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A Comprehensive Survey on Routing Schemes and Challenges in Wireless Sensor Networks (WSN)

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Abstract – This paper adds to the broad investigation of routing protocols in wireless sensor networks (WSNs). It summarizes the contributions of different researchers in improving the overall performance of WSNs by developing various new and modified routing techniques for general and specific applications in the various field of engineering and technology. A pool of almost 60 research papers and more than 20 survey papers related to various routing techniques were studied thoroughly and represented in a lucid form to help future researchers to contribute effectively in the field of sensor networks. The survey papers considered for this literature are classified for routing algorithms based on the quality of service (QoS), intelligence-based routing (IBR), and routing for dedicated applications while the current research work is distinguished based on cluster head selection phenomenon, forwarding node and other factors contributing to the performance improvement of routing algorithms as per the current focus on routing is concerned. A comparative analysis of the latest contributions in the paper mainly focuses on routing schemes, the parameters are taken into account, and comparison to existing routing techniques as a large amount of research work was concentrated on reducing energy consumption during routing, energy balancing followed by increasing network lifespan, reducing delay, PDR and throughput. The main aim as per the paper included in our study was to design a routing strategy that would keep the network activity for a longer period as possible by reducing the energy required for various operations by an individual sensor node and maintain the overall energy of the nodes to be balanced over their lifetime. Lastly, the paper contributes to discussing the challenges in constructing a routing protocol (RP) for WSN considering the interdependency of various network parameters.

Index Terms – Routing Protocols, WSNs, QoS, IBR, Cluster Head, Energy Balancing, Network Lifespan.

1. INTRODUCTION

Wireless Sensor Networks (WSN's) are developed by random distributions of tiny sensors communicating over wireless links. These nodes have limited coverage, storage capacities, and energy resource. The QoS in WSNs depends on the performance parameters such as throughput (TP), end to end delay (E2ED), packet delivery ratio (PDR), residual energy, bandwidth, data rate, hop transmission cost, controlling cost, differential coding efficiency, overhead, error probability, etc. which are influenced by the routing protocol used for WSN. Two approaches proactive routing (used earlier) and active routing are used in routing. The proactive routing moves data over-all accessible transmission ways even these ways are rarely utilized. Accordingly, proactive routing doesn't scale well in progressively changing system topologies. Frequent changes in the topology with reactive routing techniques may still cause significant congestion. The topology alteration is due to mobile node devices or sleep cycles conserved by alternating energy [1]. End-to-end messages are delivered by selecting nodes using a host-based addressing scheme in topology-based configuration whereas geographic-based configuration and ID provided to the destination serves the purpose (position-based). The popularity of data-centric techniques in WSNs has been increased as compared to the address centric methods such as topology-based and geographic-based steering since the former is query-based.

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The sink station sends out non-specific queries (i.e. not asked to any specific node) and the sensor node able to deliver the requested data will respond to the query of the sink.

A routing technique is known as a single path strategy if there is just one case of the message in the system whenever. Other sending techniques can be delegated partial flooding and multi-way steering, contingent upon messages being sent to certain neighbors in each directing advance or when directing is performed along a couple of conspicuous ways, separately. Single-way, multipath, and flooding-based directing techniques give ensured delivery [2]. In Clustering, all nodes need to detect their radio neighborhood and to exchange enough information to form the clusters. This is achieved by protocols that can be either specific to the communication system providers or taken from standards such as the IEEE 802.15.4 one, meant for wireless personal area networks [3].

1.1. Research Objectives

Although there are contributions and previous efforts for surveying routing protocols and respectively the design challenges, the scope of the survey presented in this paper covers the contributions of researchers in various routing schemes, percentage contribution made concerning various parameters in the last two years and describes the challenges for maximum routing scheme design factors. Due to the importance of routing in WSNs and the availability of a significant body of literature on this topic, a detailed survey becomes necessary and useful at this stage. Our work is a dedicated study of routing schemes, describing and categorizing the different approaches for data routing. Also, we summarize routing challenges and design issues that may affect the performance of routing protocols in WSNs. The classification of routing protocols from the studied survey papers is broadly arranged in three different classes about routing based on QoS parameters, routing using intelligence, and routing for specific applications.

The detailed study is presented in Section 2 of this literature. The section 2 corresponds to a review of some current research work [2018-2019] dedicated to routing techniques in WSN. The work is divided into two sub-sections which include routing schemes dedicated for cluster head selection, routing for forwarding node selection for hoping, and the third sub-section lists routing schemes for other factors such as security routing, routing for link failure, routing for congestion control, routing controlling node overloading, etc. This section lastly summarizes the latest research work from section 2 in terms of performance parameters. The contribution of the latest research towards each QoS parameter is presented lucidly. Section 3 deals with the challenges in designing an efficient routing protocol for WSN. A thorough survey from several research papers had been accomplished for identifying various crucial challenges and the issues are described. The summary of the work elaborated section 4.

2. LITERATURE SURVEY

2.1. Survey Related to Classification of Routing Protocols Based on QoS Parameters

A cluster-based routing protocol (CBRP) survey had been carried in [4]. They presented a taxonomy on a related topic and put forward the design issues required for designing an efficient routing protocol. The prominent factors affecting the design of routing protocol such as node deployment, energy consumption, nature of nodes, coverage, scalability, QoS were discussed. They also classified routing protocols on various network-related parameters including network structure, initiator of communication, establishment of routing paths, protocol operation, and hoping strategy. Block, grid, and chain-based routing protocol were distinguished, and based on their merits and demerits a comparative approach was presented. A further comparison was made between popular CBRPs concerning various performance parameters viz. energy efficiency (EE), cluster stability, complexity, load balancing, and delay. Lastly, issues regarding cluster-based routing techniques were discussed to improve the performance in future design work. A similar classification was presented in [5] by Swati Mishra et. al. They presented an overview of WSN and classified RPs based on network structure, protocol operation, path establishment, and next-hop selection.

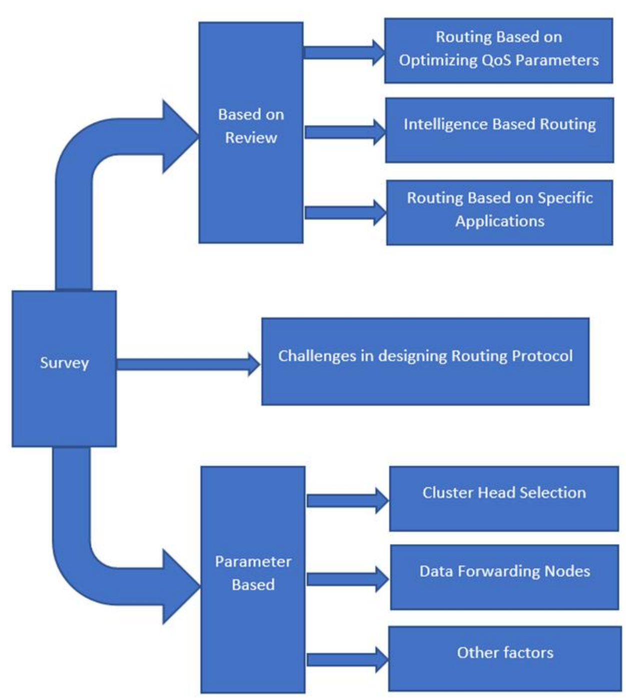

Figure 1 Summary of the Work in the Literature

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Olayinka and Attahiru provided a decent knowledge into the application challenges & implementation of WSN. The paper mainly concentrated on energy efficiency and load-balanced energy (LBE) RPs for WSNs. They emphasized on challenges in designing and developing an LBE routing protocol. Further, they classified routing protocols based on algorithms and decision-making parameters used in the algorithm. Factors related to energy consumption were summarized in a lucid manner and routing protocols were classified concerning energy efficiency and energy balancing. A comparative approach was provided for various clustering-based routing protocols in a Multi-hop clustering network for decision variables regarding the selection of cluster in-charge, the formation of a cluster, and routing to Base Station (BS). They also established the strength & weaknesses of the selection of the decision-making variables used in tuning these protocols [6].

Lucia Keleadile Ketshabetswe et. al. [7] focused on different solutions to improve network lifetime and surveyed energy-efficient routing protocols. Along with network modeling, the paper presented event extraction analysis and differentiated RPs based on homogeneous and heterogeneous routing protocols. Further, they sub-classified them concerning static, mobile, and other behavioral aspects. Lastly, they compared the performance of a few routing protocols and suggested future work directions to be considered. Some of the factors listed for designing WSN and routing protocols were energy capacity, hardware resources dependent factors, non-static networks, node placement, sensor position, fault resistance, latency, information aggregation, and scalability.

Shahul Hameed et, al. [8] reviewed traditional geographic routing and cross-layer routing protocols and commented on research gaps and challenges. Suggestions regarding challenges in routing were presented for the future design of routing protocols which included diverse network structures, multiple assets/destinations, multi-objective steering, QoS limits, security, energy sources, network packages, and development structures. The stated that the above challenges can be rectified by adopting strategies concerning the design of nodes, sensor node localization, routing based on energy strength, and QoS aware routing. Mohammed Salman Arafath et, al. [9] focused on the concept of opportunistic routing (OR) and QoS parameters viz. packet reception ratio. The paper explored two major functions of the routing algorithm and presented the difference in OR routing based on data delivery techniques. The method suggested in the paper yielded better results and implied that improving PDR imposes difficulty for an attack on availability. The concept of OR to dynamically select forwarding node closer to the sink at the time of transmission had been elaborated and the comparison of various algorithms is presented. The major QoS parameters focused on by different researchers are shown. Their work also focused on two important functions of routing in WSNs including data forwarding using clustering and least routing time algorithm and showed that the least routing time algorithm performed better than other existing techniques.

Brijesh L. Kundaliya and Sarman K. Hadia analyzed and compared various existing RP for WSN. They broadly classified RP based on network organization, route discovery, and protocol operation. Further, they categorized the well-known RP as per their requirement for operation and outcomes such as data-centric, hierarchical, and geographical, and QoS parameters. They outlined features and functionality and compared them based on their distinct abilities and shortcomings. They concluded that an RP should provide flawless and accurate data delivery in the network and should not degenerate its performance under the continually changing topology of the network for certain unavoidable and unpredictable circumstances [10].

Ref. No.	Year	Contributions
4	2015	Survey on cluster-based routing methods
5	2017	Survey on routing protocols
6	2017	Survey on energy-efficient and energy-balanced routing protocols
7	2019	Survey on Communication protocols
8	2017	Review on routing methods
9	2018	Pithy review on routing protocols
10	2019	Analysis and comparison of routing protocols

Table 1 Survey by Researchers for Routing Based on QoS Parameters

2.2. Survey Related to Classification of Intelligence Based Routing Protocols

Rajesh Kumar Tiwari [11] worked out a deep survey on various swarm intelligent (SI) based RPs. The author classified biologically inspired routing algorithms for computer networking. He provided a summary of various classical and SI based routing from 2002-2015. The author concentrated on issues comprising WSN other than ad hoc networks, wired networks, etc., and pointed out that due to structural difficulties of WSNs routing protocols for WSN are to be different than other systems. For networks considered in literature were minimal computation and limited memory requirement, self-organization, power consumption, scalability, flexibility, connectivity, sensor location, and fault tolerance. Further few Si-based RPs were highlighted in concern to their properties and taxonomy including Ant Colony Optimization (ACO), Bee Colony Optimization (BCO), Particle Swarm Optimization (PSO) & Lime mold based RPs. The detailed classification can be obtained from their literature. Kalpana Guleria and Amit Kumar Verma [12]

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provided a guideline to researchers on how to develop routing protocol and worked in finding research gaps by reviewing routing protocols and presented future aspects for the same. They oriented their study on classical based and SI based RPs. The protocols were further classified concerning network structure and their properties. Their review also included protocols based on swarm intelligence, hierarchical, and hybridization of both. Lastly, they discussed the issues and difficulties influencing the energy-efficient hierarchical routing design and recorded execution assessment measurements of the routing techniques. The paper suggested a concentration on application-specific routing protocols including video and imaging where QoS is required with energy efficiency. They stated that work should be oriented to explore the capability of the routing protocol to tackle mobile nodes or sinks, dynamic topology overheads, energy constraints, and QoS requirements.

Challenges	Evolutionary Algorithms	Merits
Routing	GA	Reduced power consumption, Increased system lifetime
Clustering	EDA	Best route from cluster in-charge to node, Decreased power consumption
Coverage	NDSA	Enhanced coverage through optimized energy and increased active nodes
Localization	GP	Enhanced coverage power, distributed power consumption over the system

Table 2 Merits of evolutionary Algorithms for Challenges in Routing

K. Tarunpreet and K. Dilip presented a review on CI based routing protocol (RP) with QoS parameters as a guide to future researchers for designing efficient RP in future. Their work focused on various challenges about RP in WSN [13]. It included objectives, mechanism, operation, and simulation result for the CI based RP and explained the need, merits, and demerits for the same. They compared various existing RP based on QoS parameters. Lastly, they concluded that for designing efficient RP, several techniques such as cross-layer approach, heterogeneous traffic load, mobility, error-free transmission, and fault tolerance routing, and hybrid intelligence can also be considered. Ali Jameel Al-Mousawi made a review on the impact of evolutionary intelligence (EI) in sensor networks and its conclusions. In their work, they addressed the problems which affect the efficiency of sensor networks such as adaptability, power consumption, routing process, localization, clustering, and coverage. The evolutionary intelligence algorithm discussed in their paper includes GA, GPA, Evolutionary strategy algorithms, Evolutionary Differentiation algorithms, Non-Dominated Sorting GA, and Learning Classifier Systems. Important aspects of determining the application of the proper evolutionary algorithm to a particular challenge in sensor networks were worked out as per the properties of each of the algorithms. Table 2 shows challenges, evolutionary algorithms, and merits as per the work done in [14].

2.3. Survey Related to Classification of Routing Protocols Based on Specific Applications

Classification and design of RP based on various aspects of WSN applications were presented by Reem E. Mohamed et. Al [15]. They highlighted research challenges and existing routing problems for energy-efficient RP homogeneous proactive WSNs. They introduced detailed taxonomy to assist real-life applications of WSN with the design aspect and corresponding network features. An analytical study was performed on RP listing their strength and weakness based on the network lifetime and stability period of the WSN. They put forward three major factors required for energy-efficient RP protocol i.e. network adaptability, overhead, and route selection.

Tariq Islam and Yong Kyu Lee classified RP based on node localization for underwater acoustic sensor networks. Further sub classification was performed for both localized nodes and localization free nodes concerning mobility. The protocols based on an exclusive parameter set which includes mobility, forward hop selection strategy, node grouping, link management, sink, and node placement that covered most of the fundamental aspects of RP were analyzed [16]. Mohsin Khalil et. al [17] listed out the importance of routing protocol for smart cities and reviewed them for productive research and proposed how their classification can be useful for operational utility. They segregated the routing techniques based on operation and utility and classified them concerning four parameters including topology, data-centric, location assisted, and mobility-based. Lastly, they discussed the requirement of the reviewed routing technique in dominant areas.

2.4. Routing Based on Cluster Head Selection

K-means clustering was utilized to cluster and the selection of group head was achieved by a fuzzy logic system. Further, the rules of fuzzy were set using a Genetic Algorithm. Rules were coded as chromosomes and the fitness function was considered to be the lifetime of the network [18]. They showed that the energy balanced routing protocol (EBRP) provided a higher life to the nodes and the best balancing of energy in the network for varying networks when compared with SEP, LEACH-C, and LEACH. Work proposed by Yasha Istewal and Shashi Kant Verma [19] focused on four parameters including stability, lifetime, energy consumption,

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and throughput. Their work included heterogeneity in energy levels and distinguished four different types of sensor nodes accordingly. The nodes were either super, advance, intermediate, or normal with the normal nodes having less energy than the supernodes. Instead of one cluster captain, they chose two cluster heads to share the task thus reducing bandwidth, time, and utilization. Compared to SEP, TSED, and ETSSEP, the proposed DCHRP4 outperformed concerning throughput, stability period, and network lifetime.

Amine Rais et. al. chose a hybrid RP called efficient Honeycomb clustering algorithm (EHCA) [20] which is a set of hierarchical protocol and geographical protocol along with the Honeycomb clustering technique. With 1000 sensor nodes over 600 m radius and 6 sinks over the edges, they simulated using IEEE 802.15.4 standard and evaluated the system performance for alive nodes, average delivery latency, and the ratio of successful data delivery parameters. They compared EHCA with hierarchical protocols (HEER), geographical protocol (GAP), and other hierarchical protocol (PEGASIS) and showed that their EHCA performed better. They associated localized nodes with a virtual grid of honeycomb and cells with hexagonal structure and concluded that clustering uniform and adjacent honeycomb with multi-hop steering in intra-cluster save node residual energy. Energy balancing was maintained by changing the location of the cluster head which mitigated the load on neighboring nodes.

Haibo Liang et. Al. [21] worked on reducing energy consumption during data routing using LEACH and increasing the network life cycle. The number of optimal cluster representatives was estimated according to the overall energy lost for each round to decrease overhead due to excess selection of cluster monitors. A Voronoi diagram was used to select cluster nodes nearer to optimal cluster heads. Therefore, communication in the intra-cluster reduced energy consumption. Cluster head in the vicinity of Base station was added to talk with remote cluster head using multi-hop routing optimized with ACO technique controlled the cluster head number in the range $3 \leq N \leq 10$, increased network lifetime by 127%, percentage of received data packets boosted by 71.4% and the energy cost per unit node was 2.0084×10^{-4} J.

A Fuzzy logic-based energy-efficient technique (FL-EDC/D) was proposed by Abdulmughni Hauzah et. al. which considered minimum length enforcement between cluster leaders due to the ability of FIS to combine and blend effectively input variables/parameters to develop appropriate decisions for selecting the cluster head. A sensor node's chance to become a cluster leader was determined by five factors including energy residue, path length to a base station, the density of cluster area, compactness of nodes around the node under consideration, and average energy consumed locally [22]. FL-EDC/D was compared with LEACH, K-mean, S-LEACH, and FL/D considering efficiency for energy cost and network life span, which outperform the others. The energy efficiency of the RP was evaluated using Gini Index measurement means to check the performance concerning maintaining energy over the network. Huarui Wu et. al. modified LEACH for cluster head selection criteria, the formation of the cluster, and routing mechanism. The improved LEACH called improved chain-based clustering hierarchical routing (ICCHR) was periodic and partitioned into two stages per round i.e. formation of cluster regions and stability to data communication [23]. They used a static network with a symmetric link with sink node energy level to be unlimited. For cluster head election, the ICCHR scheme adopted a threshold adjustment for the orchard long direct deployment environment, uniform clustering, and chain clustering mechanism. They restricted inter-cluster communication from sensor nodes and authorized the chain leader. They showed that ICCHR is superior to E-LEACH, P-LEACH, LEACH-IR, PEGASIS, and PEGASIS-E related to network life span, throughput, time complexity, and homogeneous distribution to use of energy.

In [24], the authors improved the network lifetime by using cluster-based routing through the Neuro-Fuzzy Rule-based clustering approach in WSNs with IoT. Energy modeling was achieved with Machine Learning & fuzzy rules to update weights. The performance was compared with LEACH, FLCP, and HEED protocols, and was concluded that their approach performed better. In [25], the RP was based on adaptive rank. The choice of the cluster head to forward a message was decided as per the rank decided on energy residue and geographical location of the node. The performance parameters were compared with peer competitive routing methods such as ACO, AODV, EMCBR, IACR, and LEACH. The effectiveness of the presented steering scheme was evaluated in terms of PDR, E2ED, energy cost, and message success rate.

Mengjia Zeng et. al. [26] considered heterogeneous energy networks and proposed the ECRP-energy coverage ratio protocol to be an improvement over LEACH to reduce energy consumption over the network. In the light of the least energy utilization and regional coverage maximization, the optimal number of clusters and cluster head was determined. The cluster leader with low energy residue and high utilization was substituted to extend network lifetime. They compared ECRP with LEACH, SEP, and DDEEC protocol and found prolonged stability time and network life and reduction in overall energy consumption. Catalina A. S. and Mihaela C. extended their earlier work on Spatio-temporal event detection and reporting in the mobile sink. They improved the reactive, anchor-based RP with dynamic clustering and restricted flooding for reducing energy consumption and improved the processing capability of the link nodes [27]. Table 3 shows the Summary of routing based on cluster head selection.

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Ref. No.	Year	Merits	Demerits
18	2018	Reduced Energy consumption and balanced network	Not applicable to all types of networks
19	2018	Increased stability, network lifetime and throughput	Performance compared to only three other routing schemes
20	2019	Number of active nodes, latency and data delivery percentage	Reduced lifetime
21	2019	Lifetime and energy efficiency	Single path optimization
22	2019	Energy efficiency in terms of network lifetime and energy consumption	Average improvement in terms of first node dead and half nodes dead
23	2019	Network lifetime and average energy consumption	-
24	2019	Energy utilization, PDR and network lifetime	All nodes are assumed to be trustful which is not possible
25	2019	Message success rate, energy consumption, end to end delay and PDR	Time and computational complexity
26	2019	Network lifetime, load balancing and overall energy consumption	Applicable for heterogeneous networks only
27	2019	Energy consumption and composite events detected successfully by the sink	-

Table 3 Summary of Routing Based on Cluster Head Selection

Alma Rodriguez et. al. used YSGA (Yellow Saddle Goatfish Algorithm) to determine the optimal selection of cluster heads in the network while ensuring other sensors in the vicinity of the cluster heads. YSGA was utilized for reconfiguration of the network to reduce the transmission distance. The algorithm minimized the energy consumption, improved the lifetime, and prolonged the stability time of the network [28]. Kasheef Naseer Qureshi et. al. used Gateway nodes in coordination with the cluster heads selected from the centroid of the cluster to reduce the burden of cluster heads. The gateway nodes were selected from each cluster which routes the data to the base station. The GCEEC routing scheme was used in agriculture applications for monitoring temperature, humidity, and illumination and showed reduced overhead and energy consumption whereas increased the network lifetime [29].

Similar work had been carried out by Anamika Walter et. al. where the authors concentrated on reducing the numbers and the duration of transmissions using energy-efficient clustering and shortest path routing protocol (EECSRP). A time-based cluster head was selected based on node degree, residual energy, and Received Signal Strength. The results showed packet delivery, average energy consumption, control overhead, and average end-to-delay with consistent performance and better performance in terms of energy consumption and network lifetime [30].

Nalluri Prophess Raj Kumar et. al. [31] limited cluster size to ¼ th of total nodes randomly deployed and optimized the hop count to a maximum of one or two to transmit data to the base station from any zone. The zone head selection mechanism considered energy, position, and distance from the base station. Their work showed improvise results over Network energy consumption, Average energy consumed by the sensor node, Packet delivery ratio, packet loss percentage, and Network throughput. The base station was placed inside the sensing field. More power would dissipate if the base station is placed outside or at an unreachable point from the zonal heads. Turki Ali Alghamdi [32] in his work considered four parameters including energy, delay, distance, and security for selecting the cluster heads. Using hybridization of dragonfly and firefly algorithm, optimal cluster heads were selected for transmission. The author obtained better performance in terms of the number of alive nodes, network energy, delay, and risk probability. The algorithm affects the initialization and the number of iterations.

Deepak Saxena [33] used proximity, communication cost, residual energy, and coverage for cluster head selection process and optimization-based route identification for data transmission which uses the Sailfish algorithm. Compared to other optimization algorithms, the work proposed showed better results in terms of energy consumption, throughput, packet delivery ratio, and network lifetime. The work proposed by Salim EL KHEDIRI et. al. in [] represented the Minimum Weight Low Energy Adaptive Clustering Hierarchy model for clustering depending upon the surplus energy of the nodes and the distances between them. The initial stage cluster heads keep moving in all directions for collecting data and transmitting it to the base station. The technique guarantees a speedy process and provides fault tolerance thus improving throughput, packet delivery, energy intake, network lifespan (duration), and delays [34].

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2.5. Routing Based on Selection of forwarding Node

Shivkumar S. Jawaligi and G. Bivadal in [35] used a single mobile sink with a technique for the selection of forwarding nodes based on strength of signal and scheme for transmission path. The work focused on IPv6 RP for low power and lossy WSN. They presented a new RSSI based appropriate node selection algorithm to forward data and implemented multiple timers for handoff optimization to achieve a fault-tolerant system and made the protocol delay-sensitive. The work presented by Habib Mostafaei [36] proposed DLA (Distributed Learning Automation) algorithm considering the problem as multi-constrained in finding an optimal path for data transmission. QoS requirement was met using advantages of DLA to find minimum numbers of the node under end to end reliability and delay. For this RRDLA was suggested which exploits the pruning rule and improved convergence which in turn saves more energy for the sensor nodes. The RRDLA introduced includes four phases: Initialization, learning, transmission, and retransmission. In the first phase of initialization, it works similar to DLA, the second phase includes a selection of minimum numbers of nodes with high PDR, and packets were delivered in the third phase and retransmitted in the last phase. The reliability of the proposed energy-efficient RP was compared with REER and DETR routing techniques.

Nester Zamora Cedeno et. Al. [37] evaluated QoS parameters using an NS-3 simulator under AODV RP. They considered mesh topology with various sensor nodes configuration and indicated that with an expanding number of sensor hubs it is conceivable to discover the best path-way during transmission with high energy cost and reduced life span of the sensor nodes. The QoS parameters considered were the number of packets received or lost, PDR, and throughput for a maximum of 60 nodes. The work proposed in [38] developed the routing technique RCER for non-homogeneous WSNs. The network field was divided into geographical clusters to construct a more efficient network and the routing was optimized for improvement in next-hop node selection considering multiple parameters. These heterogeneous nodes in WSNs consisted of additional energy in comparison to normal nodes. Only one cluster leader was used to send data to the base station using multiple hops. A fitness function used for choosing of subsequent hop node is the integration of hop count, energy residue, and weighted round trip span. The technique reduced the clustering overhead as the phase required to set up the cluster execute only precise time at the start of the initialization of the network. A new cluster head was selected at any other portion of the cluster. For a stable network, they evaluated parameters such as network lifetime, route lifetime, TP, energy cost, average E2ED, and PDR. The following table 4 shows the performance comparison with the other four well-known RP. Table 5 shows the summary of routing based on selection of forwarding nodes.

Sr. No.	Parameters	Routing Protocols			
		ETSSEP (%)	TBC (%)	LCM (%)	LEACH (%)
1	Network Lifetime (Improved)	11.5	12.2	14	23
2	Energy Consumption (Reduced By)	14	15	33	46
3	N/W Throughput (Increased)	17.5	19	27	36
4	End to End Delay (Reduced By)	9	10	16	23
5	Route Lifetime (Longer By)	15	16	23	34
6	PDR (Increased By)	20	21	24	37

Table 4 Performance Comparison of RCER with Other Existing Routing Techniques

Ref. No.	Year	Merits	Demerits
35	2018	Higher PDR and low delay	Contention and link disruption
36	2018	Energy efficiency and end to end delay	Average delay in node selection process is proportional to number of nodes
37	2019	Good performance of AODV when nodes are increased	High energy cost and reduced lifetime when the network grows
38	2019	Improved energy consumption, network lifetime, network throughput, end-to-end delay and route lifetime	Sensitive to weighted factors

Table 5 Summary of Routing Based on Selection of Forwarding Nodes

Layla Aziz and Hanane Aznaoui aimed their work to enhance the process of forwarder selection using an efficient combined multicriteria model using the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. They improved the inter-cluster communication by controlling the distance between the sink and cluster heads. The nodes having strong signals were allowed to participate for cluster heads. Their

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model was aimed to select the most efficient hop for routing the data to the sink thus maximizing the residual energy and network lifetime of the network [39]. Identifying malicious nodes in the network and finding availability of a dual-disjoint path with no-shared components using evolutionary assisted WSN protocol is proposed in [40] by R. Sunitha and J. Chandrika. They used two key functions: Network Condition Aware Node Profiling and Malicious Node Detection and the Evolutionary Computing assisted Dual-Disjoint Forwarding Path for ensuring QoS centric and energy-efficient routing. The proposed routing protocol obtained higher throughput, low energy consumption, and low delay using the Genetic algorithm to perform routing decisions.

2.6. Routing Based on Other Factors

In [41], the authors worked on controlling congestions during routing in WSNs. The nodes were deployed using the hybridization of K-means and Greedy first search technique. For high PDR, the flow control of packets was optimized using First Fly optimization and routed using the ACO technique. The performance of the approach was estimated in MATLAB and evaluated for energy utilization, TP, PDR, energy efficiency, mean E2ED, and reliability and compared with existing RP such as PDI, CDTMRLB, and FBCC.

Ammah Hawbani et. Al. proposed ZPRC (Zone probabilistic routing) [42] based on the multiplication of probability distribution of four controllable factors including transmission distance, direction, residual energy, and orthogonal distance. The parameters can be initialized and controlled exponentially to meet different requirements in terms of performance parameters. Simulation work carried showed improvement over the RP such as DHA, DRP, and DAPR in respect to energy cost, energy balancing, network life span, and delay.

The authors in [43] used combined abilities of source routing and minimum function and eliminated the need for counting tables with the individual sensor node. The routing problem over link and node failure was solved using SRMCF which recovered failure links. They conducted analysis and simulations and showed that the proposed hybrid routing when compared with MCF alone yielded higher throughput and reduced energy consumption.

Work presented in [44] prevented nodes near the sink from overloading and maintained equal distribution of load with nodes in the vicinity of the sink node thus decreasing overall energy cost and extending the network age. They proposed an improvement in the routing algorithm to optimize energy consumption for all the cluster heads. Comparison with LEACH and EEUC showed stability with the proposed routing technique. A trust-based secure routing protocol (TSRA) with efficient energy is presented in [45] by M. Selvi et. Al. They used evaluation based on trust scores to identify unwanted thefts in WSN. The energy-aware TSRA selected the best path with security in the network using routing based on a decision tree. Deebak B. D. and Fadi Al-Turjman [46] worked to improve data security in ad-hoc sensor networks. They incorporated features of MARS, RC6, Serpant, and Two fish and proposed secured routing and monitoring RP that used eligibility weight function to identify guard nodes symmetric key to be complex that reduced malicious attacks. The algorithm performed better to achieve improved monitoring and detection as compared to work done earlier.

2.7. Analysis of Current Research Work

The contributions of some of the researchers discussed above is depicted below in table 6. The table mainly focuses on routing schemes, the parameters are taken into account, and comparison to existing routing techniques. Figure 2 shows that most of the latest research work was concentrated on reducing energy consumption during routing followed by increasing network lifetime, reducing delay, PDR, and throughput. Network stability holds a place between crucial parameters and the parameters which had been less attention like latency, reliability, and security.

A survey carried from 2015 to 2019 by different reviewers also concluded that the foremost parameter considered for research was node energy cost and energy balancing in the network. The contributions made by various researchers on WSN over the past few years is indicated in figure 3. Due to rapid growth and immense applications in the field of Wireless Sensor networks, research is carried in various aspects of this field and thus the contributions are increasing every year.

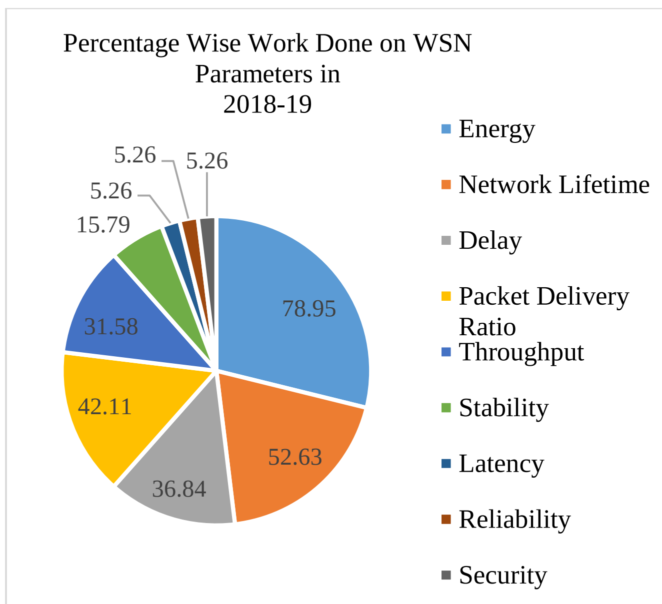

Figure 2 Current Research Done (%) for QoS Parameters

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Sr. No.	Reference	Work Proposed	Compared to	Parameters
1.	Ammar Hawbani et. al.	Zone Probabilistic Routing	DHA, DRP, DAPR	Energy utilization, Energy balancing, Network life span and Delay
2.	Shivkumar S. Jawaligi and G. Bivadal	IPv6 RP for low power lossy networks	-	PDR, control strategy for route selection and data collection and end-to-end delay
3.	Habib Mostaface	Distributed Learning Automation routing algorithm for finding optimal path for data transmission	REER and DETR	PDR and Energy Efficiency
4.	Lin and Donghui Li	Balanced Energy RP	SEP, LEACH-C and LEACH	Energy balancing and Network lifetime
5.	Yasha Jetwal and Shashi Verma	DCHRP4 with two cluster heads	SEP, TSED and ETSSEP	Throughput, network lifetime and stability period
6.	Amine Rais et. al.	Efficient Honeycomb clustering algorithm	HEER, GAF & PEGASIS	Energy consumption, Energy balancing, PDR and Latency
7.	Khalid Haseeb et. al.	Reliable cluster-based energy-aware RP for non-homogeneous WSNs	TBC, ETSSEP, LCM and P-LEACH	Network lifetime, route lifetime, throughput, energy cost, average E2ED and PDR
8.	Pan Feng et. al.	Improved energy balanced routing (IEBR) algorithm for Underwater WSN	UDAR, BTM and EBR	Network Life span, Effective throughput and transmission attenuation
9.	Abdulmughni Hauzah et. al.	Fuzzy logic-based energy-efficient technique (FL-EDC/D)	LEACH, K-mean-LEACH and FL/D	Energy cost, efficiency and network life span
10.	Vikas Srivastava et. al.	Energy-efficient optimized rate-based congestion control routing	PPI, CDTMRLB and FBCC	Energy cost, throughput, PDR, energy efficiency, mean E2ED and reliability
11.	Huarui Wu et. al.	Modified LEACH for cluster head selection criteria	E-LEACH, LEACH-IR, P-LEACH, PEGASIS-E and PEGASIS	Network lifetime, throughput, time complexity and even distribution of energy usage
12.	K. Thangaramya et. al.	Cluster-based routing through Neuro-Fuzzy Rule	LEACH, FLCFP and HEED	Energy utilization, PDR, delay and network life span
13.	Premkumar Chithaluru et. al.	Energy-efficient opportunistic routing scheme in light of adaptive rank	LEACH, AODV, ACO, IACR and EMCBR	PDR, E2ED, energy utilization and message success rate
14.	Catalina A. S. & Mihaela C.	Improved reactive, anchor-based routing protocol	ASC(CF), ARER (CF&DC) and ASC(CF&DC)	Energy utilization, average energy precipitate, active clusters count, and percentage of successful events processed by the sink
15.	Fardin Derogarian Miyandoab et. al.	Energy-Efficient RP for WSNs adding Source Routing and Min. Cost Forwarding	MCF	Throughput and Energy consumption
16.	Xingjin WANG et. al.	Improved Unequal Cluster-Based Routing	LEACH and EEUC	Energy Consumption, Network Lifetime and Stability

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		Protocol		
17.	M. Selvi et. al.	Trust-based secure routing protocol	LEACH, HEED, STRM	Energy Consumption, PDR and Delay
18.	Deebak B. D. et. al.	Hybrid Secure Routing and Monitoring Mechanism in IoT-based WSNs	OLSR, DSDV, AOMDV and TARCS	Security
19.	Mengjia Zeng et. al.	Heterogeneous Energy Wireless Sensor Network Clustering Protocol	LEACH, SEP and DDEEC	Stability time, network life and energy consumption

Table 6 Work Done by Researchers for Improving QoS Performance Parameters of WSN through Improving Routing Protocols. Their Comparison with Existing RPs is listed for the Performance Indicators.

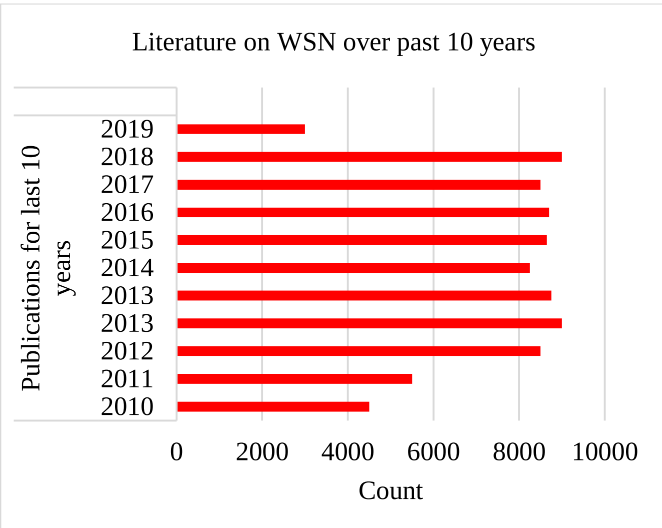

Figure 3 Number of Publications on WSN over Past 10 Years

3. CHALLENGES IN DESIGNING ROUTING PROTOCOL FOR WSN

The design of an efficient routing protocol is not an easy task. The design issue is prone to many interdependent quality factors that adversely affect one another. The main aim is to design a routing strategy which would keep the network activity for a long duration as possible by reducing the energy required for various operations by a node and keep the overall energy of the sensor nodes to be balanced. No single node should die before the others. The routing protocol design should be independent of the topology, environment, type & nature of tiny nodes, the number of nodes in the network, and node deployment techniques. Some of the factors affecting to route protocol design are listed in Table 7 below.

Sr. No.	Challenges	Issues
1.	Nature of Node/ Diverse Topologies	The scattered nodes can be homogeneous and heterogeneous concerning their processing capability, energy, and transmission range. In several applications when the nodes are moving or the sink/base station is non-stationary, the selection of proper nodes plays a vital role. Diverse network topologies have their own merits and demerits. Designing an RP for such diverse topology networks is a tough task.
2.	Node Deployment/Sensor locations	It can be manually static or random (for harsh regions) depending upon the nature of sensor nodes and application. Many applications require the sensor nodes need to be mobile after they are positioned either manually or randomly. Therefore, the deployment is application-specific and suitably solve the coverage problem.
3.	Energy Sources	Most of the WSN applications include geographical locations where sensor nodes are initially placed randomly from a long distance where a human cannot reach. The fate of such a node is governed by its energy source and environmental conditions. The only energy source that can be obtained for a distant sensor node is solar energy or energy from any other renewable energy source. In such cases, the routing protocol needs to be energy efficient.
4.	Coverage	Coverage or transmission range is subjected to the type of environment in which the sensor nodes are working. For stationary nodes with a good

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		environment, the distance connectivity between neighboring nodes is larger but for a harsh environment, the connectivity is poor and will lead to route failures.
5.	Self-Organization	The routing scheme should be self-adjustable to varying network structures. That is many of the sensor nodes may die out (Exhaust batteries) with a period disturbing the routing paths and network structures. The routing algorithm should have self-management and self-organizing properties in such network node failures.
6.	Energy Consumption	Almost 70-80% of the literature is oriented in this aspect. The limited energy constraint of a sensor node places a great constraint in designing. Most of the energy is consumed in sensing, processing, receiving, and transmitting the information. Out of which the data transmission requires a large amount of energy. When a member node is selected as the group head or selected frequently for routing information (forwarding or Hoping node), it limits balancing the network's overall energy which in turn needs alteration in the topology of the network and connectivity.
7.	Connectivity	Maintaining connectivity in the network over time is a challenging issue. Due to processing and routing mechanism over time, dark spots are formed about low energy nodes and most of the routing schemes isolate such nodes from taking an active part in the routing mechanism. This is done to achieve balanced energy in the network but leads to connectivity problems and new routes are to be formed. The routing scheme should be capable enough to maintain the network paths under such conditions.
8.	Flexibility	The design of RP should be flexible to meet the varying resources of the WSN and constraints owing to diverse and tremendous applications of WSNs.
9.	Reliability & Fault Tolerance	Subsequent node failures with time greatly affect the performance of WSN. The reason for the failure of a sensor node can be a cause of physical damage, noise interference, or no power. The functionality and performance of the routing algorithm must not degrade with such node failures. The routing scheme should be able to find an alternate solution without affecting any other performance parameters. Incorporating some fault tolerance technique will help in increasing the reliability of the network.
10.	Scalability	Every sensor node holds a routing table in its memory. For a small network, the table information is limited and the sensor node has no overload in maintaining the knowledge of network topology. But when the network has an extensive or large amount of sensor nodes placed in the geographical positions, it is not feasible to maintain a global knowledge of the network topological structure. Hence the RP should be framed to handle such a massive network.
11.	Minimal Computations	A sensor node has limited processing capabilities. Therefore, the routing algorithm should have a minimal processing burden on the sensor node to keep the node computation cost low so that the energy cost of the sensor node will be less and requires low circuitry as a processor.
12.	Memory Requirement	The memory capacity of a sensor node depends on network size which holds the global network topology information. And for a tiny sensor node, the amount of memory is limited. The routing algorithm should be smart enough to hold and read back the information from the memory without consuming much of the power of the sensor node. The routing technique must be able to route through the sensor node by accessing a small part of the memory.
13.	QoS	The routing protocol should have the ability to provide good QoS to the

		network in terms of various parameters. Literature shows that there is a compromise between various parameters when the routing is application-specific. For example, nodes nearer to the sink have less delay and nodes away from the sink requires a larger delay, but in turn, the nodes in the vicinity to the sink reduces their energy rapidly as they are used frequently in routing others information too to the sink rather than the nodes which are away from the sink. Therefore, a balance between various QoS parameters is a crucial issue in designing an efficient routing protocol.
14.	QoS with Constraints	Achieving a single QoS requirement is difficult in some applications. When QoS is limited by some constraints, it becomes even more difficult to design a flexible routing scheme. The commonly considered QoS parameters are jitter, delay, bandwidth, throughput, packet delivery ratio, and energy consumption. For designing a cooperative routing algorithm, failure probability is one of the QoS necessities.
15.	Network Packages	Recent demand for design includes networks belonging to LTE, Cognitive Radio, Wireless LAN, and Cellular network other than concentration on WSNs. The research should concentrate on the above network packages.
16.	Error Free Transmission	Some of the crucial applications including health care monitoring, on war communication, military surveillance, intrusion detection, and disaster management need to be secured and trusted data with minimal delay and better reliability. In such critical cases, a trustworthy routing protocol is required to fulfill QoS parameters.
17.	Multiple Assets/Destination	A network with large numbers of nodes may have other merits but it suffers from data flooding at the sink. Data packets are delivered through different paths to reach the sink/Base node. The routing algorithm should be intelligent enough to overcome this overhead at the sink/Base node. Also, the possibility of collision among data increases when the network is densely populated.
18.	Multiple Objective Routing	Existing routing algorithms with some kind of modifications are used to meet the requirement of a dedicated application in a compromising manner. The same scheme when applied to the different applications provides no better results in terms of QoS parameters. The QoS required for an application differs from the QoS required for any other application. It includes error rate, security, delay, throughput, data consistency, and others that affect the selection of routing protocols for a selected application.
19.	Data Security	WSNs suffer various types of vulnerable security strikes. There are several security requirements such as confidentiality, secure management, authentication, availability, freshness, QoS, and integrity. Confidentiality should guarantee delicate data to be covered and secured from an unapproved extruder. Authentication should differentiate genuine clients and intruders. Integrity control should guarantee no data adjustment across the pathway by any unseen user. Information freshness should guarantee crisp messages. Secure management is concerned with data steering and encryption. Availability guarantees timely data as an when required. The complexity overhead of Security systems must not limit the performance of the system anyway.
20.	Development Structures	After several research papers review, it is found that the existing routing protocol is meant for a few applications. Most of the new routing schemes are modified and improved to fit a specific application. Efficient and improved routing schemes are required for more practical

		applications.
21.	Applications	The RPs are application-specific. That is for a different scenario or diverse networks, we require different RP. Hence designing a generalized routing protocol which will suit most of such heterogeneous network environment situation is complex and challenging.
22.	Hardware Approach	Almost all the existing routing scheme performances are evaluated on the simulator. Development of routing protocol on the simulator platform may not be able to utilize some aspects of the algorithm but they can show better performance of real physical components. The only concern is the cost of the hardware but the performance of the routing scheme on testbeds can put some limitations on the performance of the algorithm. Thus, implementing the routing technique on real hardware is still the biggest challenge.

Table 7 Challenges & Issues in Designing an Efficient Routing Protocol

The above-listed parameters are interdependent and need proper attention while designing a routing scheme. Different specific applications have different requirements. Till now, work had been concentrated on optimization with few parameters in consideration since controlling one parameter would adversely affect the others. Every challenge stated above has its requirement depending upon various other factors. For example, if network lifetime is the issue, an efficient and secure data aggregation property is required in a cluster-based routing scheme. Therefore, researchers have made assumptions and initialization at the start of the network design stage.

A malicious node can easily modify the information in the network and thus there is a need to investigate an efficient multi-path key. Consideration of various scenarios gives rise to new challenges and demand for drastic changes in the prevalent architecture assumed in most of the routing schemes. The parameters required for routing schemes evaluation is briefed along with their need for analysis.

4. CONCLUSIONS

Today, WSN finds immense widespread due to its incorporation in diverse applications including health monitoring, military surveillance, underwater communications, monitoring in a hazardous environment, volcano prediction, intrusion alarming, animal tracking, space research, and investigation. The hardware constraints had imposed challenges in the design and development of sensor nodes to be energy efficient and routing techniques to be reliable. Also, there is a need and encouragement for mathematical modeling of the routing scheme to a larger context and provide a broader perspective. Most of the reviewed literature is focused on the static nature of sensor nodes and the sink node, but the real-world applications suggest work to be carried out for mobile networks where the nodes are not stationary which includes applications like monitoring, surveillance, and tracking. Every single application has its parameter consideration and thus researchers have suggested and used different routing schemes for different applications. Grouping nodes to form a cluster and defining a cluster head is one of the commonly used approaches by the researcher to enhance the scalability and overall energy of the network.

The summary of the most challenges leads to formulating a common network lifetime maximization problem with multi-objective tasks corresponding to energy minimization during deployment, localization, clustering, routing, and connectivity. Out of which routing exhausts most of the energy and considers other factors when data is transmitted in the network. Finding a key to all problems in common is a task with a challenge.

The challenges discussed above are conflicting and should be accepted simultaneously and carefully. In such a scenario the concept of optimal weapon differs and the result is selection using tradeoff between two parameters. In such situations the decision is difficult. To find a unique solution to all problems, a new routing scheme is required. The multi-objective problem can be properly mathematically modeled with all inputs and constraints with accurate and realistic calculations and solved using either robust optimization techniques or hybridizing two or more optimization schemes.

Security seems to be a different issue in WSNs, but designing a secure routing scheme can solve the problem to a considerable extent. Digital signatures can be one the approach for preventing malicious activity. A secured routing can guarantee the validity of nodes and routes but at the cost of abundant memory for saving signatures at each sensor node even more than the actual number of physical nodes present in the network. A good signature encoding scheme can be implemented to reduce the size of the signature. Finally, we call attention to open issues and future research bearings for Routing in a more realistic detecting model that mirrors the anisotropic properties of WSNs.

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