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A Survey of Energy-Efficient Routing Protocols for WSN-based IoT Networks

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Abstract: Internet of Things (IoT) based network offers various advantages to users, such as scalability, stability, and connectivity, with the advent of high-speed wireless communication networks. Wireless sensor networks (WSNs) play a crucial role in the dissemination of the IoT since sensor devices are both cheap and widely available. The concept behind IoT involves integrating embedded devices into common objects. Simultaneously, the widespread adoption of WSNs is greatly facilitated by the affordability and widespread availability of sensor devices, which play a crucial role in the expansion of IoT. The biggest problem in WSN-based IoT networks is sending massive amounts of data produced by sensor devices, which may shorten the life of a node owing to its high energy requirements for communication. Researchers are constantly digging deeper into the problem to find a solution to this issue. Therefore, it is of utmost necessity to provide remedies for network-based crises, including energy efficiency, dependable routing, congestion avoidance, network heterogeneity, security, and quality of service. Increasing the sensor's lifetime has been a primary focus of recent research, with much attention paid to how much energy each sensor node consumes. This study offers a review of existing procedures and methods that are effective in conserving energy.

Keywords: Internet of Things (IoT); Wireless Sensor Networks (WSNs); Routing Protocols; Energy-efficient; Nodes.

1. Introduction

The evolution of wireless technologies like Wi-Fi, Bluetooth, Wireless Sensor Networks (WSN), RFID, etc., has introduced a new form of wireless systems known as the Internet of Things (IoT). These technologies have been built on integrating different concepts with embedded intelligence and communication capabilities. IoT is the most significant advancement of today's technologies, progressing from delivering human-to-human communication to a wide network of connected devices. Hence, IoT is a continually evolving framework for securely connecting diverse and intelligent objects to the Internet. IoT was introduced to the world in 1999 for supply chain management and has since been widely used in various industries, including home, transportation, agriculture, medical services, and the environment [1]. Using sensors, wireless interfaces, and electronic circuits has enabled effective communication between these devices in IoT applications, and it is important to note that each communication technology has unique features, such as its coverage range, usefulness, cost, and quality. Figure 1 depicts the three-layered IoT architecture comprising perception, network, and application layers. Sensors are utilized in the perception layer to acquire information about their surroundings. Protocols for inter-device communication are included in this layer. Every day, more and more homogeneous and heterogeneous devices are being created and linked to the Internet using standard protocols for exchanging data. IoT devices are limited in terms of battery life, processing power, and storage capacity. Near Field Communication (NFC), Zonal Intercommunication Global-standard (Zigbee), wireless fidelity (Wi-Fi), Sigfox, Weightless, and Long-Range Wide Area Networks (LoRaWAN) are examples of IoT perception layer technologies. The protocols at the Network layer are in charge of figuring out the best way to get data packets from one host to the next over the network. End-to-end security for authentication, secrecy, and integrity are provided by the (IPsec) protocol at this layer. Notably, all Internet Protocol version 6 (IPv6) services must use IPSec. IPv6 over Low-Power Wireless Personal

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Area Networks (6LowPAN), Time-Slotted Channel Hopping with IPv6 (6TiSCH), Routing Protocol for Low-Power and Lossy Networks (RPL), Cognitive and Opportunistic RPL (CORPL), and Caching Array Routing Protocol (CARP) are the protocols utilized at the network layer. Examples of protocols used at the application layer are Advanced Message Queuing Protocol (AMQP), Message Queuing Telemetry Transport (MQTT), Constrained Application Protocol (COAP), Extensible Messaging and Presence Protocol (XMPP), and Data Distribution Service (DDS) [2]. Wireless ad hoc networks (MANETs), wireless sensor networks (WSNs), and many more technologies, such as vehicular ad hoc networks (VANETs), smartphone ad hoc networks (SPANs), and wireless mesh sensor networks (WMSNs), etc. are all included in the Wireless Self-Organizing Networks category. As shown in Figure 2, self-organizing wireless networks are overlapped to form IoT [3]. Wireless Sensor Networks (WSNs) are used to collect data in IoT systems, and their computational capabilities can be increased via the use of cloud computing. IoT aims to make the Internet more resilient and pervasive, and it can potentially improve user experience and satisfaction.

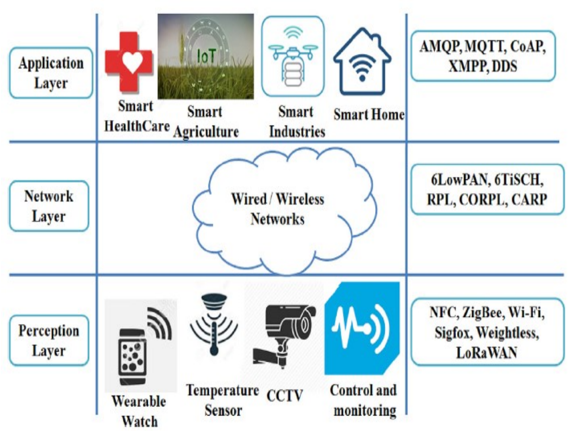

Figure 1 The three layers of IoT Architecture [2]

Additionally, the associated heterogeneous gadgets are often equipped with sensors, actuators, remote handsets, battery systems, and controlling processors, which enable them to monitor their surroundings and transmit or receive data. IoT applications span multiple disciplines, and one of the most complicated barriers to accomplishing their objective is maintaining adequate energy to run the network without losing the quality of service (QoS) [4]. The fundamental goal of IoT is to link equipment objects to the real world and turn the data received through these things into valuable information without the assistance of a human guide [5]. The battery power of equipment components is constantly drained during assembly and data transmission, as when a large quantity of data is acquired and gathered, this will use more energy. In terms of energy needs, there is a fundamental necessity to maintain a trade-off between the amount of energy used by IoT devices and the type of data extracted. Energy depletion affects the operation of different IoT devices. Thus, a fundamental demand is to reduce energy consumption while increasing the device's lifetime and enhancing its function [6].

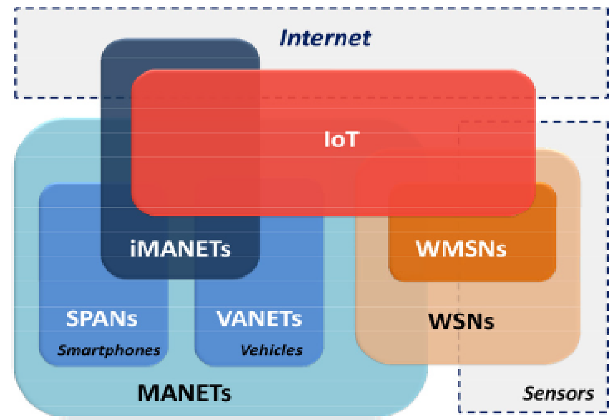

Figure 2 Main overlapping emerging wireless networks. [3]

Data packet transmission from the source node to the base station accounts for a significant portion of WSN's total energy usage. It is defined as the sum of the individual sensor nodes' power consumption times their total number. Formatted as;

$$Total\ Energy\ Consumed\ = n * energy\ consumed\ by\ one \qquad (1)$$

In this context, n represents the total number of nodes used as sensors. An efficient process uses less energy to get the same result. The number of data packets received at the destination to the number of packets transmitted from the source node is referred to as the packet delivery ratio. The definition of the packet delivery ratio is as follows;

$$PDR = \frac{Number\ of\ packets\ received\ at\ the\ destination}{Number\ of\ packets\ \ sent\ from\ source\ node} \qquad (2)$$

Packet delivery ratio (or "PDR") measures how many data packets were successfully sent and received, with which an efficient design results in a high packet delivery ratio [7]. The throughput is the maximum rate at which data may be carried over the network. It's the time it takes for a data packet to travel from one location to another.

$$Throughtput = \frac{Amount\ of\ packet\ sent}{Time\ taken\ to\ transmit\ the\ packet} \qquad (3)$$

The latency is the average time it takes for data to travel from its origin to its final destination. The average latency is calculated by subtracting the time it takes for data to travel from the source node to the destination node from the total time the data takes to travel [8].

$$Average\ packet\ delay = received\ time - send\ time \tag{4}$$

Two primary elements influence the amount of transmission power needed to get to the receiver: distance and wireless connection quality. The transmission power decreases with increasing distance. A weaker connection is established as the distance between the transmitter and receiver grows. As the signal weakens with distance, the transmitter must increase or decrease its power output to keep communication stable. Interference from other wireless devices, weather, physical barriers, impediments between the transmitter and receiver, and signal-to-noise ratio are only some of the elements that might reduce the quality of a wireless connection. The network's uptime is increased when its energy footprint is reduced therefore, one way to reduce power usage and increase node lifespan is to limit the sensor transmission range to that of the node's farthest neighbor [9].

The remaining sections of this work are grouped as follows. Section 2 contains a description of the related works in this field. The third section details the classification of routing protocols. Models of energy consumption in WSN are described in Section 4. The conclusion of this paper is in section 5.

2. Related Works

Energy consumption throughout the routing procedure may cause a problem owing to the device's short battery life. In WSN, numerous sensor nodes are distributed over a vast geographical area, and the whole system may become inoperable if sensor nodes cease to function due to internal issues or external ecological changes. Sensor nodes are powered by batteries, which are sometimes difficult to activate once installed; hence, energy efficiency is vital in extending the system's longevity. If the battery level of the sensor nodes is sufficient, the sensor-based devices will operate effectively; otherwise, they will fail to function properly [10]. When the sensors are deployed in the workplace, their batteries eventually run out. This requires various power reservation techniques to handle such severe circumstances, with energy efficiency as the main priority [11]. One of the WSN applications is environmental monitoring, in which the sensors collect the data over a large region and then make it accessible to a central sink. It is usually linked to a computer for complicated processing of the gathered data. How data is collected at sensors and routed across the network greatly influences sensor node energy consumption and total network lifespan. The time interval between the deployment of a sensor in a given region and the period when the sensor fails due to a wireless connection or power failure is known as the network lifespan. Because sensors consume energy to convey data, uploading the data straight to the sink may necessitate extensive communication ranges, degrading the energy of the sensors. The sink can only connect with a few sensors due to the small wireless communication range, particularly the sensors in the sink area. Some sensors near the sink may capture more data than others because they aggregate data from other sensors. As a result, congestion builds upon these sensors, and their energy rapidly depletes, causing delays and making them more vulnerable to shutdown. Congestion occurs when a sensor has more data flow than it can handle, as each sensor has limited storage space. Specific intermediate sensors may fail to receive or send more data to the sink at any given time because the amount of data gathered exceeds the amount that can be transmitted. Local congestion developed at these intermediary sensors, resulting in increased data loss and decreased overall network performance. The sensors may connect with several neighbors via radio interfaces sharing a single wireless channel. During data transmission, two sensors on the same wireless channel may interfere, causing packets to be lost and not received [12]. Three factors need to be adjusted carefully for designing a reliable routing protocol. First, energy consumption as wireless sensor radios operates in four modes: transmission, reception, idle, and sleep. Energy consumption is comparable in idle, transmission, and reception modes. As a result, sleep scheduling approaches place nodes in sleep mode with the radio turned off whenever feasible, using far less energy [13]. Another factor is minimizing collisions, which prevents two interfering nodes from transmitting simultaneously, avoiding energy waste due to retransmissions. The third and last factor is the Data-driven techniques that need attention, as their objective is to minimize bit transmission by reducing data redundancy. The research community has been driven to investigate the possibility of enhancing it due to its limited communication bandwidth, processing power, storage, and energy resources. Communication restrictions, such as 250 kbps in IEEE 802.15.4 standard, limit the viable solutions to those that do not require a large bandwidth. Wireless sensor computing limits include a standard microcontroller speed of 8-48 MHz. Memory constraints usually fall between 128-512 KB limit techniques that require considerable storage. Finally, their duty cycle is restricted by their low battery capacity, so regular battery resources supply roughly 27 kJ. On the other hand, the well-known wireless channel dynamics significantly impact them owing to their low transmission power reaching approximately three dBm [14]. Since wireless sensors may be installed in inaccessible regions where batteries cannot be replaced or recharged for practical reasons, the research community has concentrated chiefly on minimizing their energy usage. The radio transceiver is generally recognized as the most energy-demand component of a wireless sensor. As a result, energy-efficient communications are critical for extending the network lifespan of WSNs.

3. Classification of Routing Protocols

Typically, sensor nodes are outfitted with a microcontroller, external memory, radio transceiver, analog-to-digital converter (ADC), antenna, battery, and one or more sensors (such as temperature, light, humidity, moisture, pressure, luminosity, proximity, etc.). Once again, the nodes diminutive size means they have restricted onboard resources such as memory, batteries, computing power, and radio range. It's important to note that the design of a mobile sensor node is very similar to that of a traditional sensor node. However, extra components like localization/position finders, mobilizers, and power generation are considered in mobile sensor nodes. Figure 3 depicts the design of the mobile sensor node. The sensor node's location may be determined with the help of the location or position finder unit, and the node's mobility can be ensured with the help of the mobilizer [15]. WSNs have significant design issues due to resource scarcity, such as power, bandwidth, and processing storage.

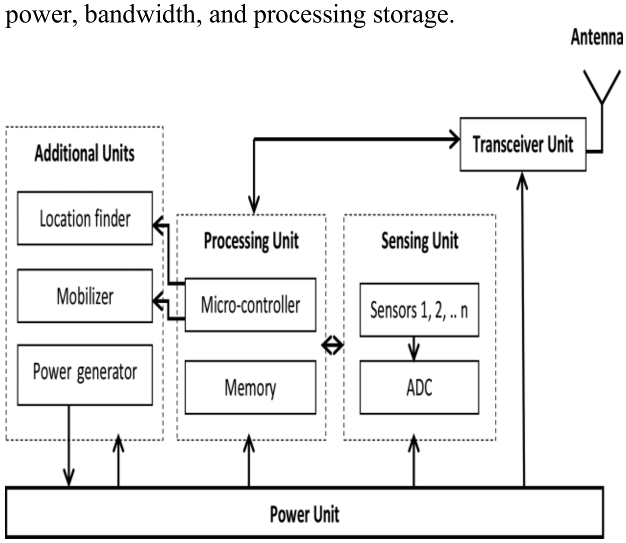

Figure 3 The architecture of the WSN node [15]

Variables like energy efficiency, complexity, scalability, delay, data transmission mode, and sensor location must be studied carefully while developing new routing algorithms. Routing protocols govern how nodes interact with one another and how data is distributed across the network. There are several classification schemes for WSN routing protocols. Kaur et al. [16] prepared a review of the categories of data-centric, hierarchical, flat-based, and location protocols in WSN. Each of these categories includes subcategories, which have been explored, such as the Low-Energy Adaptive Clustering Hierarchy protocol (LEACH) that is based on hierarchical clustering and has been improved in terms of threshold, network duration, energy, number of sinks, multi-hop communication, and so on. Node uniformity categorizes networks into the Flat Networks Routing Protocol (FNRP) and Hierarchical Networks Routing Protocol (HNRP) categories. By creating a hierarchical structure between nodes, LEACH is one HNRP technique in sensor networks that efficiently lowers transmission energy usage. In LEACH, the cluster leader acts as a data collector and processor for the cluster's nodes, sending the processed data to the base station (BS), as seen in Figure 4 When implemented, the cluster leader is chosen based on a consensus among all sensor nodes. The cluster leader is computed locally at each sensor node, making the system decentralized [17]. Enhancements to the Power Efficient Gathering in Sensor Information Systems (PEGASIS) protocol have been introduced based on leader selection factors such as the distance between the selected leader and other nodes, conjunction with the LEACH protocol, remaining energy, and the distance between nodes. In this review, Sensor Protocols for Information via Negotiation (SPIN) protocol has been improved to include distance finding and acknowledgment from sink nodes. These hierarchical and data-centric protocols have surpassed traditional routing methods such as floods and whispering. In truth, each procedure has its own set of benefits and drawbacks. The main concern is when to employ which protocol. The protocol we must choose should fully depend on the kind of application we want to use, the type of network our application will use, whether the location is required for our application, and so on.

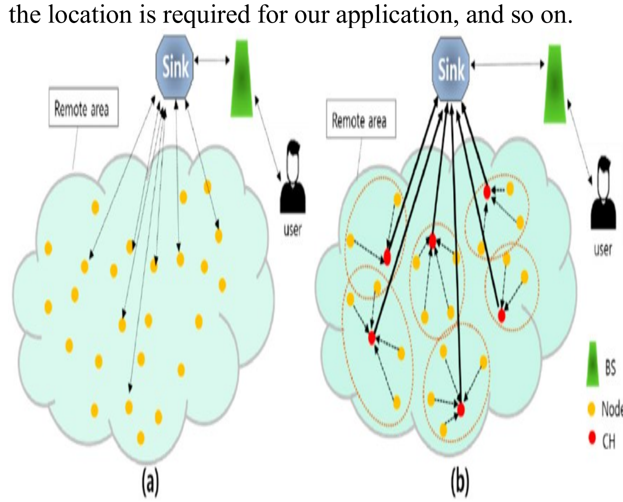

Figure 4 WSN Diagrams (a) Flat networks routing protocols. (b) Hierarchical routing protocols [17]

The other concern is if any of the aforementioned methods may be improved further. Ashish et al. [18] present a survey focused on energy-efficient routing protocols for WSNs. They classified routing protocols into seven categories: location-based, data-centric, hierarchical, mobility-based, multipath-based, heterogeneity-based, and QoS-based protocols. They present 39 routing protocols in total. In [19], WSN routing protocols were designed considering different routing challenges, design concerns, and WSN limitations. The study discusses several data-gathering methods and effective routing strategies for lowering network energy usage. It also proposed in detail the four fundamental kinds of routing protocols: location-based, info-centric, hierarchical, and multi-path-based routing protocols. Mishra et al. [20]proposed a different classification called protocol operation, consisting of four types; multi-path-based, query-based, negotiation-based, and QoS-based routing protocols. The second category is the next hop selection that branches into broadcast-based, location-based, content-based, and probabilistic routing algorithms. On the other hand, the third category is path establishment which contains proactive, reactive, and hybrid routing protocols. The fourth and last category is the network structure that branches into flat-based, hierarchical, and location-based routing protocols. In [21], The authors concentrate on clustering and cluster-based multi-hop routing protocols in this study to offer a comprehensive methodology evaluation. Some parameters for assessing the qualities of the various techniques are offered. The techniques are then categorized into four groups depending on methodology: classical approaches, fuzzy-based approaches, metaheuristic-based approaches, and hybrid metaheuristic approaches. Criteria and parameters are supplied in each classification group depending on the methodology used to assess the techniques; afterward, all methods in each class are evaluated in terms of clustering-based parameters and methodology-based parameters and finally discussed. The authors presented a novel technique for assessing methods that consider methodology-based factors such as capabilities and restrictions, investigated inputs and outputs in each method, the kind of algorithm employed in the methods, the purpose of utilizing algorithms, and so on. Ketshabetswe et al. [22]examined and contrasted Critical aspects to consider while designing wireless sensor networks and routing techniques that have been thoroughly researched. The sensor node energy problem in these networks has been highlighted, and this research seeks to overcome it. Existing wireless sensor network routing protocols have been examined and categorized into homogeneous and heterogeneous networks, further subdivided into static homogeneous and mobile homogeneous networks and static heterogeneous and mobile heterogeneous networks. Examples of homogenous network routing systems are location-based, data-centric, network flow, QoS-based, and hierarchical routing protocols. Static homogeneous networks are further characterized as cross-layer, nature-inspired, cooperative, and opportunistic routing protocols. In contrast, homogeneous mobile networks are classed as one mobile sink, one mobile sink and source, and multiple mobile sinks. Static heterogeneous networks, on the other hand, are classed as having energy heterogeneity and cost, detection, and propagation range heterogeneity. In contrast, heterogeneous mobile networks have energy, propagation range, and data rate heterogeneity. In developing these routing algorithms, we considered not only the specifics of the applications and infrastructures that use WSNs but also the networks' characteristics. The network's lifespan may be extended, and a highly efficient routing design reduces power costs significantly. Since energy limits and unexpected changes in node status give rise to frequent and unplanned topological adjustments, finding and maintaining routes in WSNs is a big concern. Some standard routing strategies that are well suited to WSNs are used by the routing approaches presented in the literature. Different and interesting approaches have been proposed by Pantazis et al. [23]that categorize the various routing protocols as depicted in Figure 5. The networks in the network structure may be categorized by the degree to which their nodes are all the same. Some networks see all nodes as equivalent and install them in a standardized fashion, whereas others differentiate between nodes. In particular, the key feature of the routing protocols in this class is the method in which the nodes are linked, and the information is routed depending on the design of the networks. This accommodates deployments of both identical nodes and nodes with varying hierarchies. Therefore, the schemes in this group may be further broken down into two categories; in a network using a flat protocol, every node serves the same purpose. There are several benefits to a flat network design, one of which is the low cost involved in maintaining the underlying infrastructure between communicating nodes. Another protocol is the hierarchical protocol that imposes a hierarchy on the network. The hierarchical protocols in this system improve efficiency, stability, and scalability [24]. In this category of protocols, nodes in the network are clustered, with the node with the highest residual energy, for example, taking on the position of cluster leader. The leader of a cluster is in charge of organizing its members' efforts and sharing information with other clusters. Clustering can lessen the network's power supply load and increase its durability. They can scale well, have a high delivery ratio, and their energy consumption is balanced. The energy reserves of the nodes closest to the hub or central station will be depleted first. When parts of a network become inaccessible, this is known as disconnectivity. If a single node fails that connects a region to the rest of the network, the region will be isolated [25]. Another group of protocols is based on the communication model in which the network can transfer more information using the same amount of power. This family of protocols may also achieve near theoretical optimal performance in both point-to-point and broadcast networks regarding dissemination rate and energy use. Data transferred using protocols based on the Communication Model sometimes fail to reach their intended recipient. Therefore, they cannot promise that information will be sent.

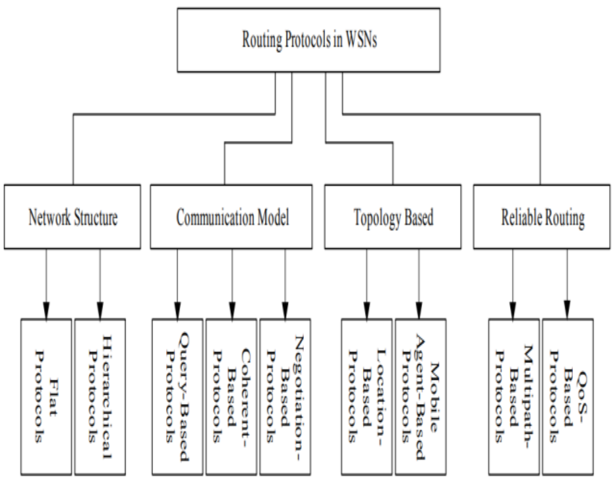

Figure 5 The main classification of routing protocols [23]

This scheme's protocols may be broken down into three categories; the first is the query-based protocols in which a node issues a query for data (sensing task), which is then relayed to other nodes at the destination, and any nodes that possess the requested data transmit it back to the node that issued the query [26]. Secondly, there are two types of protocols, coherent and non-coherent. In coherent routing, data undergoes little processing before being sent to aggregators. Raw data is processed at each node in non-coherent data processing routing before being sent to other nodes. Negotiation-based protocols use third meta-data negotiation to reduce unnecessary data transfers [27]. Other protocols are based on Topology; moreover, these are predicated on the idea that all network nodes store and update topology data, which drives the core of the protocol's functionality. In this scheme, the protocols may be further categorized into two types of protocols, Location-based Protocols, and mobile agent-based protocols. In the first type, location data distributes gathered information locally rather than broadcasting it over the whole WSN. This family of protocols can decrease the power requirements of the sensor nodes while still determining the best route from one point to another. If the nodes are mobile, their scalability decreases. The positions of other nodes are also something that each node has to be aware of or understand. On the other side, the protocols that are based on Mobile Agents, data is routed from the detected region to the destination via mobile agent protocols, which is an exciting field. A mobile agent is a crucial part of mobile agent systems; it may move between different network nodes and carry out its duty independently and intelligently, depending on the circumstances [28]. Compared to traditional WSN operations based on client-server computing architecture, mobile agent protocols may offer the network more flexibility and new possibilities.

The last category is the reliable routing protocols which consist of two types; the first type is the multipath-based protocols that accomplish load-balancing routes or provide specific QoS metrics like time, energy, and bandwidth. The protocols on this scheme are more resistant to route failures. Maintaining routing tables and the QoS measurements at each sensor node might burden the network nodes. Moreover, load balancing is achieved, and route failures are tolerated better through multipath-based protocols. On the other side, the network can strike a balance between power consumption and data quality using QoS-based protocols. The network's detected nodes must transmit at a certain quality level whenever a sink requests data [29].

4. Energy-efficient Models in WSN

Two methods are used for transmitting data in WSNs. The first is known as Flooding, while the second is known as gossiping. Various operations use significant energy, including communication, sleep, idle listening, control overhead, and collision. Transmission and reception require the most amount of energy of any activity. For a long time, researchers have been attempting to create energy-efficient routing algorithms to boost network lifetime. Routing algorithms are critical components of the IoT system, and one of the noticeable routing algorithms is Low-Power and Lossy Networks (RPL), designed for wireless networks that use little power and are prone to packet loss. It is a proactive protocol that runs on IEEE, uses MAC and PHY layers in 802.15.4, and is based on distance vectors. It is geared for multi-hop, many-to-one, and one-to-one communication [30]. RPL is a routing protocol that uses the Destination Oriented Directed Acyclic Graph (DODAG) architecture. When multiple nodes sense a large number of data, the volume of data generates network congestion and traffic. To avoid such instances, node priority and transmission rate are used. The priority of each node is changed to 1 or 0 depending on the traffic volume; low traffic is set to one, while excessive traffic is set to zero. Massive amounts of data gathered may be classified as video data representing high traffic and audio data representing low traffic. The way of routing is detected prior to packet routing to assess traffic Given the conditions. Audio data is transferred when there is a lot of traffic, and vice versa. Synchronization between the transmitter and receiver is accomplished by using time division multiple access (TDMA) time slots for energy saving and also help reduce delays. The network Base Station (BS), which has a maximum power source by default, collects data considering each network node's position and energy, which helps in the formation of clusters. The genetic algorithm determines which cluster head (CH) is picked. Since the BS contains all node information, it selects the nodes based on their high remaining energy and low data. The node with the most remaining energy is more likely to be chosen [31]. Instead of generating routing overhead, ER-RPL employs a subset of nodes based on regions for route finding. Nodes are classified as reference or normal, and their location information is used to separate them into distinct regions using a self-regioning method based on the node's border code information. It achieves the best results in terms of packet delivery, hop count, energy consumption, and network overhead. On the other hand, EC-MRPL creates a network structure based on mobility that enables applications such as healthcare, autos, and logistics. The mobility of nodes in the RPL DODAG architecture is difficult to manage since it impacts throughput and energy and incurs latency due to connection failures. The primary principles behind this study are detecting node movement and offering proactive behavior by anticipating the next parent node before connection loss to prevent data loss. To circumvent difficulties caused by parent node mobility, mobile nodes (MN) are configured as leaf nodes. Each mobile node is an associated node (AN) since it is linked to the parent node. AN uses the Received Signal Strength Indicator (RSSI) measure to forecast node mobility. It handles data packet exchange and finds a new AN from the candidate parent set for an MN before disconnection. It demonstrates positive outcomes for energy usage, packet delivery ratio, and delays [32]. An energy-efficient and delay-aware routing algorithm is proposed by Wen et al. [33] to cut down on power use while keeping end-to-end delays to a minimum by giving the optimization issue a mathematical shape to apply the dual decomposition approach to make it decentralized. In addition, a decomposition approach is used with an estimate of the single-hop latency to arrive at a completely distributed solution to the optimization issue. The results of the experiments show that the suggested routing method may increase efficiency, guarantee reliable transmission in a single hop, and decrease latency between intermediate nodes. However, when nodes are dispersed sparsely in a network, the suggested routing method ignores the void zone issue. Krishna et al. [34] proposed an energy-efficient cluster leader selected first using the Multi-Hop and Chaotic Particle-swarm Krill Herd (CPKH) approach proposed by the study. Also, the Self-Adaptive Step Glow Worm Swarm Optimization (SASGWS) Algorithm was devised, which analyzes the system's condition on demand and dynamically detects potential risks while increasing power efficiency and bandwidth. Sheeja et al. [35] integrated the Black Hole algorithm (BHO) and Tuna Swarm Optimization (TSO) methodologies to offer a revolutionary energy-saving routing; this heuristic algorithm is called Adaptive Black Hole Tuna Swarm Optimization (ABTSO). For optimal routing in WSN, it is necessary to take into account a wide variety of metrics, such as the number of restarts, link quality, node centrality, node degree, path loss, Packet Drop Ratio (PDR), delay, distance between the Cluster Head (CH) and the Base Station (BS), the distance between the sensor nodes, and the CH's remaining energy. This multi-objective determined CH selection aids in increasing both network performance and system longevity. Chaurasia et al. [36] Proposed a Meta-heuristic Optimized Cluster Head Selection-based Routing Algorithm for Wireless Sensor Networks (MOCRAW) to reduce node power consumption while maintaining high throughput. Through the use of the Dragonfly Algorithm (DA), where the decision is based on Local Search Optimization (LSO) and Global Search Optimization (GSO), MOCRAW eliminates isolated nodes or hot-spot issues and delivers loop-free routing. The best Cluster Head Selection Algorithm (CHSA) and Route Search Algorithm (RSA) are used in this protocol's two sub-processes. Energy Level Matrix (ELM) is used by CHSA. ELM considers factors including node density, residual energy, CH-to-BS distance, and inter-cluster formation to determine optimal parameters. In RSA, the optimal route from source to destination is determined by the inter-cluster via the allocation of levies. Parameters including latency, packet delivery ratio, and average energy consumption are used to evaluate MOCRAW's performance compared to competing clustering and routing protocols. To create a WSN that is both dependable and economical with energy, a novel adaptive coding routing protocol has been proposed in cluster-based routing protocols by Daanoune et al. [37]. The new protocol enhances data transmission between nodes, cluster formation, and CH selection. It chooses CHs based on the excess energy of nodes. So that there is no imbalance in energy consumption and no strain on the CHs, equal clustering has been implemented. Since the distance inside a cluster is smaller than the threshold do, a single hop is used. In particular, the suggested strategy chooses the node (CH or AN) with the least distance to the BS and the most residual energy to act as the central node, which collects data from distant CHs/ANs or does not have enough energy. Each CH/AN in the inter-cluster controls its routing table to determine the best path to the BS. However, we applied the RS and LDPC codes with our suggested method to provide a routing protocol that is both energy-efficient and reliable, guaranteeing the integrity of sent packets. Comparing the suggested method to LEACH and BRE-LEACH in simulations revealed that it provides superior performance in terms of stability, network lifespan, energy consumption, and throughput. In addition, the strong performance in terms of BER and coding gain shows that our suggested routing protocol is more suited for LDPC code than RS code. Kumar et al. [38] introduced a revised Speed Up-Greedy Perimeter Stateless Routing Protocol for Wireless Sensor Networks (SU-GPSR) and an Energy Harvest Greedy Perimeters Stateless Routing Protocol (EH-GPSR) to manage data transmission in WSNs and the issue of detector energy supply. In contrast to previous GPSR algorithm variants, SU-GPSR delivers full energy usage while evaluating the next hop for both stationary and mobile nodes inside a single framework. In addition, the SU-GPSR skip selection technique is used to keep track of long-standing data. The authors determined that the EH-GPSR improves upon the greedy routing approach by using an EH rate that is created by the Mobilized Minimum Path Recovery Time (MMRT) method. It gradually selects the next hop by combining the data cost of the node with the EH rate, which is a weighted algorithm. To attain a good compromise between route dependability and energy consumption, Nivedhitha et al. [39]presented a dynamic Multi-hop Energy Efficient Routing Protocol (DMEERP). Cluster formation and multi-hop route construction were modeled for the network with the help of certain fundamental assumptions. All information pertaining to Cluster Heads (CHs) and cluster members is kept in the Super Cluster Head (SCH). If the current cluster leader fails, a new one may be chosen by estimating the node's activity and weight factor. For efficient packet routing that causes no additional packet loss, the route reliability ratio is computed. The channel capacity model is the basis for the energy model's implementation. The effects of packet delivery success rate, network longevity, data flow, energy consumption, route dependability, control overhead, and latency have all been simulated and analyzed. To enhance the effectiveness of network learning and provide higher-quality results, Akbari et al. [40] suggested a method that uses fuzzy logic and reinforcement learning to save energy without sacrificing effectiveness. Based on the node's remaining energy, available bandwidth, and distance to the sink, the fuzzy logic system and reinforcement learning optimize energy usage and network lifespan during routing.

5. Conclusion

Improvements in the Internet of Things (IoT) are revolutionizing modern living. Reviewing the existing literature, we learn that significant progress has been made in this area; nevertheless, the IoT applications are still struggling with and will continue to struggle with concerns linked to the lifespan of nodes impacted owing to reduced energy. Some novel approaches related to energy-efficient routing methods for IoT applications are shown in this work, providing a comprehensive overview of the critical factors.

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