	:	Defense Advanced Research Project Agency
RSS	:	Received Signal Strength

1. INTRODUCTION

WSNs empower the perception of up until recently concealed peculiarities at high spatial and worldly goal. WSNs processors in different modes (rest, inactive, dynamic), power source (A battery or Coin batteries, Sunlight based chargers), memory utilized for the program code and in-memory buffering, radio utilized for transferring the got information to some capacity site, sensors for temperature, dampness, and light and small [1]. Sensor hubs in a WSN have engaging usefulness, for example, simplicity of establishment, deformity sign, level energy conclusion, high reliability, simple coordination with different hubs in the organization, control conventions, and straightforward organization communicates with other brilliant gadgets [15]. Accordingly, there are various directing conventions to perform information transmission and calculation expected to convey information from the source to the objective. These conventions are arranged into two classifications in view of organization design and course assurance, and some of those are: LEACH [49], DD [56], GEAR [22], GAF [19], SPIN [14]. Another dynamic directing convention is proposed in this proposition to expand network lifetime. Which works on the organization's presentation in conveying the necessary information to the objective, as confirmed by measurements that show us the energy utilization, throughput, and information transmission process. Spatially distributed autonomous sensors are included within the WSN for monitoring the environment or physical conditions. The parameters of pressure, sound, temperature, etc [50]. are considered as physical or environmental conditions in a network, also the data has been transmitted over the network towards the main location. The activity of the sensor is controlled in modern networks as they are bidirectional. Different kinds of applications of WSN are included industrial, military, as well as consumer areas for machine health monitoring and industrial process monitoring, etc. The nodes are built in the wireless sensor network that includes from a few to several hundred or even thousand, and one or more sensors in the network are connected to each node. Typically, several parts are presented at each sensor node in the network, and they are included a microcontroller, an internal antenna embedded to a radio transceiver or an external antenna is connected, a source of energy which is usually an embedded or battery form of an energy harvesting [51], and an electronic circuit to interface with the sensors. Wireless communication using electromagnetic waves has been possible since their discovery at the end of the 19th century [52]. The Open System Interconnection Reference Model (short: OSI model), which has

been standardized since 1983 and has been developed for data transmission, provides a tool for modern wireless data transmission. The OSI model describes data transmission as a process that goes through different layers, as shown in Figure 1.1 When a computer communicates with another computer, the protocol levels used by the sender are run through from top to bottom until the message is finally transmitted. The recipient of the message, on the other hand, processes the protocol stack from bottom to top to interpret and use the received data in a meaningful manner. The wired differs from the wireless communication mainly in the transmission medium and the lower three layers, which are explained in detail below for the understanding of the present work.

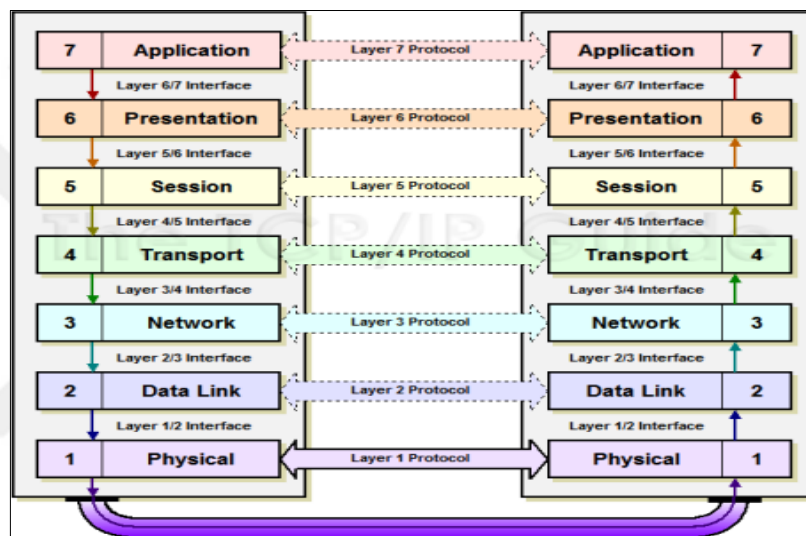


Figure 1.1: OSI Model for Computer Communication (Sumit Kumar et al., 2014).

1.1 WIRELESS SENSOR NETWORK

The sound surveillance system is the first wireless sensor system comes in the 1950s, to find Soviet submarines. This technology is also used in the monitoring of sea wildlife. In the 1960s and 1970s hardware has been developed for utilizing the sensor into the internet. In the 1980s, The United States Defense Advanced Research Project Agency (DARPA) introduced the Distributed Sensor Silicon Laboratories to explore the challenges in a wireless sensor network. Table 1.1 describes the generations of Sensor Networks [57].

Table 1.1: Generations of Sensor Networks.

Attributes	First Generation (80-90s)	Second Generation (Early 2000s)	Third Generation (Later 2000s)
Size	Attach or larger	Paper book or Smaller	Small , eve a dust particle Grams or less
Wright	Pounds	Ounces	Grams or less
Deployment Mode	Physically installed or air-dropped	Hand-Placed	Embedded or Sprinkled based on nanotechnology based
Node Architecture	Separate Sensing, Processing and communication	Integrated sensing, processing and communication	Fully Integrated sensing processing
Protocols	Proprietary	Proprietary	Wi-Fi,Zigbee, WiMax etc
Topology	Point to Point star and multihop	Client Sever and peer to peer	Fully peer to peer
Power Supply	Larger Batteries or line feed	AA batteries	Solar or Possibly nanotechnology based
Life Span	Hours days and longer	Days to weeks	Months to years

In recent decades, WSN has come into prominence because it has the attributes to change the living standards using monitoring, automation, and management of applications. WSN is a collection of tiny computers. These tiny computers are called sensor nodes. WSN is used basically for the monitoring the environment, field area, machines, etc using sensing the activities. For designing, implementation, and operation of a sensor network, care should be taken of signal processing, routing, protocols, data management etc [56]. Four basic components of the sensor network are the assembly of sensors which are distributed or localized, connect to another network, collection of information at a center point, resources that handle data collection and mining. WSNs have some general properties and assumptions. These properties make WSN different from others.

- a. Limited resource of single sensor.
- b. Connections between nodes are not planned; the only assumption is that nodes will detect its neighbors.
- c. Sensor nodes only sensed and send the data. No other moderation is operated.
- d. The WSN is a system for communication, which senses data and collects the data from a explicit area and passes on that information to the main area. For such kind of network should be competent, safe, easy to handle and consistent. The WSN is valuable for military applications, monitoring in farms and forests [57].

Wireless sensor network applications provide benefits to the environment. The basic formation of the WSN is shown in Figure 1.2.

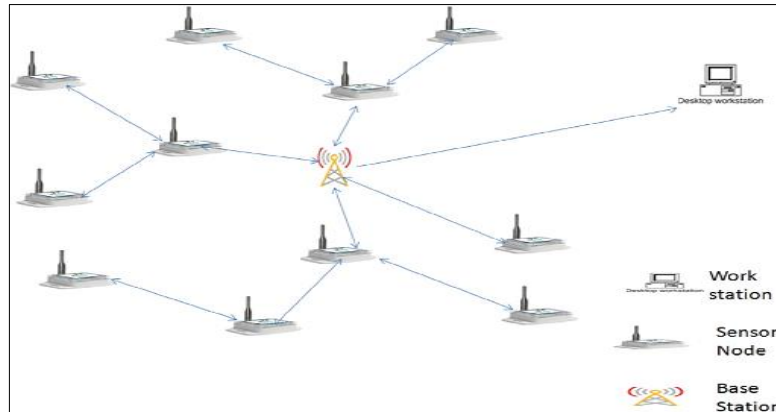


Figure 1.2: Basic of Wireless Sensor Network.

The main feature of WSN is, less in size and cost of nodes, energy efficient network, all nodes are connected with each other automatically, the network is self-organized, nodes have less computational memory, packet size is small and network scalable. The wireless sensor network can easily handle the node failure. Nodes of WSN can be mobile. In a single wireless network, both types of nodes are available heterogeneous and homogeneous. The WSN is designed for the harsh environment. This network is easy to use [56][57].

1.2 PROBLEM STATEMENT

The features of WSNs and application requirements have a direct impact on the design problems for networks based on performance and capacities. For the design of the architectural structures of sensor networks, the unpredictability of a large number of sensors and the dynamism of their operational environment creates special problems. WSNs provide a number of obstacles to the research community despite their fantastic and numerous benefits, such as distributed localized computing, large area coverage, and extreme environment area monitoring. Despite their wonderful and numerous benefits, such as distributed localized computation, wide-area coverage, and extreme monitoring of environments, WSNs provide a number of obstacles to the research community. We have made an effort to identify some of the most significant challenges encountered when planning the routing in WSNs, including: node capabilities, node deployment, hardware resource constraints, energy consumptions, data delivery models, and data aggregation, network dynamics in nature, and network scalability. Given that the architectural model and the routing protocol's performance are tightly related, WSN routing methods are distinct from the standard network algorithm according to their features and specifications. Since

each node has a finite quantity of energy, it is crucial to create an energy-efficient routing protocol to increase the network's lifespan. The network must be designed to minimize data transfer and reduce redundancy of information by aggregating data. In this network, expressly essential for reducing energy consumption is multi hop communication. Routing protocols shouldn't include overly complicated calculations; the routing method itself should be straightforward and effective, able to adapt to changes in the dynamic topology, have a fault tolerance mechanism, reduce communication costs, and increase transmission efficiency. The way routing paths are built up, the network's structure, how the protocol operates, and how the interactions are initiated are all factors that can be used to categorize different sensor network routing protocols. The problem with WSNs is their inherent constraints, including as cost, size, and constrained power. We are working to address the power usage issue because it is crucial to extending network longevity.

1.3 RESEARCH OBJECTIVES

The major objectives of this thesis are as follows:

- a. A comprehensive SMS on energy-efficient routing protocol in WSN.
- b. A deep analysis of the current research trend in the area of energy-efficient routing protocol in WSN.
- c. The identification of critical challenges in the WSN routing protocol energy efficiency.
- d. Proposed new developed Leach protocol and evaluate the proposed with recently works.

1.4 MOTIVATION

WSNs are small devices that gather data from important sites that humans cannot reach, and they rely on limited energy sources such as batteries. There have been many studies that explore energy-efficient protocols, but prior studies only handled one protocol at a time to save energy. So, we proposed a new strategy to combining two protocols in a dynamic manner using two energy-efficient protocols from two classes and the appropriate network structure based on specific factors including the amount of data, status of network, and node state from an energy standpoint.

1.5 THESIS ORGANIZATION

The structure of this thesis is as follows:

In Chapter 2, we provide a thorough literature survey focusing on application-specific design, energy-efficient wireless sensor networks.

Chapter 3, we describe our energy-efficient data collection schemes and how we compared its performance against existing approaches. Also, to investigate the general trends, demographics, and productivity in this research zone. In doing so, the study classified the identified studies by analysing the researches.

In chapter 4, This chapter includes the analysis, presentation, and interpretation of the study's findings.

In Chapter 5, we present and evaluate our new proposed for Leach protocol it's have been developed and We describe our wearable sensor network energy-efficient design in detail.

Therefor chapter 6, The conclusions from the various implementations stated above and discussed are presented in this chapter. The chapter also discusses possible future paths for research.

2. LITERATURE REVIEW

2.1 WSNS OVERVIEW

The WSNs are targeted to achieve the goals of transmitting detected data towards sink nodes or the BS or reporting events of predetermined nature for analyzing the information further. In WSNs, each node is playing a key role in data originator in addition to a router (Elappila et al., 2018). Through a single hop or multi-hop, sensor nodes detect and transmit the data towards destination. The transmission must be energy efficient as a sensor node has included restricted as well as irreplaceable battery sources. Due to the several constraints on energy efficiency in the network, the challenging task is to design the routing protocols in WSNs. For determining the lifetime of sensor networks, the routing algorithms for WSN mostly consider the finding of energy-efficient paths. The sensor networks can't observe events from the target areas of some parts as the power is exhausted on efficient paths rapidly in the sensor network. The energy efficiency has been considered in the routing algorithms in addition to the degree of energy left in every sensor. Due to the right time power exhaustion, the routing algorithms are working by keeping away from nonfunctioning sensors. To prolong the lifetime of network, the significant source of energy utilization is considered as data transmission, and designing an energy-efficient scheme is a severe challenge in WSNs. Figure 2.1 illustrate the typical scenario for the WSN.

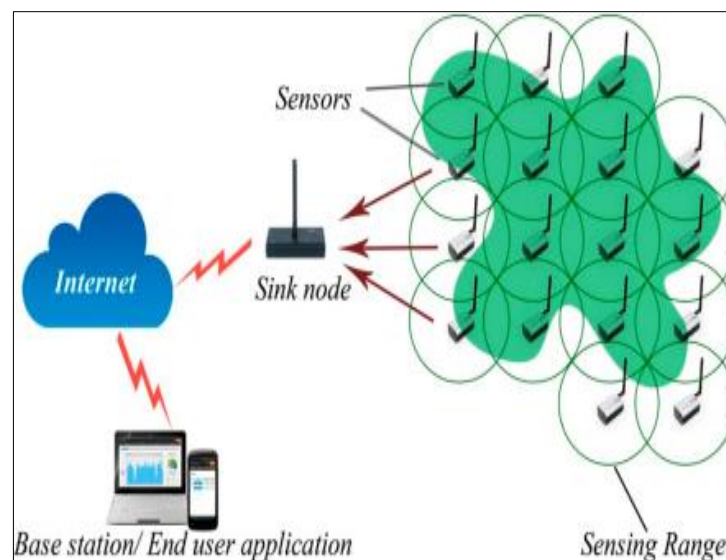


Figure 2.1: The Scenario of WSNs [17].

2.2 ARCHITECTURE ELEMENTS OF SENSOR NETWORK

- a. Vineyard monitoring Using wireless sensor network, the reduction of water irrigation and vine sicknesses has been identified in a timely manner. Sensors also help to minimize the water usage, control the air temperature pressure and humidity in covered farms. The Sensor nodes can deploy all over the vineyard and information has been gathered by base station [57].
- b. Bridge monitoring for measuring the structural integrity of an old bridge sensor network has been used. Sensor network measured the traffic and pressure on the bridge. For this sensors node are deployed in the various areas of bridge such as curves under angles, turns.
- c. Fire detection for detecting the fire earlier, the wireless sensor network is deployed all over the area. The sensor network senses the high temperature and raises the alarm.
- d. Tunnel monitoring of tunnel is important to know the exact situation inside the tunnel sensor nodes provides the information related to the traffic of the tunnel.
- e. Animal monitoring and recognition We can easily monitor and recognize the animal using sensors. The sensor measures the movement of animal and sends their location to the base station. It also measures the level of gas like methane, ammonia and Hydrogen sulfide in the animal closed farms. Vibration and movement of wireless sensor nodes are used to find the stress stage of the animal.
- f. Highway monitoring Highway monitoring is also possible using the WSN to avoid the accidents on the highway. Sensor nodes sense the speed of the vehicle on the highway and pass the information to the nearby sink station where the controlling officer can stop the vehicle.
- g. Home control Using WSN, it is easy to operate the home appliances from outside the house. Sensor nodes are deployed on the various appliances like refrigerator, microwave, water tanks, and security system from where nodes sense the activities and send the data to the sink station. The server application will then receive that data from the sink station.
- h. Building automation Wireless sensor network has been used in the building automation to reduce the energy wastage by controlling the light, to control the humidity, automatically operate the ventilators and air conditioners. Sensor nodes are deployed into a room and they sensed the number of people in the room to control the above-mentioned conditions.

2.3 CHALLENGES IN WSN

2.3.1 Fault Tolerance

It is essential to remember a point that the wireless sensor network as a whole can tolerate any kind of faults like damaging of nodes or run out of energy or permanent interruption between two nodes in the wireless communication. If all nodes are operated correctly in the network, a redundant deployment is strictly required using more nodes for tolerating the node failure.

2.3.2 Lifetime

A limited supply of energy is required for nodes in many cases, and the energy sources in the field can't be replaceable in the practical scenario. For a given period or as long as possible, a WSN should be operated for efficient transmission. Based on this, a figure of merit is considered a lifetime of a WSN. Accordingly, the operation of the WSN should be energy efficient. The direct trade-offs of the lifespan network are quality of service and energy, which means the quality of service is increased if more energy is invested. Still, the lifetime of a network is decreased automatically.

2.3.3 Programmability

Information processing can be done using the network's wireless nodes, and also, they are reacted instantly to the modified tasks. If new modified tasks become essential, the nodes in the network must be programmable according to the changes during operation. However, the information process is not sufficient in a fixed way.

2.3.4 The Wide Range of Densities

The number of nodes per unit area has included a varied operation in a wireless sensor network. Different node densities will present in different types of applications [59]. The density of nodes can vary according to the time and space as the nodes are moved or failed in any given application. The density of the overall network need not be in a homogeneous form because the deployment process is done imperfectly, and the nodes should adapt such variations.

2.4 LITERATURE SURVEY

In the area of wireless sensor transmission, the design of WSN is considered as one of the most challenging areas as they are energy constrained. In various applications, the nodes of WSN cannot be recharged because they are small, lower-cost, and power limited batteries. In the design of WSN, the application of energy-efficient algorithms becomes essential. For instrumentation and predictive maintenance systems [61], a wireless smart sensor platform presented. By using a RF link for communications in a point-to-point topology, the plug-and-play capability supports the hardware interface in the generic smart sensor platform in which the payload and communication requires of multiple inertial and position actuators and sensors. A WSN based intelligent system is proposed by for indoor management systems. To provide background and concentrated illuminations, wireless sensors have been utilized which are responsible for estimation of current illuminations along with the usage of local lighting and whole lighting devices. The user locations are demanded by the illumination requirement which is a combination of concentrated and background illuminations. For achieving the desired optimization goals, a closed loop device control algorithm is exploited by adjusting the illumination of devices. With the feedback taken from light sensors carried by sensors, an autonomous light control system is proposed by including the energy efficiency and preferences of users, the design has been focused along with the consideration of both whole and local lighting devices. A surface tracking is utilized to monitor the local lighting devices. The solutions are adapted to the environmental changes and no requirement of tracking of users location as they are autonomous. For assessment of lifetime in a cluster-based network scenario, an efficient energy utilization algorithm by using LEACH protocol has been proposed [62]. The system is degraded based on energy usage and network communication lifespan by indulging the energy utilization where is shown in the analysis. In the application environment, a need of improving a method of a standard well adapted clustering for increasing lifetime of the network and enhancing the energy utilization [63]. For development of runtime reconfigurable WSNs, an approach to open new horizons has been presented. The changes are occurred in the usage of WSNs due to the feasibility of the integration of new reconfiguration techniques in WSNs. Both runtime hardware reconfiguration and software updates have been included in the reconfiguration updates. The updates involve new functionalities, online testing, dynamic task allocation, debugging, updating of security information, and repair. A novel wireless nose platform is

designed for cooperative chemical sensing by following a power saving sensor strategy which is implemented based on Tiny OS [64]. By considering the capability of locally estimated air quality and chemicals concentrations, an on-board sensor fusion component harmonizes the software architecture. In the experimental scenarios, a measurement approach is applied to model and estimate the power savings. In WSNs, the energy minimization problems are investigated by for estimating of noise-corrupted parameters jointly and the digital signals are transmitted to a fusion center in the sensor network via orthogonal channels. The minimization of energy consumption at the sensors has been achieved by choosing a modulation order, a quantization level, and a transmission bandwidth by each sensor for its link to the fusion center. To improve the existing trade-off among energy consumption, reconstruction error, and resource utilization, a novel distributed compressed sensing transmission methodology known as Amplify and Forward Compressed Sensing (AFCS) [65], which is proposed by. In this method, the number of active nodes and reliance on the cost function are used to control the trade-off between energy consumption and reconstruction error. It is possible to integrate several optical fiber-wired sensors effectively by establishing a generic WSN Platform which is explored for the potential of creating a hybrid WSN. By coupling advanced optical sensor techniques to the WSNs, the potential of a sensor system is maximized. To make easier the integration of the optical fiber sensor modules each wireless node is configured as a generic platform in a WSN. By using a Received Signal Strength (RSS) based localization, the performance of WSN is analyzed by in terms of energy consumption and computation power of nodes. For enhancing the performances, Weighted Least Square (WLS) algorithm [66], is used in this method to improve the location estimation and anchor optimization. Furthermore, the locations of target nodes are estimated by an improved performance using an anchor node which is included high resources and known its location in the system.

2.5 ENERGY EFFICIENT ROUTING PROTOCOLS IN WSN: EXISTING WORK

description and presents the problem regarding to the information movement in wireless sensor networks [1]. They have shown the architecture with two attributes for the illustration: a functional repartitioning and an intra-node router. They contend that their design lessens traffic through the router. [2], describes in network hundreds and thousands sensing nodes

are available. These nodes have the attribute to be energy efficient and less in cost. After analyzing advantages and disadvantages of existing protocols author developed LEACH that decreases the energy dissipation. Clustering setup phase and localized coordination has been used in LEACH to make coordination between cluster head or base stations in regular change. Local compression has been used for reducing global communication. [3], describe the sensors used are extremely small, low power device that programmed to sense the data. Now the challenge is how this sensed data or information collect and store within the sensor network. In this article, the author describes an architecture called SINA (sensor information network architecture). This SINA provides querying, monitoring and tasking facilities for the sensor network. SINA works like middleware to organize the sensor information. The kernel of SINA is a set of configuration and communication primitives. It provides scalability, robustness and energy efficiency to a sensor network. The first step of an establishment of the WSN is the deployment of wireless sensor nodes. Low power hardware components and customized system architecture are necessary to create a network [4], have introduced a concept to select the wireless sensor nodes in such a way so that all monitoring area is covered completely. The author made jointly exclusive sets of wireless sensor nodes where only one active set at once. Simulation results show that by using only a set of sensor node energy saving is achieved. A cellular network is a collection of the sensor network with more than one cluster. Cluster and cluster head is in cluster network and the sink is in a cellular network. For increasing life of sensor network [5], have worked on the connection between bandwidth and energy consumption. The author proposes a fine-grain variable bandwidth allocation with proper use of bandwidth. To reduce average power consumption a polynomial time slot is assigned to the algorithm for multiple cluster sensor networks [6], have proposed a new threshold algorithm to get better network lifespan. This algorithm's main idea is to choose a new CH (cluster head) so that it can cut the lower energy node to become cluster head. Threshold has been modified for selecting CH at next level. Different threshold compares with a random number and greater probability nodes elect as a cluster head. The lower level of the network connection is situated near to the sink. The sensor nodes need to handle network traffic because these nodes deplete their energy very soon. There is an imbalance of workload in the network which is called hotspot problem [7]. Have proposed an algorithm EAMTR for solving hotspot problem. EAMTR is energy aware multitree routing algorithm. In high-density sink-type network EAMTR gives energy balancing, an

extension of network lifetime and reliability using route redundancy [8]. goes into extraordinary length about bunching systems. A bunch is an assortment of sensor hubs. In a progressive framework, each bunch has a head. These group heads complete basic capabilities like as combination and collection. Sensor hubs recognize the information and send it to CH. The information is solidified by the group head and shipped off the base station. Since CH sends information to the base station and, now and again, with more noteworthy distance, CH exhausts energy rapidly. Thus, the solution to this issue is to reappoint another bunch chief in each group. Base station is an information handling point. The base station is in many cases found some separation away from the sensor organization. CH fills in as a connection between node sensor hubs and the base station. Hierarchical cluster head concept is useful for that application those require scalability. the load balancing and efficient resource utilization is related to Scalability. The adaptive cluster head algorithm is among the approaches to decrease the consumption of energy of WSN [9]. Have projected a new energy-aware cluster head algorithm through the use of Ant colony optimization technique. The authors use a cost function that is implemented on the base station and minimize the distribution cost transmission of long-distance. Using ACO algorithm cluster heads have been selected and change the distance dynamically between CHs and distributed clusters [10], examine the Filter defects, for example, bunch head choice and disregarding hub remaining energy. In light of these lacks, the creator offers another reasonable Drain approach. At the second period of Drain B group head choice depends on the excess energy of the sensor hub [11], introduce a cross-layer approach and propose a cooperative LEACH protocol. Cooperative LEACH has M cluster heads in a cluster. These M cluster heads send data to sink or higher layer cluster heads. This method is most likely multipath routing scheme. Cooperative LEACH protocol decreases high energy utilization [12], mainly take into account the efficiency of energy and end-to-end latency and. It is explained how several routing protocols including TEEN, APTEEN, SPEED, RAP, and RPAR compare in terms of energy efficiency and timeliness. When it comes to energy efficiency, TEEN is the sensor network protocol utilized for time-sensitive data sensing applications. The main drawback of TEEN is CH will not have information when the sensor nodes die. APTEEN is a protocol for an energy-efficiency sensor network that is adaptively sensitive. It is used for periodic collection of data and critical events. The drawback of APTEEN is that it requires additional complexity. Stateless Non-deterministic Geographic forwarding protocol maintains

immediate neighbor's information for minimizing memory requirements. For removing congestion backpressure re-routing techniques has been used. RAP is a real-time communication architecture for massive wireless sensor networks. RAP offers event and query services. RPAR is real-time power-aware routing in WSN. Increasing the amount of packets that meets their deadline is the primary goal of this protocol. RPAR also maintain properties of WSN like loosely links limited memory bandwidth [13], have introduced a spare selection phase into LEACH and propose a new protocol called LEACH-SM. Spare node strategy has been used for improving network life. There are active and passive nodes for efficient usages of energy. Nodes become inactive node when awaking spare time is over and previously active node reached their exhausted limit. One of popular routing scheme of WSN is converge cast. In which every sensor node sends the packet to the base station using configured routing paths. For saving energy converge cast routing technique send a single packet in which all received data has been merged along with own data [14]. Propose a chain routing with even energy consumption protocol. IN CREEC a centralized control at BS has been processed for the longer lifetime. Calculation of routing path and schedules throwing is done by BS. Throwing is a technique in which packet directly transmit to the base station. CREEC uses two main rules one is fairness of energy allotment and another one minimizes the total energy utilization. A feedback mechanism is also used for energy distribution. The base station calculates the energy of each node. According to that energy level chain is re-build. Lower energy node will get light roles. CREEC implement two types of transmission Throwing and forwarding. Scalability and simplicity are the characteristics of energy-aware geographic routing scheme for WSN. Geographic routing provides the pure location information rather than global topology information to route data packets. This location information feature makes it efficient, simple and scalable. There are two modes of working in geographic Greedy mode and Detouring mode. The most frequent error in geographic protocols is packet delivery, which is uncertain in the detouring mode. An energy-aware interference sensitive geographic routing (EIGR) protocol is proposed by [15]. Total energy conservation and interference reduction are two factors that EIGR takes into account. EIGR used an anchor list to provide the guidance to deliver the data. For data delivery, greedy forwarding scheme is used. An energy-efficient relay region has been introduced. This relay region is beneficial for energy conservation. A device wastes a big amount of energy if their battery discharging is not managed. So the study of battery behavior is important for

improving network life [16], has presented a scheme called BAR (battery-aware scheme). This scheme is independent of any routing protocol. Nickel-cadmium or Lithium-ion are power provides for wireless devices. The author divides the time into fixed-length durations so that it will fit into the packets witched network. The author also gives an online model for computing battery capacity. For prioritizing services BAR an enhanced scheme developed called PBAR. BAR scheme is used in PBAR [17], for improving network life by routing techniques there are two main problems occurs first one is routing overhead is very high and second is route maintenance scheme is not suitable for energy efficiency. Therefore, author proposes a new metric for link cost for finding energy efficient routing path and a protocol for improving path setup transmission, performance, and energy consumption. PEER quickly search the energy efficient path and maintains route active for respond to topology. PEER protocol's route request packet having two information one hop count and energy consumption. This information will update after receives to an intermediate node, then the packet will rebroadcast if one of the following conditions occur [18]. Explains how a wireless sensor network is utilized to gather information from various sensors. So, this type of application requires multiple sources to collect data and multiple sinks. When we are having such type of application that required multiple sources and sinks for data collection, single sink protocols are ill-suited. There are various protocols having a single sink. To solve above-mentioned problem author, develop MUSTER protocol having many to many communications in WSNs. MUSTER having distributed path merging and load balancing features. MUSTER doubles the lifetime of WSNs [19], describes almost all existing energy-efficient protocol selects the minimum energy path and lowest energy consumption for transmission of packets. This is the main reason of unbalance distribution of residual energy in sensor nodes. By consideration of this author propose an algorithm called Energy-Balanced Routing Protocol (EBRP). The author uses physics concept and constructs a potential field with respect to depth, energy density, and residual energy. Packet moves to sink using dense energy and residual energy. Topology, applications, routing are the reasons of imbalance in energy distribution. Deployment optimization, topology control, mobile sink/relay nodes, aggregation of data and energy-balanced routing are the possible solution to balance energy consumption. [20], propose a method to find out the specifications of network resources. Network specifications are the number of accessible nodes; sensing range and spatial sensing coverage etc. after that author develop novel criteria by considering SSC

as the wireless sensor network successful operation criteria. Life time-aware routing and the desired sensing spatial coverage of the field of interest are the two main challenges in WSN. Author's work is focused on network layer and routing algorithm FA proposes for optimizing the lifetime and sensing coverage of the network. FA algorithm will increase the monitoring and sensing coverage ability and the lifetime of the network.

2.6 GAPS IN EXISTING RESEARCH

Several technologies are developed to increase the battery life of sensor node by focusing the selection of cluster head, coverage area, and power consumption. For instance, low power consumption, selection of high energy cluster heads, distribution of cluster heads has received much attention recently.

- a. Cluster head selection and distance between a candidate node and base station need to be identified simultaneously. Little work has been done to this effect. A new protocol needs to be proposed and investigated so that an energy efficient network will be introducing.
- b. A lot of scope for work in the area of multiple levels of cluster hierarchy. Evenly distributed cluster heads can improve the network life and data loss in the network.
- c. A lot of scope remains in the area of dissipated energy, the frequency of cluster head election and transmission of data.
- d. A lot of scope for work in the area of the current sensor node and head node energy calculation for energy- efficient sensor network. Similarly, the problem of data security of sensor network which requires each application to secure the information.

LEACH algorithm is required changes [2], although various changes are already done and mentioned in literature survey. By considering LEACH algorithm and changes in LEACH algorithm, we will try to develop a new concept for improving network life. The primary goal of the new algorithm is to cover the gap between existing approaches so that network life will increase. These are the points which need to be added to the algorithm to make it better.

- a. Cluster head selection will improve.
- b. Cluster formation will improve.
- c. Energy selection equations will be modified.
- d. Selection of threshold value will improve.
- e. By considering abovementioned points network life will improve.

3. ROPOSED SYSTEM

3.1 INTRODUCTION

WSNs lifetime depends solely on the residual energy level of the network nodes. In WSNs, in most situations, it is challenging, if not impossible, to recharge the battery of a given node [1]. Therefore, the effective and efficient utilization of available energy sources of a node is imperative. The literature review shows that there are many energy-efficient routing protocols proposed and used the existing restricted resources for sensor nodes more effectively and efficiently [2][4]. These protocols generally aim to discover available paths that have minimal energy capacity for optimization. However, utilization of paths with minimal energy is not ideal as network lifetime can be affected particularly in long-period connectivity. In the past decade, the interest in energy-efficient routing in WSNs is consistent with key works published. Also, some review studies were published in this research theme. However, from our general findings, a Systematic Mapping Study (SMS) is not conducted in the field of study. Therefore, conducting it is imperative in filling this research gap. Hence, SMS is conducted by extensively analysing key and relevant published studies in the last five years (2016-2021). This SMS adopted an evidence-based systematic mapping method to ascertain the reporting of important literature by utilizing an unbiased study selection procedure. This methodology is composed of the search strategy for relevant studies, criteria for inclusion and exclusion criteria, and procedures for data extraction and synthesis. Therefore, the objective of the SMS is to investigate the general trends, demographics, and productivity in the area of this research. In doing so, the study classified the identified studies by analysing the research facets, contribution facets, validation methods, routing architectures, performance metrics, simulation tools and general characteristics of the chosen studies' population. Knowing these will aid researchers in identifying the overall trend in the research area. Following is the study's organisation: Section 3.2 described the research methodology, while the results of the review findings are presented in Section 3.3. Section 3.4 discussed the systematic literature review study, the final section (Section 5) concluded the study.

3.2 METHODOLOGY

From Figure 1, the reader can see the SMS stages outlined in detail. Hence, the SMS process for this study is adopted from Kitchenham [5]. In conducting a mapping study, the reader will be provided with an evidence-based systematic and clear procedure for the identification of vastly significant works in a particular area of research to aid in answering the defined Research Questions (RQs) [6]. Thus, the essential objective of the review is to plan existing examination by breaking down generally efficiency, demography, and patterns in a particular exploration region. Interestingly, precise writing surveys (SLRs) are utilized to find, assess, and decipher pertinent examination for a particular subject. Look at Figure 3.1, the initial stage of this SMS is to identify the need for undertaking this study. Further, the review scope is defined by defining the RQs the SMS is trying to address. Hence, after the RQs are clearly defined and evaluated, the search query is outlined to help in the extraction of relevant works from the selected data sources. After collecting the primary studies (PS), our inclusion and exclusion criteria will be used to evaluate them and remove studies that are deemed not fit. Furthermore, the final PS will be collected and data will be extracted to help answer the defined RQs followed by data synthesis.

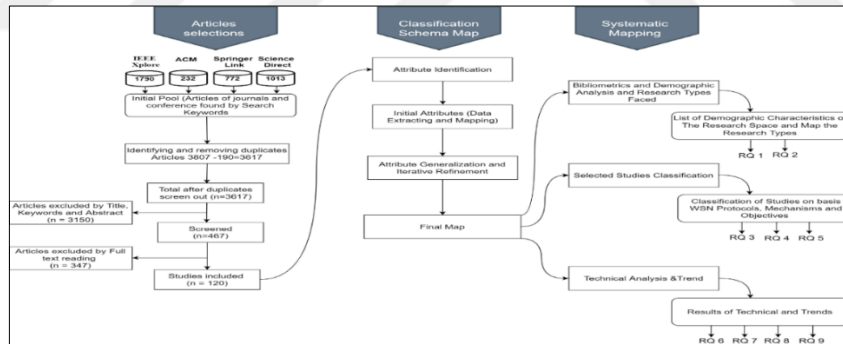


Figure 3.1: The Mapping Process.

3.3 RESEARCH QUESTIONS

For this SMS, the main objective is to institute a general understanding of energy-efficient routing protocols for WSNs and provide researchers with a general summary of the research conducted in the research area to give them perspective for future works. In achieving such, SMS gives a broad view of the research area. Hence, the RQs of this study are outlined in Table 3.1. The RQs will aid in the categorization and general understanding of the research area.

Table 3.1: Research Questions

RQ #	Research Question	Motivation
RQ1	Which demographic features are present in the relevant studies?	To highlight the publication trends of the selected studies, followed by the publication venues and highly cited studies.
RQ2	What Research facets have been focused by the studies in this domain studies?	To categorize the studies based on the research facets used.
RQ3	What are the classifications for chosen studies based on WSNs' energy-efficient routing protocols?	To classify the studies based on WSNs protocols (the state-of-the-art energy-efficient routing protocols)
RQ4	What are the classification of energy efficient mechanisms have been used in selected studies?	To classify the existing studies based on the energy-efficient mechanism they utilized.
RQ5	What classifications do the chosen studies fall into based on their objectives?	To map the categorization conducted in RQ3 with regards to the objectives
RQ6	What distinct performance measures were utilised in the chosen studies?	To identify the utilized measures of performance by the selected studies.
RQ7	Do the selected studies use single or multi-hop for routing communication?	To identify a single or multi-hop is used by the selected studies.
RQ8	What validation techniques did the chosen studies employ	To know the validation methods used by the selected studies, i.e., Experiment, simulation, and so on.
RQ9	What are the simulations tools used by the selected studies?	To identify and categorize the simulation tools used in evaluating proposals in this domain.

3.4 DATA SOURCES AND SEARCH TERMS

This segment portrays the review's information sources and search queries. IEEE Xplore, Science Direct, Springer Connection, and ACM were utilized as information sources. All pertinent papers in the subject of exploration are supposed to be recovered by utilizing these information sources. These sources of information are acknowledged in this study as the main hotspots for obtaining any expected related works. For a thorough and comprehensive search to be conducted, it is essential to identify key studies. In doing so, the selection of key terms is important during the search in the data sources. In this study, for the purpose of making the search more uniform, a generic search query was created. Therefore, in searching

for studies in our data sources, a generic search query is utilized. Look at Table 3.2, each data source's query was described in greater depth. Subsequently, the pursuit catchphrases were all steady. We utilized this to execute a brought together inquiry across all information sources. In any case, every data set has its own point of interaction for modern pursuit, with connectors like OR AND that are sporadically exchanged in light of the information sources utilized.

Table 3.2: Search Strings.

Data Source ID	Database Name	Web link	Search String
DS1	IEEE Xplore	http://ieeexplore.ieee.org/	((("Document Title":energy efficient) OR "Document Title":routing protocol) AND "Document Title":wireless sensor network) OR "Document Title":WSN)
DS2	Science Direct	http://sciencedirect.com/	Energy efficient AND routing protocol AND wireless sensor network OR WSN
DS3	Springer Link	https://link.springer.com/	'Energy AND efficient, AND routing AND protocol, AND wireless AND sensor AND network, AND WSN'
DS4	ACM	http://dl.acm.org/	[Publication Title: energy efficient] AND [Publication Title: routing protocol] AND [Abstract: wireless sensor network] AND [Abstract: wsn] AND [Publication Date: (01/01/2016 TO 31/12/2020)]

3.5 INCLUSION & EXCLUSION CRITERIA

To answer the identified RQs of Section 2.1, inclusion & exclusion criteria that will guide the selection of relevant studies for this work. This criterion is utilized in all the studies retrieved from the selected data sources. The period of time for study search on each data source was set from January 2016 to January 2021 (5 years period) for studies search. By

doing this, it is made certain that only recent studies were incorporated. In addition, earlier quoted research was also included, provided that the complete text of the studies was accessible. Table 3.3 highlight the process of selecting studies. In the last 5 years, 3807 studies were retrieved from the data sources, however, 467 were only chosen according to their importance to the research topic. Finally, 120 studies were selected. These studies fulfil the defined inclusion and exclusion criteria set. These criteria are presented in Table 3.4.

Table 3.3: Study Selection Process.

Data Source ID	Name of database	Initial results collected	Screened results based on relevance	Final selected studies on the basis of fulfilling the IC/EC criteria
DS1	IEEE Xplore	1790	209	87
DS2	Science Direct	1013	116	16
DS3	Springer Link	772	98	12
DS4	ACM	232	44	5
Total		3807	467	120

Table 3.4: The Designed Inclusion & Exclusion Criteria for the Study.

	Inclusion Criteria
IC1	Works that have been peer-reviewed
IC2	Works that focused on energy-efficient routing protocols in WSN
IC3	Works that were published online from 2016 - 2021
IC4	Works that aim to provide insights into the underlying research questions
	Exclusion Criteria
EC1	Works written in different languages apart from English language
EC2	Works that are not related to the research questions
EC3	Works without details like publishing date, volume, and issue numbers
EC4	Duplicate Works (in this case, latest studies of the same theme were chosen)
EC5	Works with no results and findings discussed

3.6 DATA EXTRACTION

All the 120 selected studies were analysed by the authors collectively. The full text for each article was evaluated by a minimum of two scholars. Therefore, key and important information that will help answer the RQs were retrieved using our data extraction form. The data extraction form comprised the list of items. The following the items listed below:

- a. Title
- b. Publication year
- c. Publication venue
- d. State-of-the-art energy-efficient routing protocol proposed
- e. Research facet
- f. Network structure
- g. Single or multi-hop
- h. Performance measure

Hence, collecting this information will help in answering all the relevant RQs in this study.



4. RESULTS & DISCUSSION

4.1 RESULTS

The findings of this study were presented in this section. The result presentation is aligned in line with the study's RQs.

RQ1: What are the demographics characteristics of the relevant studies?

From the 3807 studies retrieved using our search string, 467 studies were collected according to their relevance, while 120 were found suitable for the analysis in this study. The selected studies for the analysis were critically analysed to address the defined RQs in this study. An overview of the selected studies was presented in Appendix A. In answering this RQ, the general demographics of the selected studies will be analysed and discussed. Facets such as publication over time, citation impact, publication channel, most represented Journal, most represented institutions, and most active countries are all discussed.

4.1.1 Public Action Over Time

Regarding the year of publication for the selected 120 studies, Figure 4.1 presents the statistics from 2016 to 2020. This statistic represents a five-year research output in this research domain. Hence, we observed a high level of interest in addressing energy-efficiency issues with consistent and stable publications since 2016. We further observed that 2017 was the year with few studies with only 16 studies published. However, from the year 2016, we have seen a rise in quality publications onwards. With 2018, 2019, and 2020 had 27, 29, and 31 published studies, respectively. This surge can be explained by acknowledging the evolution in the field of study from basic WSN sending sensor data to the cloud. Hence, this has brought new issues and challenges concerning energy-efficient routing and data collection. Therefore, various critical studies have been proposed in this regard [7][9].

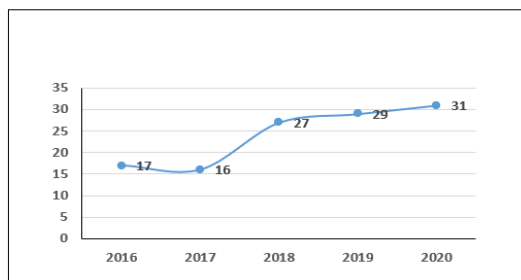


Figure 4.1: Publication Over Time.

4.1.2 Publication Channel

Publication channels are key indicators of the quality of works in a given field of research. When many Journal, articles are published, researchers tend to see the works in a given area as been qualitative and less qualitative otherwise. The selected studies have shown five types of publication channels: conference proceedings, Journal articles, Magazines, Symposium proceedings, and book chapters. Based on Figure 4.2, most of the studies (75 studies) were conference materials published in different conference proceedings, followed by Journal articles (40 studies), Magazine (2 articles), Symposium (2 articles), and Book chapter (1 article). Hence, the general quality of the studies in this research domain is reasonable considering the amount of Journal articles published but can be further improved.

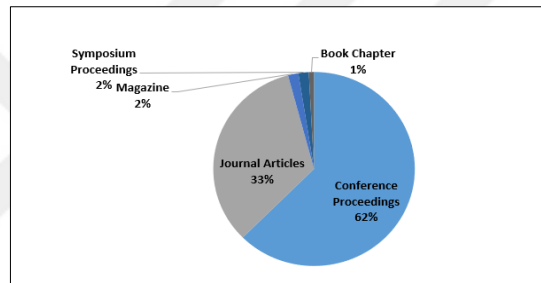


Figure 4.2: Publication Channel.

4.1.3 Citation Impact

The top 10 most cited papers among the selected articles were shown in Table 4.1. We obtained the citation counts of the papers from google scholar. Hence, it is subject to change over time. The total number of a citation for all the studies is 870. However, we have found that 45 studies (37.5% of the selected studies) have no citations. Most of these studies are published in 2019 and 2020, respectively. Furthermore, we also observed that eight out of the ten most cited papers in Table 4.1 are all published in Journal houses. These papers are highly regarded in the research domain, and more weight is generally given to Journal articles compared to other published sources.

Table 4.1: The Top 10 Most Cited Articles.

Author	Publication source	Publication channel	Citation	year	Authors' Names
[10]	International Journal of electronics and communications	Journal	73	2017	Ramnik Singh, Anil Kumar Verma
[11]	Engineering science and technology	Journal	65	2017	Samayveer Singh, Aruna Malik, Rajeev Kumar
[12]	Cluster computing	Journal	51	2017	Jianhua Huang, Yadong Hong, Ziming Zhao, Yubo Yuan
[13]	Computer networks	Journal	44	2016	D. Yi, and H. Yang
[14]	Computers & electrical engineering	Journal	38	2018	R. Logambigaia, Sannasi Ganapathyb, A. Kannan
[1]	International conference on informatics and analytics	Conference	33	2016	M.Selvi, R.Logambigai, S.Ganapathy, L.Sai Ramesh, H.Khanna Nehemiah, Kannan Arputharaj
[15]	Computers & electrical engineering	Journal	33	2018	Mohit Sajwana, Devashish Gosainb, Ajay K. Sharma
[16]	Computer networks	Journal	31	2018	Reem E. Mohamed, Walid R. Ghanem, Abeer T. Khalil, Mohamed Elhoseny, Muhammad Sajjad, Mohamed A. Mohamed
[17]	International conference on electrical, electronics, and optimization techniques (ICEEOT)	Conference	30	2016	Alka Singh, shubhangi Rathkanthiwar, Sandeep Kakde
[18]	Journal of systems architecture	Journal	28	2017	Wenbo Zhanga, Guangjie Hanb, Yongxin Fenga, Jaime Lloret

4.1.4 Top Most Represented Journal

Identifying the top 10 most represented or active Journal in a field of research is highly imperative. This is because new researchers can easily identify the publication venues that are more in-line with their research interest. Hence, it is vital to identify these venues in an

SMS study. Therefore, for the journals that published studies on energy-efficient routing protocols, Table 4.2 lists the top 9 journals with most frequent publications. We observed that the IEEE Access was in the leading authors across all journals involved with 15 works published, followed by the Journal of Computer Networks and Cluster Computing with 3 publications each. Moreover, the rest of the Journals have 2 works published each, respectively.

Table 4.2: Top 9 Most Represented Journals.

Title	Publisher	Studies	No
IEEE Access	IEEE	M14, M15, M16, M18, M19, M22, M23, M24, M26, M46, M25, M53, M56, M57	15
Computer Networks	Elsevier	M38, M74, M79	3
Cluster Computing	Springer	M34, M40, M41	3
IEEE Wireless Communications	IEEE	M1, M2	2
Ad Hoc Networks	Elsevier	M46, M83	2
The Journal of Supercomputing	Springer	M35, M37	2
Computers and Electrical Engineering	Elsevier	M76, M78	2
IEEE Sensors	IEEE	M54, M98	2
International Journal of Electronics and Communications	Elsevier	M58, M85	2

4.1.5 Most Active Countries

In accordance with findings from the selected studies, 28 unique countries that were involved in this research domain were identified. From Table 4.3, the reader can see that the top 10 most active countries (that published more papers in this domain) were highlighted. Besides, India was found to be the most active with 43 publications, followed by China with 23. Hence, these two countries (India and China) are the most active countries with more publication in this domain so far. The third most active country is Iran with 6 publications, followed by USA (4), Malaysia (4), Canada (3), France (3), Taiwan (3), Egypt (3), and KSA (2), respectively. Each of the remaining countries has a single publication.

Table 4.3: Top 10 Most Active Countries in the Research Domain.

Countries	Studies	Number of Studies
India	M6, M8, M10, M12, M13, M17, M21, M34, M39, 40, M43, M49, M50, M52, M60, M63, M64, M65, M66, M68, M69, M70, M75, M76, M78, M80, M81, M83, M84, M85, M86, M87, M88, M90, M92, M93, M96, M100, M105, M106, M107, M109, M112, M117, M119	45
China	M1, M2, M7, M9, M19, M23, M25, M36, M37, M42, M44, M45, M46, M53, M55, M59, M69, M73, M74, M89, M94, M97, M98	23
Iran	M4, M34, M72, M82, M114, M116	6
USA	M22, M29, M51, M116	4
Malaysia	M28, M48, M54, M56	4
Canada	M16, M31, M95	3
France	M32, M47, M108	3
Taiwan	M14, M15, M101	3
Egypt	M18, M79, M104	3
KSA	M24, M30	2

4.1.6 Most Active Institutions

Based on our analysis, the most productive institutions in this area of research were recognized among the 7 distinctive institutions that we identified. These institutions are presented in Table 4.4. Furthermore, all the 7 identified institutions were found to be ones that prioritize academics. Hence, we concluded that the research in this domain is dominantly academic centric. With respect to the institutions, Anna University has the most publications with 4 papers, seconded by Nanjing University of Information Science and Technology (2), University of Ha'il (2), Tianjin Normal University (2), Mahidol University (2), University of Calcutta (2) and Islamic Azad University (2), respectively.

Table 4.4: TOP 7 Most Represented Institutions in the Research Domain.

Institution	Studies	Number of Studies
Anna University, India	M40, M60, M78, M92	4
Nanjing University of Information Science and Technology, China	M44, M45	2
University of Ha'il, KSA	M24, M30	2
Tianjin Normal University, India	M2, M53	2
Mahidol University, India	M11, M71	2
Islamic Azad University, Iran	M72, M82	2
University of Calcutta, India	M96, M107	2

RQ2: What Research facets have been focused on by the studies in this domain studies?

This mapping study aim is to explore the distinct research facets in this study area. Based on the selected studies, four research facets were identified. As presented in Figure 4.3, these

research facets are Solution proposal, Evaluation research, Experience paper, and Investigative study. Solution proposal is a kind of research type facet that focuses on proposing a new and novel solution to a specific research problem or a significant improvement to an existing algorithm. Hence, a novel proposal is tested and demonstrated based on existing evaluation criteria. Implementing and contrasting current methods in practice with a thorough evaluation of the techniques is the goal of evaluation research. Therefore, this kind of research type facet shows a technique's applicability in practice. Lastly, an Investigative study seeks to investigate a specific phenomenon or issues in a domain scope. Thus, a particular shape for study aims to answer specific RQs or research community has in mind. From our analysis of the chosen research, the finding reveals that the majority of the studies proposed solutions to a given problem. Hence, they are based on solution proposal with 90%, followed by experience paper and evaluation research with 4% each. And lastly, investigative study with 2%. This shows the field of research; most papers are tailored toward proposing novel solutions with experiments done in a controlled environment. Therefore, this infers that there is a need to investigate and evaluate studies to evaluate deeply how effective these proposals based on decreasing energy consumption and network lifetime in a WSN. The research classification aimed to characterize the papers based on their novelty and validity degrees. Hence, we grouped all the selected studies into four categories as follows.:

- a. Solution proposal: A novel solution or a significant expansion of an existing technique that is proposed to solve a given problem in the research domain.
- b. Evaluation research: This type of study investigates a solution which can be implemented practically. Hence, the solution is measured using defined criteria. The results are examined using field studies or practical case studies.
- c. Experience paper: The personal and actual life project experienced by the author is reported in this kind of study. It describes how the real project was done and what was performed in it.
- d. An investigative study: This is a type of study which supports the designing of future studies and intervenes with improving the method of future performance of the various strategies.

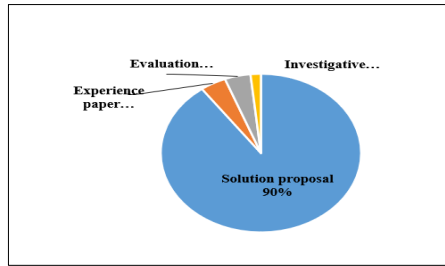


Figure 4.3: Research Facets.

We further look at the solution proposal in isolation. We analysed all the studies based on solution proposals and categorized them based on the year of publication, as presented in Figure 4.4. We observed that progressively, more solution proposals were published consistently in the last five years. Hence, research in this domain is persistently active.

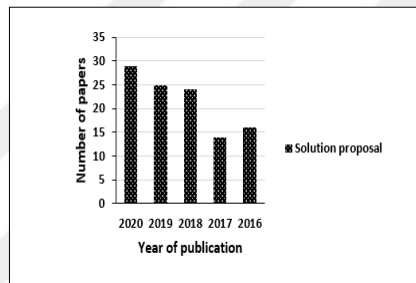


Figure 4.4: Solution Proposal Distribution in the Last Five Years.

RQ3: What is the classification of selected studies on basis energy efficient routing protocols in WSN?

Findings of the classification of a few studies using WSN protocols are presented in this section. Energy-efficiency is crucial in WSNs, and in recent years, numerous energy-efficient routing techniques have been suggested. However, all of these are not efficient enough. Many directing conventions have been created to resolve various issues, and various conventions for energy effective steering, especially in WSNs, have been proposed throughout the course of recent many years. A significant number of these are given by and large in different reviews. To group conventions for scientific categorization reasons, the use of explicit classifications has been recommended, as displayed in Figure 4.5. This arrangement isolates conventions into four classes in light of.

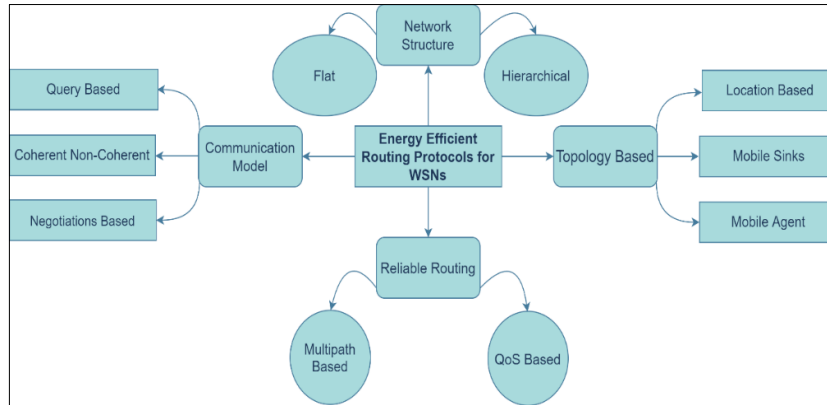


Figure 4.5: Categories of Energy-Efficient Protocols in WSN.

As see in table 4.3. We categorized the studies based on routing protocols in WSN. Also, A bubble map in Figure 4.5. presents the selected studied based on routing protocols in WSN over the year of publication. The classification of routing protocols in WSNs is briefly described. As a result, the network structure, communication scheme, topology schemes, and effective routing schemes are used to classify routing protocols. The following subsections discussed the classification in details.

4.2 NETWORK STRUCTURE

This classification's plans cover two kinds of hub arrangement or designs: hubs with similar degree of network and hubs with unmistakable progressive systems.

Flat Protocols: To direct detecting obligations, all hubs in the organization are appointed equivalent jobs. Using an information-driven steering strategy, the base station asks specific districts for information while waiting for sensor information from those locations. This engineering has the advantage of requiring less cost to keep up with the framework between correspondence hubs.

Hierarchical Protocols: This plan's directing conventions force a design that accomplishes energy effectiveness, steadiness, and versatility. The organization is coordinated into various groups in this class, with one hub (with the most elevated remaining energy) filling in as the bunch head (CH). CH oversees group movement and imparts data between bunches. Bunching decisively saves energy use and increments network life span.

Communication scheme: This gathering of conventions is worried about how parcels are directed through the organization and spotlights on conveying more information for a given

measure of energy. An unfortunate information conveyance proportion is an inconvenience of this methodology. The conventions are coordinated as follows.:

- a. Query-based protocols.
- b. coherent and non-coherent based protocols.
- c. negotiation based protocols.

4.3 TOPOLOGY BASED SCHEME

Geography put together conventions' tasks are based with respect to organize topological and take advantage of the rule that each hub in an organization stores geography data. This plan's conventions are as per the following:

- a. Area based conventions: a hub ought to know area of different hubs and take advantage of it to hand-off got information to specific district and not the entire WSN.
- b. Mobile agent-based protocols: The versatile specialist brilliantly moves among network hubs to satisfy an undertaking, and this convention empowers network adaptability.
- c. Reliable routing-based scheme
- d. The conventions in this plan load balance courses and meet determined QoS models like time, energy, and transmission capacity, making them stronger to course disappointments. This plan's characterizations are:
- e. Multipath-based protocols: it accomplishes load adjusting and upgrades dependability accordingly becoming strong to disappointments.
- f. QoS-based conventions: information transmission needs to meet a specific degree of value alongside effective energy utilization.

Table 4.5: Classification of Selected Studies Basis on Energy Efficient Routing Protocols in WSN.

Class	Type	Studies (identifiers)	Number
Network Structure	Flat	M13, M27, M32, M42, M53, M91	6
	Hierarchical	M19, M21, M23, M25, M26, M28, M29, M36, M35, M38, M39, M41, M43, M44, M47, M56, M58, M59, M62, M64, M68, M70, M71, M73, M75, M77, M78, M79, M82, M87, M89, M93, M95, M98, M102, M92, M99, M103, M105, M110, M111, M117, M118, M120, M4, M5, M6, M7, M9, M10, M11	51
Communication Model	Query Based	M14, M16, M17, M24, M31, M48, M57, M66, M67, M88, M101, M97, M104, M114	14

Table 4.6: Classification of Selected Studies Basis on Energy Efficient Routing Protocols in WSN
 “Table continued”.

	Coherent Non-Coherent	M107	1
	Negotiations Based	M69, M74	2
Topology Based	Location	M12, M15, M61, M63, M106, M108, M116, M1	8
	Mobile Sink	M30, M37, M45, M46, M49, M50, M52, M54, M55, M72, M80, M82, M83, M85, M119	15
	Mobile Agent	M20, M94	2
Reliable Routing	Multi Path	M33, M51, M76, M86, M98, M2, M3, M8	8
	QoS	M18, M22, M34, M40, M60, M65, M84, M96, M100	9
Known		M90, M109, M112, M115	4

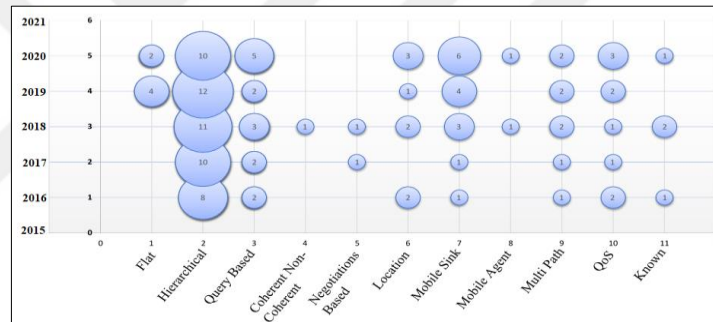


Figure 4.6: Bubble Plot of Routing Protocols Based on Publication Year.

RQ4: What are the classifications of energy-efficient mechanisms by selected studies?

In this section, the RQ is answered by classifying the existing energy-efficient routing mechanisms identified from the selected studies. The energy-efficient routing mechanisms can be classified into five main schemes, which are cluster architecture, energy routing metric, multipath routing, relay node placement, and sink mobile. These mechanisms are highlighted in Figure 4.7. The general energy-saving strategies of various routing paradigms are covered in the section that follows. Table 4.6 presents the mechanisms pertaining to the studies that used them. We observed that cluster architecture and energy routing metric are the most utilized with 45% and 24% of the selected studies. In combination, they amount to 69% of the selected studies.

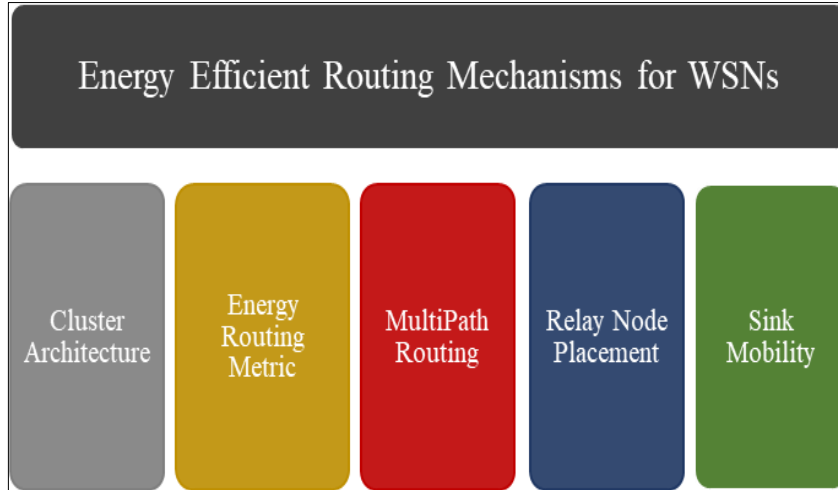


Figure 4.7: Energy-Efficient Routing Mechanisms for WSNs.

Table 4.7: Energy-Efficient Routing Mechanisms.

Energy-Efficient Mechanisms	Studies (identifiers)	NO.	%
Cluster Architecture	M4, M5, M7, M9, M11, M12, M19, M21, M23, M24, M25, M26, M27, M28, M29, M35, M36, M38, M39, M40, M41, 43, M44, M47, M53, M54, M62, M63, M64, M65, M68, M69, M71, M72, M76, M78, M79, M82, M85, M88, M90, M93, M95, M96, M99, M100, M102, M103, M105 M110, M111, M117, M118, M120	54	45%
Energy Metric	M6, M8, M13, M16, M17, M22, M31, M34, M42, M43, M48, M49, M56, M57, M58, M59, M67, M70, M75, M80, M89, M91, M92, M98, M101, M107, M113, M114, M115	29	24%
Mobile Sink	M14, M20, M30, M37, M45, M46, M50, M52, M55, M73, M81, M83, M84, M86, M94, M97, M119	17	14%
Relay Node Placement	M1, M3, M10, M15, M61, M74, M106, M108, M109, M112, M116	11	9%
Multipath	M2, M18, M32, M33, M51, M60, M77, M87, M104	9	7.5%

RQ5: What are the classifications of selected studies on basis their objectives? In answering this RQ, we identify key objectives that were generally focused by the proposed routing protocols in their respective papers. Basically, every routing protocol contains certain basic characteristics, including the objective to maximize network lifetime, to minimize delay, or to maximize reliability of an energy-efficient routing protocol. These three objectives, which are Maximization of network lifetime, Ionization of delay, and Maximization of reliability are the key objectives that we found from the selected studies. Hence, they are worthy of categorization. Figure 4.8 presents these objectives.

- a. Maximizing Network Lifetime: form our analysis, we identified that focused on the maximization of network lifetime in their respective studies. Network life expectancy is

regularly described regarding first hub passing (when the primary hub kicks the bucket), half hub demise (when a portion of the hubs bite the dust), last hub demise (when the last hub bites the dust), or parcel conveyance proportion.

- b. **Minimizing Delay:** Another objective of many works is to minimize the delay, the expected end-to-end delay from all sensor nodes to the sink. We identified (number of studies) that focused on minimizing delay for the energy-efficient routing protocols.
- c. **Maximizing Reliability:** One another objective of the few works is to maximizing the reliability, define the reliability of a WSN to be the probability that an end-to-end communication is successful, like the packet is received by the sink.

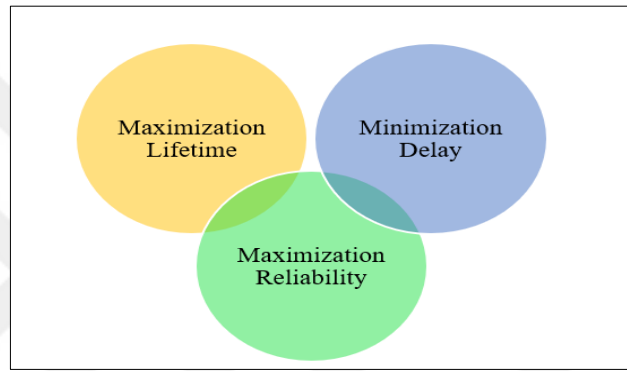


Figure 4.8: Energy Efficient Routing Protocols Objectives.

From Table 4.7, one can see the categorization of the selected studies and their focused objectives. From this categorization, the articles that have talked about a particular goal can be easily tracked. It will help novice researchers by reducing the time and effort spent looking for relevant articles. Hence, Maximization of network lifetime is the most focused with 65.8% of the selected studies focusing on it, proceeded by minimizing delay with 14%, and maximization of reliability with 6.6% of the selected studies, respectively. This result can be explained as in this research domain, more focused and attention of researchers is geared towards the proposing new energy-efficient routing protocols that will maximize lifetime of the network. Hence, saving energy while routing.

Table 4.8: Classifications of Studies on Basis Their Objectives.

Objective	Studies	No	%
Maximization Lifetime	M5, M4, M11, M12, M21, M26, M27, M28, M29, M35, M43, M44, M54, M62, M63, M64, M69, M71, M72, M78, M82, M88, M90, M93, M95, M99, M100, M102, M103, M105, M110, M111, M117, M120, M6, M8, M16, M42, M48, M49, M56, M58, M70, M75, M89, M92, M98, M101, M107, M113, M115, M66, M2, M18, M32, M51, M60, M87, M104, M1, M3, M10, M15, M61, M106. M108, M109, M116, M14, M20, M30, M46, M50, M55, M73, M86, M94, M97, M119	79	65.8%
Minimization Delay	M7, M9, M24, M40, M68, M13, M16, M17, M80, M91, M92, M67, M32, M112, M81, M83, M97	17	14%
Maximization Reliability	M31, M65, M96, M19, M114, M115, M108, M118	8	6.6%

What are the different performance measures used by the selected studies, while providing the answer to this research question, various performance metrics that have been used in the selected studies to access the performance of a given proposal were identified? These performance measures are given in Table 4.8. RQ4 result shows that energy consumption and network lifetime are the considered performance measures with 71 and 69 studies, respectively. Followed by packet delivery ratio, throughput, delay with 16, 15, and 12, respectively. The rest of the performance measures, as presented in Table4.8, all have less than six studies utilizing them. The reader can easily observe that the numbers are more than our selected studies. For clarification, the categorization is done based on a paper utilization of a given performance measure. Therefore, a paper can use both network lifetime and energy consumption. Hence, we categorized such papers in both.

Table 4.9: Identification of Performance Measures.

Performance Measures	Studies	No.	%
Network lifetime	M38, M39, M58, M78, M79, M59, M77, M47, M40, M57, M53, M85, M102, M42, M62, M35, M80, M73, M99, M52, M4, M65, M82, M64, M69, M95, M19, M66, M71, M45, M109, M101, M25, M84, M88, M72, M89, M48, M111, M113, M12, M104, M110, M18, M14, M26, M23, M37, M90, M46, M114, M100, M103, M106, M51, M49, M29, M16, M20, M6, M13, M119, M21, M91, M28, M105, M8, M10, M32	69	57.5%
Energy consumption	M76, M87, M59, M77, M47, M40, M86, M98, M74, M53, M42, M93, M56, M35, M80, M70, M52, M75, M60, M81, M33, M4, M54, M55, M82, M97, M34, M15, M19, M61, M96, M22, M94, M101, M9, M11, M43, M68, M84, M48, M111, M5, M12, M104, M110, M14, M24, M116, M83, M23, M37, M44, M50, M100, M49, M107, M16, M7, M13, M31, M27, M115, M118, M63, M120, M105, M8, M10, M32, M2, M1	71	59%
Packet delivery ratio	M92, M98, M74, M57, M62, M75, M82, M97, M22, M9, M84, M18, M83, M46, M108, M31	16	13.3%
Throughput	M85, M102, M52, M75, M81, M33, M19, M22, M101, M83, M23, M106, M36, M10, M32	15	12.5%
Delay	M92, M98, M57, M60, M81, M33, M82, M22, M94, M84, M18, M31	12	10%
Nil	M67, M3, M17, M112, M117, M30	6	5%
Dead nodes	M85, M70, M75, M105	4	4%
Residual energy	M78, M70	2	2%
Latency	M97, M108	2	2%
Alive nodes	M75, M81	2	2%
Scalability	M76, M91	2	2%
Computational overhead	M74, M22	2	2%
Efficiency	M41, M1	2	2%
Load balancing	M56	1	1%
Energy balance	M41	1	1%
Stability	M85	1	1%

RQ7: Do the selected studies use single or multi-hop for routing communication?

Hop count for data collection and energy-aware consumption is very important when designing an effective energy efficient aware routing protocol. Some protocols or studies use a single hop count for their architecture, while others use multi-hop architecture. In this mapping study, we feel the need to identify and categorize the selected studies based on the kind of architecture they utilized concerning single or multi-hop. Hence, to answer this question, we categorized the studies as presented in Table 4.9. With 59.17%, Multi-hop architecture is the most utilized in the last five years, with less used on a single hop architecture. It is unsurprising as the former is better than the latter. Another finding is that 33.33% of the studies that were chosen were not clear on which architecture they utilized. Hence, we are unable to identify it and were categorized it as Unknown. It is concerning as clarifying the architecture, whether it is multi-hop or single, is imperative for new researchers in the field study. We recommend researchers to clarify it in future works. Also, some studies use both single and multi-hop architecture. Hence, we categorized such studies as a hybrid.

Table 4.10: Classification of the Selected Studies Based on Single, Multi, or Hybrid Hop Usage.

Studies (identifiers)	Hop	No.	%
M38, M44, M64, M71, M86, M88, M87, M90, M97, M41, M59, M60, M68, M66, M74, M73, M89, M93, M98, M46, M47, M52, M51, M79, M78, M99, M113, M111, M109, M108, M107, M106, M103, M102, M100, M4, M3, M5, M6, M9, M10, M11, M13, M40, M42, M43, M49, M48, M57, M55, M54, M53, M77, M81, M80, M85, M115, M116, M118, M84, M83, M37, M23, M28, M29, M33, M15, M16, M18, M19, M20	Multi-hop	71	59.17%
M58, M61, M65, M63, M62, M92, M96, M39, M67, M70, M72, M94, M95, M35, M76, M69, M50, M75, M114, M112, M110, M104, M101, M12, M34, M36, M56, M91, M117, M119, M120, M31, M30, M24, M27, M32, M1, M2, M17, M21	Unknown	40	33.33%
M45, M7, M8, M25, M22	Single hop	6	5%
M26, M82, M105	Hybrid	3	2.5%

Figure 4.9 gives the systematic map of these architectures with respect to the year of publication. We observed that since 2016 protocols based on multi-hop were consistently proposed, with single hop on a sharp decline. However, the rise of Unknown studies is alarming. Hence, more studies should clarify it in future works.

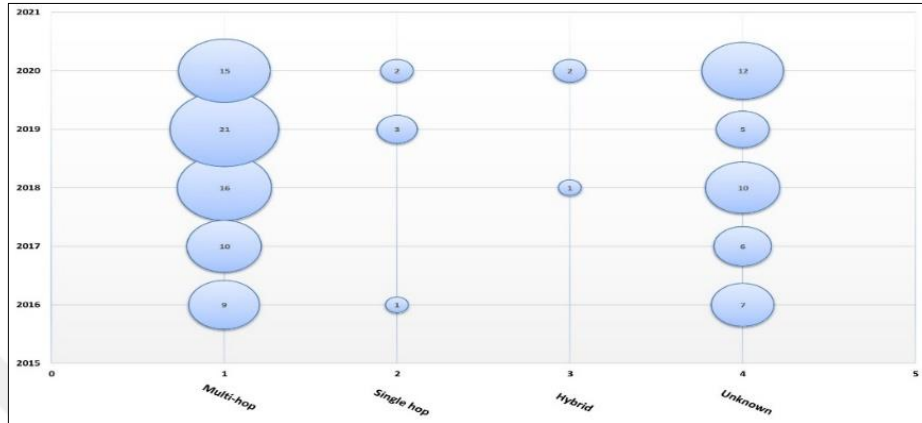


Figure 4.9: Mapping for Hop Methods Used Against the Year of Publication.

RQ8: What are the validation methods used by the selected studies. Three validation methods were identified within the area of study from the studies that were selected. These methods are Simulation, Experiment, and case study. This categorization is done with respect to each paper authors clarification. Hence, if the authors state that they are conducting an experiment, or simulation, or case study, we record the information as that. As shown in Table 4.10, our analysis found that 81.67% of the selected studies used simulation for proposal validation, followed by experiments with 12.5%.

Table 4.11: Validation Methods Utilized by the Selected Studies.

Validation method	Studies (identifiers)	NO.	%
Simulation	M13, M43, M104, M11, M70, M117, M82, M26, M22, M14, M119, M31, M30, M24, M27, M32, M21, M115, M116, M118, M84, M83, M23, M29, M33, M15, M16, M18, M19, M20, M7, M25, M36, M34, M56, M12, M3, M5, M6, M9, M40, M42, M49, M48, M57, M55, M54, M53, M77, M81, M80, M85, M101, M76, M35, M69, M50, M114, M46, M52, M51, M79, M78, M99, M113, M111, M109, M108, M107, M106, M103, M102, M100, M94, M72, M39, M89, M93, M98, M73, M41, M59, M66, M74, M45, M96, M58, M61, M62, M38, M44, M64, M71, M86, M88, M87, M90, M97	98	81.67%
Experiment	M95, M1, M75, M110, M120, M2, M37, M28, M8, M4, M10, M105, M60, M68, M92	15	12.5%
Unknown	M91, M63, M17, M112, M67, M65	6	5%
Case study	M47	1	0.83%

Figure 4.10 shows that mapping of validation methods against the research facets. The result shows that studies that conduct simulations and experiments are mainly studies that proposed solutions to a given research problem.

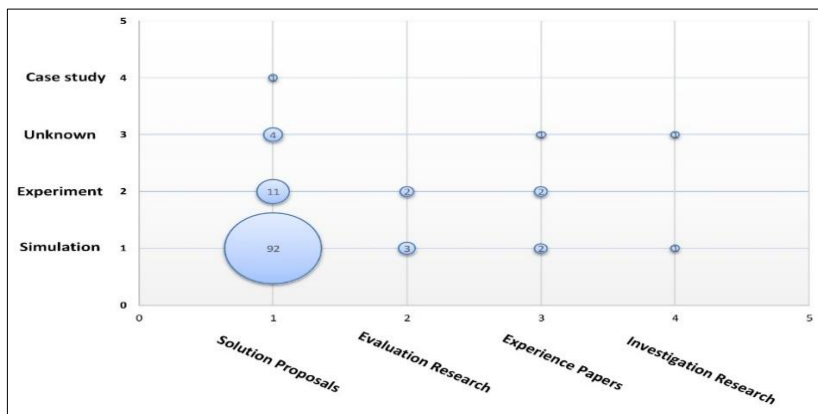


Figure 4.10: Mapping for Validation Methods Used Against Research Facets.

RQ9: What is the simulations tool have been used by the selected studies?

In answering this RQ, we have identified the existing Simulation tools used that helped in facilitating the evaluation of a given proposal in the domain of this study. Furthermore, the studies selected are categorised with respect to the simulation tool utilised. Nine simulation

tools were identified, which are MATLAB, NS-2, NS-3, OMNET++, Visual C++, python, Java, COOJA, and Qualen. Hence, we found that MATLAB and NS-2 are the most utilized with 56% and 26% of the chosen studies that utilised them. Table 4.11 presents the simulation tools pertaining to the studies that used them.

Table 4.12: Simulation Tool.

S/N	Simulation Tool	Studies (identifiers)	Number of study	%
1	MATLAB	M3, M6, M7, M9, M11, M12, M13, M14,, M15, M16, M18, M19, M21, M23, M25, M26, M27, M29, M30, M35, M36, M38, M39, M40, M41, M48, M51, M53, M55, M56, M58, M64, M66, M70, M72, M73, M76, M77, M79, M81, M83, M85, M86, M88, M89, M98, M99, M102, M106, M109, M113, M115, M116, M117, M118.	55	56%
2	NS-2	M32, M33, M42, M43, M44, M45, M49, M50, M62, M71, M78, M82, M84, M87, M90, M96, M97, M100, M101, M103, M104, M107, M108, M119.	25	26%
3	NS-3	M22, M31, M52, M57, M74.	5	5%
4	OMNET++	M54, M80, M93, M111, M114.	5	5%
5	Visual C++	M61, M94.	2	2%
6	Python	M5, M20.	2	2%
7	Java	M24, M46.	2	2%
8	COOJA	M59.	1	1%
9	QualNet	M69.	1	1%

4.4 DISCUSSION

The SMS aim is to investigate the general trends, demographics, and productivity in the energy-efficient routing protocols for WSNs areas. Hence, having an energy-efficient aware protocol that is effective is very imperative in the domain of research. The summary of the research findings was presented based on the addressed RQs in this section. Furthermore, the threat to validity is also outlined.

4.4.1 Research Findings

This paper's primary goal is to synthesize previous works in the field of study. Therefore, we carefully investigate 120 studies based on our outlined criteria from trusted sources (as shown in Section 3). Hence, the key findings are outlined as follows.

- a. For the past 5 years, the research community has been paying increasing attention to this field of study. Mainly to join in the rush to proposed novel energy-efficient aware routing protocols for WSNs. From our findings, we observed that 2017 was the year with the least amount of publication with only 16. However, from the year 2016, we have seen a rise in quality publications onwards. Therefore, this research domain is found to be very active and consistent. Hence, we project more novel proposals in the future. Most of the studies were observed to be Conference materials (75 studies), followed by Journal with 40, Magazine, Symposium, and Book chapter 2, 2, and 1, respectively. Hence, the general quality of the studies in this research domain is reasonable considering the amount of Journal articles published but can be further improved.
- b. IEEE Access with 15 studies published is regarded as the most influential Journal house in the domain as highlighted in Table 6. Furthermore, India and China with 45 and 23 published works are the most productive research countries in the domain of this research.
- c. Concerning the type facets research, we have identified four aspects of research: solution proposal, evaluation research, experience paper, and investigative study. The result reveals that the majority of the studies proposed solutions to a given problem. Hence, they are based on solution proposal with 90%, followed by experience paper and evaluation research with 4% each. And lastly, investigative study with 2%. It shows that most papers are tailored toward proposing novel solutions with experiments done in a controlled environment in this research field. Therefore, it infers that there is a need for more investigative studies and evaluation studies to evaluate deeply how effective these proposals are in terms of decreasing energy consumption and network lifetime in a WSN.
- d. Regarding contribution type facets as presented in Table 4.7, various contributions with regards to new and novel proposals were proposed. Some significant improvements to existing protocols were done in some studies [20][21].

- e. With respect to energy-efficient mechanisms, five mechanisms were identified as presented in Section 2.5.4. We found that cluster architecture and energy routing metric are the most utilized with 45% and 24% of the selected studies utilizing them.
- f. Regarding to RQ5, three key objectives were found, which are maximization of network lifetime, minimization of delay, and maximization of network reliability. Based on our analysis, we found that 65.8% of various studies we looked at were primarily concerned with the maximization of network lifetime. Several performance metrics used by the analysed studies to access the performance of a given proposal were identified in this study. From our findings, the result shows that Energy consumption and Network lifetime are the considered performance measures with 71 and 69 studies, respectively. Followed by packet delivery ratio, throughput, delay with 16, 15, and 12, respectively.
- g. We further categorized the studies based on the architecture they used. Some used a single hop, while others used multi-hop architecture for routing. With 59.17%, Multi-hop architecture is the most utilized in the last five years, with less used on a single hop architecture. It is not surprising as the former is better than the latter. Another observation is that 33.33% of the selected studies were not clear on which architecture they utilized. Hence, we are unable to identify it and were categorized it as Unknown. It is concerning as making clear the architecture, whether it is multi-hop or single, is imperative for new researchers in this study area. We recommend researchers to clarify it in future works. Also, some studies use both single and multi-hop architecture.
- h. We further identified Simulation, Experiment, and Case study as the validation strategies the chosen studies employed. Our analysis found that 81.67% of the selected studies used simulation for proposal validation, followed by experiments with 12.5%. 5% of the selected studies were not clear on which validation methods they utilized. Hence, the result shows that studies that conduct simulations and experiments are mainly studies that proposed solutions to a given research problem.

4.4.2 Threat to Validity

In this mapping study, three threats to validity are discussed. These threats are construct validity, internal validity, and conclusion validity. Hence, the threats are discussed below. Construct validity is directly related to identifying selected studies. Therefore, to identify many relevant primary studies and include them, key search terms were identified and

proposed by the researchers. These search words were used to search important studies in many iterations across the data sources. As shown in Table 4.2, four key terms were used for the study search. However, despite the validity of the terms, the terms might still not be complete, and more or alternative terms might have to change the final selected studies list. Hence, publication bias was reduced by considering only relevant publication sources in all the publication channels of this domain. With this critical threat, it was mitigated by capturing important studies by searching four important sources of data. In order to identify, thoroughly review, and take into account all studies pertaining to software usability, we also used a forward and backward snowball sampling. Internal validity is related to the extraction and analysis of data. Inaccuracy in data extraction can have an impact on how primary studies' results are classified and analysed. To reduce this threat, a data extraction form was created (as discussed in Section 2) to ensure that all-important data are extracted effectively and clearly. With this form formulation, the threat can be successfully mitigated and lead to a more reliable data extraction result. Therefore, the decision on which data to retrieve and how it should be classified depends on the researchers' judgments conducting the mapping study. Hence, when disagreement occurs or deficiency in data analysis, the final decision of the most senior researcher is taking into consideration to reduce this bias. Conclusion validity focuses on identifying the incorrect relationship between entities that can lead to formulating an incorrect conclusion. According to this study, this threat is related to key factors such as incorrect data extraction, incorrect classification, and missing studies. This bias affects the interpretation of the results. To be neglected this bias, the performed steps in the selected studies and data extraction were described clearly for other researchers to follow and draw the same conclusion.

4.5 CHAPTER SUMMARY

In this chapter, a summary of the existing studies in the field of energy-efficient aware protocols in Wireless sensor networks (WSNs) was presented. Out of 3807 studies initially collected from 2016 to 2021 This SMS adopted an evidence-based systematic mapping method to ascertain the reporting of important literature, 120 were carefully selected based on the set of criteria presented in Section. The results obtained from the SMS showed that, for the last five years, the research area has been gaining attention from the research community in a bid to join the rush to the proposal of novel energy-efficient aware routing protocols for WSNs. From the

year 2016, there has been an increase in quality publications onwards; therefore, this research domain is considered active and consistent. The majority of the studies were Conference materials, according to the examination of the chosen research (75 studies), followed by journals with 40 magazines, Symposium, and Book chapter with 2, 2, and 1, respectively. Hence, the general quality of the studies in this research domain is reasonable considering the number of Journal articles published, though there is still room for improvement. Regarding the research type facets, four research facets were identified as follows: Solution proposal, Evaluation research, Experience paper, and Investigative study. The result revealed that the majority of the studies (90%) proposed solutions to a given problem; hence, they are based on solution proposal, followed by experience paper and evaluation research (4% each). With respect to energy-efficient mechanisms, five mechanisms were identified as presented in Section 2.5.4. We found that cluster architecture and energy routing metric are the most utilized with 45% and 24% of the selected studies utilizing them. Furthermore, three key objectives were found, which are maximization of network lifetime, minimization of delay, and maximization of network reliability. Based on our analysis, we found that the maximization of network lifetime is the main focus of many studies with 65.8% of the selected studies focusing on it.

Various performance measures taken in the chosen studies to assess the performance of a given proposal were also identified. From the findings, energy consumption and network lifetime are the most considered performance measures with 71 and 69 studies, respectively. However, multi-hop architecture for routing is the most utilized in the last five years (with 59.17%), while single-hop architecture is consistently reduced. At last, the essential objective of this planning project is to offer the WSN research local area with an intensive handle of the general exploration efficiency, demography, and patterns that have melded the examination space. This work can help and feature likely opportunities for both new and prepared specialists to perform more work to further develop the examination area of introducing exceptional plans to diminish energy use in WSN

5. LEACH DEVELOPED

5.1 LEACH PROTOCOL OVERVIEW

Leach is a forerunner in the field of hierarchically routing protocols for WSN [15]. These protocols' main objective is to cluster wireless network nodes and provide a means to balance the cluster head election process so that node selection as a CH doesn't happen again. The setup phase and the steady state phase are the two steps that make up LEACH. The selection of the cluster head, the construction of the cluster head, and the CH's assignment of a TDMA (Time Division Multiple Access) schedule to the member nodes are the primary goals of the setup phase. All participating nodes establish a random priority number between 0 and 1 at the start of the process in order to select the proper node as a Cluster head. This node will become the cluster head if its number is less than a predetermined threshold, $t_{(n)}$, where P is the proportion of nodes that will become cluster head, G is the total number of nodes that have not been elected as cluster heads in the previous $1/P$ rounds, and r is the current round. It goes without saying that sensor node that has served as a cluster head in round r cannot be chosen again in rounds $1/P$. The results in an evenly distributed spreading of energy loss among the nodes and a balanced method of selecting a node as a CH. It has been determined that 5% is the ideal CHs proportion. A node sends an advertising message to other nodes as soon as it becomes a CH. The remaining nodes in the network decide which cluster head cluster (CH) whose advertisement has attracted most interest to join and send a response message to that particular CH. The clusters with the related CHs are produced as a result of this process. The CH then produces a TDMA protocol schedule and sends it to the sensor nodes that are part of the CH. Each node is given precise timing for information transfer, and the TDMA protocol schedule is utilized to prevent congestion throughout the data transmission time. Only after every node is aware of the TDMA schedule is the setup step finished. The steady state phase starts as soon as this occurs. Data transfer between nodes and CH as well as from CH to BS occurs during the steady state period. In the first scenario, only the timeslot designated by the TDMA schedule is used by the nodes to transfer data to CH. The rest node that is a member of the same CH is in sleep mode when this node sends data. This prevents congestion and helps the sensor nodes lifetime use less energy. The cluster head uses a TDMA schedule to transfer the information it has gathered from the cluster nodes to the BS. LEACH protocol balances the cluster head election process across

network wireless sensor nodes, as was already indicated, lengthening the network's lifespan. Moreover, knowledge of the entire internet is not necessary. Also, TDMA scheduling prevents data collisions during transfers. However, the CH election process does not take into account the nodes' remaining energy. As a result, neither nodes with low energy levels nor nodes sensor with significant energy reserves have a higher likelihood of becoming a CH. Moreover, because LEACH employs single hop routing, it is not advised for WSNs deployed across vast regions. Dynamic clustering also generates overhead, which might limit any increase in energy use.

5.2 ROUTING PROTOCOLS HIERARCHICAL BASED LEACH

Several LEACH-based energy efficient routing techniques have been put forth. They may be classified as single hop and multiple hope depending on the mode of cluster head communication with based station.

- a. LEACH replacements that utilize single-hop communication While using the leach protocol communication single-hop on based protocols, the CHs communicate their data straight to the BS. One-hop communication is actually only appropriate in tiny WSNs. These are some of the protocols of this type that are most widely used: Centralized LEACH protocol [27] which the Based station conducts all cluster formation, cluster head selection, and information distribution choices, therefore decreasing node overhead. In order to restrict participation in the cluster head selection process to nodes sensor with greater energy than the average, the BS also estimates the average of the energy in cluster nodes for each set.
- b. Security Based LEACH [29], is the first protocol that proffers defense against external assaults by confirming the senders of the messages and figuring out whether they are new or old. LEACH With Greater Energy Efficiency [30], decreased communication distance between nodes is needed, and their load distribution is enhanced.
- c. A modified kind of threshold is used by LEACH - Deterministic Cluster Head Selection [28]. To be more precise, the ratio of the current energy to the beginning energy of each node is multiplied by $t_{(n)}$ of LEACH.
- d. The concept of employing a threshold according to a time interval, which in turn is determined by a timer that each node uses individually, was proposed by Time Based-LEACH [31]. The threshold is determined by adding two other metrics, namely the

present the general probability and state probability, according to Advanced- LEACH [32].

- e. A new CH selection process would only begin if the current cluster head's residual energy fell below the specified energy threshold, according to LEACH-Threshold [33]. In LEACH- Improved [34], the CHs are selected by considering the residual energy of each node, the number of nodes that surround it, and the distance from the BS. Energy Harvested Aware LEACH [35], recommends the use of energy harvested sensor nodes, and nodes with a low energy footprint and high energy harvesting capacity, which have tendency of being chosen as CHs.
- f. Another protocol is the so-called Modified-LEACH, which increases the lifetime of WSNs and offers great energy efficiency [36]. This protocol suggests using an energy threshold throughout the cluster construction and CH selection processes. To be more precise, only when the CH's energy falls below this threshold is it replaced at the conclusion of each round. Moreover, this protocol employs greater power signals for transmission between clusters and lower power signals for communication inside the cluster. Table 1 compares certain metrics between LEACH and its aforementioned single hop successors [37].

Table 5.1: Comparison of Leach Protocol with Single Hop Protocols.

Name of protocol	Scalability	Complexity	Overhead	Energy Efficiency	Delay
LEACH	Low	Low	High	Moderate	Low
DEV-LEACH	Moderate	High	Low	High	Low
LEACH-T	High	High	Moderate	High	Low
DCHS-LEACH	Low	Moderate	High	High	Low
AL-EACH	Moderate	high	High	High	Low
LEACH- ME	Low	Low	Low	Moderate	Low
EHA-LEACH	High	High	High	Very High	Low
LEACH-TB	Moderate	High	High	Moderate	Low
C-LEACH	Low	Moderate	Low	High	Low

While employing LEACH-based protocols with multiple hop communication, the CH uses intermediary nodes to transfer data to the Based Station. These nodes may be simple nodes or additional CHs. The distance between the original and end nodes is a crucial element in this sort of communication. Energy consumption rises with distance d to the power four, or d^4 , if the distance exceeds a threshold distance. Maintaining a distance as close to zero as possible or below this cutoff distance is the primary goal of multiple hop communication. These are some of the protocols of this type that are most widely used: Multihop LEACH [38] has a similar setup process as LEACH. Distant CHs are chosen as intermediate nodes to deliver data to the BS during the steady phase, while nearby CHs provide data directly to the BS. The complexity and network overhead of MH-LEACH have increased despite the fact that it is more energy-efficient and extremely scalable compared to basic LEACH due to the multi-path transmission between relay nodes. It has advanced and increases network overhead as a result of multi-path transmission across relay nodes. Higher residual energy nodes are selected as CHs in Energy LEACH [39]. A CH conveys data to the node that is the closest neighbor. This procedure is carried out repeatedly until the data is transmitted to the CH closest to the BS. In the Advance Multihop Low Energy Adaptive Clustering Hierarchy [38], CHs that are far from the BS considering their proximity to the BS and available energy, other CHs decide which relay nodes to serve as their nodes. Data is sent straight to the BS from one of the nearby CHs. The complexity and costs rise as more location data is needed for each node. In Multihop Routing LEACH, CHs are chosen for the first level, the second level, and the remaining levels based on their location and remaining energy. It uses corresponding TDMA scheduling.

The balanced LEACH, also known as LEACH-B, is an alternative protocol built on the LEACH protocol [41]. This protocol improves the process of selecting cluster by making the nodes' remaining energy a crucial criterion. According to [42], a CH proportion of between 3% and 5% is ideal. It considers both the intended proportion of CHs and the remaining node energy while choosing the CHs. If the number of CHs chosen at random is less than the sum of $n \times p$ (where n is the number of nodes and p is the desired CHs percentage), then some normal nodes will be chosen as CHs. If this number exceeds the product $n \times p$, low energy CHs are eliminated with the purpose of keeping the number of CHs constant. All CHs are arranged according to their residual energy in declining order to

accomplish this. The CHs that are rated lower than $n \times p$ is changed into regular nodes. LEACH-B decreases sensor node energy usage while enhancing cluster energy-load balancing. The primary limitations of this protocol are message overhead, scalability, and complexity. The multiple hop LEACH successors discussed above are contrasted in Table 5.2 [37].

Table 5.2: Comparison of Leach Protocol with Multiple Hop Protocols.

Name of protocol	Scalability	Complexity	Overhead	Energy Efficiency	Delay
LEACH-E	High	High	Moderate	High	High
LEACH-L	High	Low	Low	High	Low
MH-LEACH	Low	High	High	Low	High
LEACH-B	Low	Moderate	High	High	Moderate
MR-LEACH	High	High	High	High	Low

After the aforementioned theoretical study, a simulation approach was developed in order to compare LEACH, MR-LEACH, LEACH-B, and MOD-LEACH operations in a suggestive manner. Table 3 illustrates the simulation settings applied in the MATLAB testing.

Table 5.3: Simulation Parameters in MATLAB.

Parameter	Value
Network filed	200x200
Nodes numbers	100
Location of Base Station	100x100
Initial energy	S/N
Electronic energy	50 nj
Data packets	512 bytes
Reception energy	5*10

Examining these simulation data reveals that all three LEACH-based protocols outperform LEACH in terms of network longevity. When compared to the other protocols, MR-LEACH resists the final node dissipation better than all others, but less than the other protocols for the first node dissipation. Nevertheless, compared to the other three protocols, MOD-

LEACH maintains all nodes alive for a longer period of time. Figure 5 compares the quantity of packets transmitted to the BS with simulated rounds.

5.3 DEVELOPED LEACH

Protocol leach is the most used routing system for hierarchical cluster-based wireless sensor networks. In LEACH, the process of communication is divided into rounds, each of which includes the setup and steady-state stages. Clusters are collections of nodes that make up the deployed region. The time division multiple access (TDMA) scheduling table is created by the cluster head of each cluster and is used by its members to decide the time to submit data packets to the CH. As a result, sensors communicate their data to their local cluster leader rather than the distant BS on the specified scheduling time set by CH. The data are collected by the cluster head from the various member nodes, processed to eliminate duplication, and then sent to the BS. CH merely serves as a relay node during the process to assist member nodes in cutting down on transmission distance and conserving energy. Figure 1 depicts the clustering model architecture of the WSN.

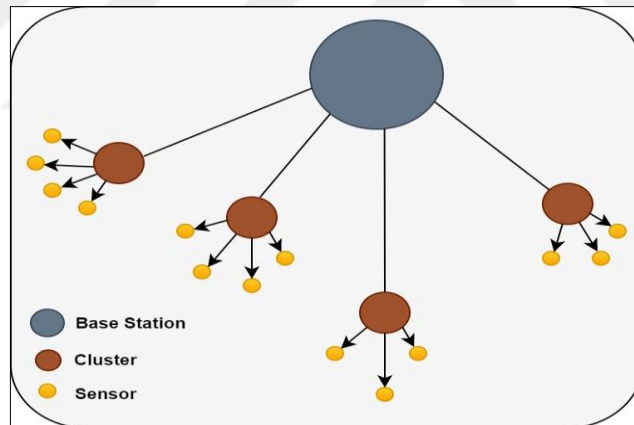


Figure 5.1: Hierarchical Clustering Method.

Each node is selected as the CH based on the likelihood of the best group leader as indicated by the networks. Each round results in a random number generated by each node that has a uniform distribution between 0 and 1. The node turns into a CH for the current round if the random number is below the threshold values $T(n)$ [5]. The dynamic calculation of $T(n)$ is performed using the formula (1). According to the likelihood of the best group leader determined by the networks, each node is chosen to be the CH. Every node produces a random number with a uniform distribution between 0 and 1 in each round. The node turns

into a CH for the current round if the random number is below the threshold values $T(n)$ [5]. The dynamic calculation of $T(n)$ is performed using the formula (1).

$$T(n) = \begin{cases} \frac{P}{1-P*[r \bmod (1/p)]} \\ 0n \ni G \end{cases} \quad (1)$$

where G is the collection of nodes that were not chosen as CH in round $1/p$, r stands for the round number, and p is the percentage of total CH nodes in the network. By LEACH, two distinct radio models were presented in [5]. the multi-path fading channel model and the free space model. When the distance between the receiver and transmitter is less than a threshold value, the algorithm uses the free space model (d^2 power loss). Instead, the multi-path fading channel model is used by the method (d^4 power loss). Hence, the energy spent by the transmitter and the associated receiver to transmit l -bit data across a distance of d is specified by the formulae (2).

$$E_{Tx}(k, d) = \begin{cases} E_{elec} * K + \varepsilon_{fs} * K * d^2 & d < d_o \\ E_{elec} * K + \varepsilon_{mp} * K * d^4 & d \geq d_o \end{cases} \quad (2)$$

$$E_{Rx}(k) = E_{elec} * K$$

$E_{Tx}(k, d)$ represents the energy used to transport K -bit data across a distance of d to the receiver, while $E_{Rx}(k)$ represents the energy used to receive K -bit data. E_{elec} stands for the energy used by the wireless send-receive circuit, whereas ε_{fs} and ε_{mp} are the energy factors used for amplification in the two radio types, respectively. No matter how far it is from the base station, the suggested approach will focus on the evenly distributed energy consumption. When we look at equation (2), we observe that energy usage is proportional to d^2 once the length is smaller than the threshold value, and when it is larger than do, it is proportional to d^4 . As can be seen in Fig. 2, the CHs were divided into two groups based on how far the base station was from the group leader, the proposed technique aims to minimize the energy used in the distant clusters.

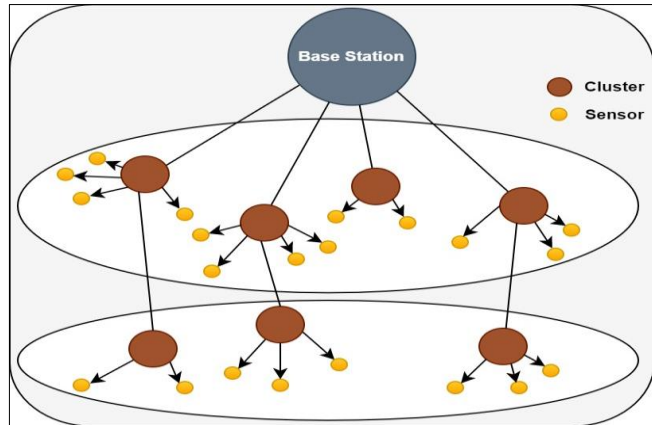


Figure 5.2: Developed Hierarchical Clustering Method.

We separate the BS's circumference into two rings, one having a diameter that is smaller than the threshold value d_0 and the other with a diameter that is larger than d_0 . Information gained from related nodes is sent directly to the main station by the CH in the first ring, while information obtained from nodes shared with it, who then transmits it to the main station on behalf of the head of the cluster. As transmission over short distances uses less power than transmission over long distances, we took these actions to reduce power usage. To simulate, analyze, and evaluate the effectiveness of the method, simulation was employed. The suggested method will be validated by comparing the results to the previous LEACH.

5.3.1 Results

Modeling of Energy Consumption Figures 5 depict the simulation results for residual energy with nodes. Evidently, residual energy using the LEACH protocol with a black cooler is smaller than that using the Modified LEACH protocol in the distant nodes, particularly in the area with a dimension of 300m*300m. The nodes were organized according to their distance from the base station. The energy data so show that the Modified LEACH approach with a red cooler uses more leftover energy than regular LEACH.

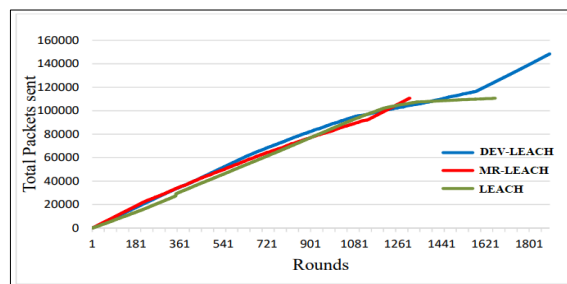


Figure 5.3: Consumption of Energy in the Field.

Viable nodes Figures 8 and 9 from the simulation show the number of LEACH-enabled working nodes and the suggested protocol for fields with 200 m x 200 m and 300 m x 300 m, respectively, of 300 nodes each. In Fig. 7, the network starts to collapse as a result of the conventional LEACH protocol at round 400, but with the modified LEACH protocol, the network starts to collapse at round 700, indicating a 70% improvement, 15% better performance while just half of the nodes are active.

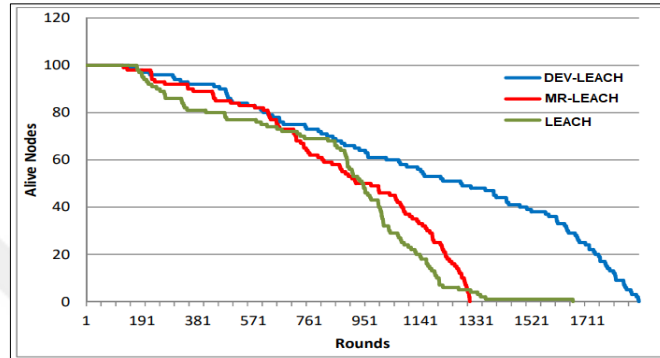


Figure 5.4: Nodes Alive Indicator in the Field.

This study offers a summary of the earlier LEACH protocol and proposes the new dev-LEACH hierarchical protocol. The outcomes were calculated as the mean of 100 simulation trials in MATLAB. By altering the energy usage between the nodes, the proposed protocol dev-LEACH increases network lifetime by up to 60%. We receive about 40% more than the E-LEACH procedure when compared to the E-LEACH treatment, which increases longevity by 50%.

6. CONCLUSION AND FUTURE WORKS

6.1 CONCLUSION

The conclusion of the work presented in this thesis is as follows. The cluster head location can be obtained in such a way that transmission energy requires a minimum. If the network has been divided into the unequal size of the cluster, then it is tough to reduce the transmission energy. In order to partition the network into clusters of identical size, the virtual grid approach can be used. This method can be used in any topology or any number of nodes in general. For the case of increasing network life, communication distance plays an important role for sensor nodes and cluster head as well. We have suggested communication ranges for the cluster to select the cluster head. Random deployment of sensor nodes in cluster affects the cluster head performance but it is the basic requirement of WSN applications. So, we suggested a method to select CH according to the number of such nodes available in a particular cluster. Network life has been calculated by time after which the first node dies because of energy depletion. The second issue examined by us is rectangular sensor field. In rectangular sensor area, deployment of sensor nodes can take place in corner of the area. These nodes are far away from the base station. So, we suggested communication range in the cluster to cover the corner nodes. Cluster head selection is based on the communication ranges and number of associated nodes. The third issue is in energy calculation for cluster head. The cluster head is associated with own cluster nodes. Cluster head depleted his energy very soon because of aggregation of data which is collected by own cluster nodes. So, we modify the energy equation according to the available sensor nodes in the cluster.

6.2 FUTURE WORKS

This thesis is mainly concentrated on cluster head selection and area division. We have investigated only a few problems associated with WSN. Some problems can further be investigated; Number of Base station position and their position. Subordinate nodes to aggregate the data to reduce the load on cluster head. The mobility of sensor nodes can also affect the cluster size and area of the network, so it will also be examined. More accurate method for sleep and awake technique especially for unwanted sensor nodes need to be examined. Deployment of sensor nodes can also be investigated for proper coverage of the

area. Data filtration investigation can also be the part of making intelligent sensor nodes. Wireless Sensor network can easily combine with IOT and will give the best results for applications.



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APPENDIX

Identifier	Study reference	Publication year	Publication channel	Citation count
M1	[8]	2020	Magazine	0
M2	[9]	2020	Magazine	0
M3	[10]	2019	Conference	2
M4	[4]	2019	Journal	6
M5	[11]	2019	Conference	1
M6	[3]	2019	Conference	0
M7	[12]	2019	Conference	0
M8	[13]	2019	Conference	0
M9	[14]	2019	Conference	2
M10	[15]	2019	Conference	0
M11	[2]	2019	Conference	2
M12	[16]	2019	Conference	1
M13	[17]	2019	Conference	0
M14	[18]	2020	Journal	0
M15	[19]	2020	Journal	4
M16	[20]	2020	Conference	0
M17	[21]	2020	Conference	1
M18	[22]	2020	Journal	0
M19	[23]	2020	Journal	4
M20	[24]	2020	Conference	0
M21	[25]	2020	Conference	0
M22	[26]	2020	Journal	3
M23	[27]	2020	Journal	0
M24	[28]	2020	Journal	0
M25	[29]	2019	Symposium	2
M26	[30]	2020	Journal	0
M27	[31]	2020	Conference	0
M28	[32]	2020	Conference	0
M29	[33]	2020	Conference	0

M30	[34]	2020	Conference	0
M31	[35]	2020	Conference	0
M32	[36]	2020	Conference	0
M33	[37]	2020	Journal	6
M34	[38]	2019	Journal	5
M35	[39]	2018	Journal	10
M36	[40]	2019	Journal	0
M37	[41]	2020	Journal	0
M38	[42]	2016	Journal	44
M39	[43]	2017	Journal	65
M40	[44]	2019	Journal	25
M41	[45]	2017	Journal	51
M42	[46]	2019	Journal	13
M43	[47]	2019	Chapter	2
M44	[48]	2016	Conference	0
M45	[49]	2016	Conference	3
M46	[50]	2018	Journal	0
M47	[51]	2018	Journal	27
M48	[52]	2019	Conference	1
M49	[53]	2019	Conference	0
M50	[54]	2018	Conference	0
M51	[55]	2018	Conference	0
M52	[56]	2018	Journal	7
M53	[57]	2019	Journal	17
M54	[58]	2019	Journal	5
M55	[59]	2019	Journal	5
M56	[60]	2019	Journal	11
M57	[61]	2019	Journal	18
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M59	[63]	2017	Journal	28
M60	[64]	2017	Conference	7
M61	[65]	2016	Conference	4
M62	[66]	2016	Conference	13

M63	[67]	2016	Conference	0
M64	[68]	2016	Conference	5
M65	[69]	2016	Conference	6
M66	[70]	2017	Conference	4
M67	[71]	2017	Conference	3
M68	[72]	2017	Conference	2
M69	[73]	2018	Conference	5
M70	[74]	2017	Conference	8
M71	[75]	2016	Conference	3
M72	[76]	2017	Conference	1
M73	[77]	2017	Conference	8
M74	[78]	2017	Journal	18
M75	[79]	2018	Journal	7
M76	[80]	2018	Journal	33
M77	[81]	2019	Journal	27
M78	[82]	2018	Journal	38
M79	[83]	2018	Journal	31
M80	[84]	2019	Journal	9
M81	[85]	2019	Journal	6
M82	[86]	2020	Journal	5
M83	[87]	2020	Journal	0
M84	[88]	2020	Journal	1
M85	[89]	2019	Journal	16
M86	[90]	2016	Conference	21
M87	[91]	2016	Conference	30
M88	[92]	2016	Conference	1
M89	[93]	2017	Conference	1
M90	[94]	2016	Conference	0
M91	[95]	2019	Conference	0
M92	[1]	2016	Conference	33
M93	[96]	2017	Conference	12
M94	[97]	2017	Conference	3
M95	[98]	2017	Conference	5
M96	[99]	2016	Conference	4

M97	[100]	2016	Conference	5
M98	[101]	2017	Journal	20
M99	[102]	2018	Conference	7
M100	[103]	2018	Conference	0
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M102	[105]	2018	Conference	14
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M108	[111]	2018	Conference	0
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M110	[113]	2018	Conference	1
M111	[114]	2018	Conference	1
M112	[115]	2018	Conference	1
M113	[116]	2018	Conference	1
M114	[117]	2018	Conference	0
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M117	[120]	2020	Conference	0
M118	[121]	2020	Conference	0
M119	[122]	2020	Conference	0
M120	[123]	2020	Conference	0