Systematic Analysis and Review of Path Optimization Techniques in WSN

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***Abstract*—Wireless Sensor Network (WSN) is a centre of research owing to prevalent applications like military and scrutinizing circumstances of environment. The recent approaches showed that the mobility of sink in a controlled path can enhance the efficiency of energy in WSN, but the constraints of the path make the routing more complicated. Thus, the sink with fixed speed poses less communication time for collecting data via sensor nodes that are arbitrarily deployed. This limitation has noteworthy issues in enhancing data collected and minimizing energy consumption. Moreover, these research constraints led to the design proficient path optimization technique in WSN. This work presents a survey based on path optimization strategies. In addition, a thorough investigation is done based on various parameters. Also, we have analyzed the merits and demerits of conventional path optimization strategies. Finally, future research directions in obtaining efficient path optimization in Wireless Sensor Networks along with the mobile sink are elaborated.**

***Index Terms*—Energy; Mobile Sink; Path Optimization; Routing; WSN.**

I. INTRODUCTION

The advancements in WSN have gained immense attention in real-time applications, which involves examining environmental conditions, handling traffic, video surveillance, preventing disasters, monitoring health, medical diagnosis, monitoring climate and weather, monitoring industries, and enterprises [1]. WSN is an autonomous networking model that contains a huge number of cost-effective nodes that have the potential for processing data to provide effective wireless communication. These nodes, which are present in the network offer self-organization, wherein WSN can collect, observe, and process the monitored data with the association and transmit the data to the user. However, the WSN nodes are empowered by battery constraints which limit the energy and problematic to revitalize [2]. Even though the design of wireless communication is a significant factor for huge scale sensors, there are issues based on the capacity of the network put up data traffic [3]. Moreover, sensor nodes comprise obstacles like complex calculation, energy, and bandwidth in memory. Moreover, there exists major drawbacks in WSN, which involve coverage problems [4].

The majority of the sensor node utilizes energy in reception or transmission of information as the nodes adapt non-rechargeable battery that exists for a few years. Hence, energy efficiency is a major motive in WSN as it is liable for enhancing the lifetime of the network, which is addressed by choosing opposite nodes as a cluster head for establishing protected routing. Besides, clustering is the foremost method to establish safe communication among sensor nodes [3]. The espousal of mobile sinks stabilizes utilization of energy with each node from a sensor network that can deal with energy holes problem. In WSN, sink poses open communication with computing resources that can be stimulated using sufficient power. Thus, the method that considers mobile sinks can minimize distance amidst sink and cluster head [5]. Thus, clustering is an important paradigm for establishing secure communication amongst sensor nodes. The clustering provides an improved solution for commencing protected communication. Thus, mobile sinks can minimize delay and enhance the utilization of energy [6].

The primary intention is to offer a comprehensive survey of different path optimization strategies considering WSN. This survey considers classical techniques based on path optimization for the analysis. The survey is made by considering the publication year, employed methodology, performance measures, and implementation tool. Moreover, the performance evaluation measures are considered for evaluating the performance of the suggested path optimization methods. The conventional methods are classified into distinct approaches, and then, the survey is carried out for the exploitation of problems. Thus, it is considered as an inspiration for the future extension of effectual path optimization.

This paper is arranged as follows, wherein Section I provides the introductory part of path optimization in WSN, and Section II elaborates the survey of path optimization approaches in WSN and Section III elaborates the evaluation of the classical methods. Section IV describes the limitations drawbacks of existing works and the conclusion of the survey is presented in Section V.

II. PATH OPTIMIZATION METHODOLOGIES IN WSN

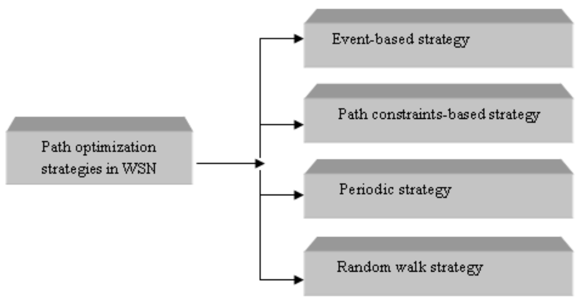

Figure 1: Categorization of distinct path optimization strategies in WSN

In this section, we have reviewed the distinct path optimization strategies**.** Figure 1 illustrates the classification of distinctive path optimization techniques. The techniques based on path optimization strategies are broadly categorized into event-based, path constraint-based, periodic, and random walk. A brief illustration of the following strategies is as given in Figure 1.

A. *Event-Based Routing Strategy*

In an Event-based routing strategy, the sensor node senses the data and forwards it to the sink node in a single or multi-hop structure. The data is collected once any event occurs like any threshold value is measured then the event is generated by the node and the data is collected by the sink node.

We have reviewed the various methodology based on event-based routing for attaining effective path optimization in Wireless Sensor Node, which is deliberated below.

Radhika R. and Binu G. S. et al. [3] developed an improved routing strategy using mobile sinks based on Ant colony optimization (ACO) by determining the optimal path. Here, the gathering of data using the mobile sink is made effectual using a clustering strategy for selecting the cluster head nodes. Moreover, the method for informing the mobile sink position was devised in WSN. The method performed effectively in terms of certain parameters like energy, throughput, and packet delivery ratio. However, the method poses high trouble during the data collection process.

Sun Y. et al. [2] devised a routing method using ACO for determining an optimal path for transmitting data in WSN. Here, the enhanced heuristic function was employed with distance, communication amongst nodes, and residual energy. Moreover, the energy expenditure was minimized and the lifetime of the network was prolonged. The method was effective, saved the nodes, and extended the lifetime of WSN. However, the method induced complexities, which created overhead in WSN.

Yang Y. et al. [7] devised three methods based on the utilization of node mobility to increase the lifetime of networks. Here, the method was divided into three sets, namely mobile sensors redeployment, mobile sinks, and mobile relays. The energy was consumed using multi-hop data delivery paths and sensors. With mobile sensors, the deployment of nodes was enhanced and mobile sinks used relay nodes for detecting the static sensors for reducing communication cost. However, the method failed to analyze the method with certain experimental measures.

Shiyao Zhang et al. [8] developed a path optimization strategy (POSC) for charging the nodes in WSN for optimizing the paths. The POSC algorithm employed a clustered energy-efficient routing algorithm for initiating the clustering process while transmitting data. The method balanced the energy consumption and minimized the death time of each node.

Tang C. and Yang N. [5] designed a virtual grid margin optimization and energy balancing (VGMEB) protocol with mobile nodes for providing balance amongst energy consumption and efficiency in WSN. VGMEB attained improved energy efficiency by developing a virtual grid margin method and discovered an effective evaluation model for selecting the cluster head. Moreover, multiple attribute decision making was adapted for discovering the weight of each measure. However, the method failed to use the data fusion method to minimize the interaction time between the cluster head and mobile sinks.

Wang J. et al. [9], utilized particle swarm optimization (PSO) for optimizing paths with mobile sinks in WSN. Here, a virtual clustering strategy was devised in the routing process, which used PSO. Moreover, the node position and residual energy were adapted for choosing the cluster head. The method showed improved energy utilization and the lifetime of the network was increased. However, the method failed to consider the energy of nodes in the transmission.

B. *Path Constraint Strategy*

There is a limitation of path selection in Path constraint strategy. The data collected by the mobile sink are sometimes a path constraint. The mobile node has to follow the same path for the data collection for every iteration**.**

We have reviewed the various methodology based on path constraints practiced for attaining effective path optimization in WSN, as illustrated below.

Hedges D. A. et al. [10] developed a model, namely a continuum model for path optimization using the density of relay nodes. The method provided an optimized relay path for initiating the routing process in WSN. The model is designed for maintaining the steady connection densities without any bound. This method reduced the end-to-end delay and minimized the complexity of processing. However, the method failed to use an optimization method for providing optimal sampling in continuum modelling.

Bhatt R et al. [1] developed fruit fly optimization algorithm (FFOA) based on different nodes considering WSN. The method provided an effective contribution of the maximum node. The method obtained low energy cost and node capture attack in discovering optimal nodes. Also, the FFOA poses high attacking efficiency amongst several node capture methods.

Moh'd Alia O. et al. [11] developed an energy-efficient network model that vigorously relocated the mobile base station using a cluster-based network model considering the harmony search algorithm. Initially, the model allocated sensor nodes considering optimal clusters, wherein each sensor node used an opposite cluster for routing data. The method enhanced the lifetime of the network and provided feasible data delivery and energy consumption. However, the method was inapplicable to complex scenarios.

Gao S. et al. [12] designed a data collection method, namely Maximum Amount Shortest Path (MASP) that enhanced the throughput of the network and preserved the energy by increasing optimality of sensor nodes. Here, MASP was modelled as a linear programming issue and was addressed using a genetic algorithm (GA). In addition, a two-phase communication protocol was devised on the basis of zone partition by executing the MASP method. Here, a distributed approximate algorithm was adapted to address the MASP problem. However, the method still suffered from a sub-sink selection problem for maximizing the lifetime of the network.

Ciancio A. et al. [13] devised a method that employed different coding methods for WSN routing. Here, the technique used sensors with high energy for initiating data transmission. Moreover, the compression techniques were employed for aggregating data by evaluating partial wavelet coefficients. The method was operated by choosing an optimal routing method using the data representation algorithms. However, the technique failed to employ a heuristic method for determining the merging paths.

Wang C. et al. [14] devised a route configuration issue using an optimization method wherein constraints and bit error rate (BER) was considered for optimizing the path to provide efficient routing. The method adapted Karush-Kuhn-Tucker (KKT) theorem for discovering the best solution using hop lengths. The method significantly enhanced the performance when the number of hops increased. The method helped to recognize the least energy-consuming route using the configuration of routes.

Ghorbel M. B. et al. [4] designed energy-efficient elucidation for minimizing the consumption of energy amongst nodes by accumulating data from dispersed wireless sensors. The goal is to discover the sensors positioned in the nearby nodes for determining the energy-efficient path in WSN. The method was effective in offering improved results in contrast to other methods by optimizing communication and energy consumptions.

Naidu S. et al. [15] devised a strategy for optimizing the paths to mitigate certain attacks that occurred in the network. The method mitigated the attacks generated in the nodes to provide smoother data transmission. Moreover, the energy constraints related to the nodes was efficiently solved using the method.

Singh B. and Lobiyal D. K. [16] devised a mobile sink -based path optimization considering the ABC algorithm method (MSPOABC) in WSN. Initially, the issue of complete energy consumption was analyzed in the network by reducing the total hops present in the mobile sink. Moreover, an enhanced ABC was devised for speeding the rate of convergence. The Cauchy mutation operator was devised for increasing the diversity to generate the best solution and improve global searchability. However, the method failed to evaluate time delay constraints using multi sink environmental,

Y. et al. [17] developed mobile sink-based path optimization method in WSN with ABC for path optimization to conduct data routing in WSN. Initially, the issue of complete energy consumption was transformed using transform present between the sub-nodes of the mobile sink. Here, the fitness function and the constraint criterion were formed for smoother functioning. The method enhanced the energy and real-time performance of the method in providing effective path optimization.

Arti Deepika [18] designed a Bio-Inspired strategy for optimizing the paths present in the WSN. Here, ABC was employed for optimizing the routing paths and increase the lifetime of the overall network. The method offered feasible communication in case of any faults. The aim was to handle the lifetime of the network during data transmission. In addition, the ABC was employed for optimizing the huge set of test functions. However, the method failed to solve constrained problems while determining the optimal solution.

Alghamdi T. A. et al. [19] designed a secure and energy-efficient technique using Dij-Huff Method (DHM) for path optimization. Here, maximum energy was considered for transferring the data between nodes. Whenever the node revealed similar energies then the least distance path concept using Dijkstra's algorithm was employed to choose a suitable node. The method minimized the packet loss and delay and improved the lifetime of the network.

Tian J. et al. [6] devised an optimal coverage method using improved GA and binary ant colony algorithm (ACO) based on energy and density parameters for path optimization. Here, the optimal nodes set were obtained based on max-coverage area and working sensor constraint for optimizing the generated paths. The method attained the optimal working with the least number of nodes and a high coverage rate of the network.

Zhu X. and Zhang Y. [20] devised a method named particle swarm optimization (PSO) algorithm for optimizing the paths in WSN. Here, the mutation operators were designed for determining an effectual optimization in WSN routing. Moreover, the quality of the solution increased the success rate and offered improved convergence with high accuracy in WSN.

Sun Y. and Tian J. [21] designed a method for optimizing the route in WSN. Here, the ACO and GA were employed for data routing the WSN. The method overwhelmed the issues like long initial population time, slow convergence speed, and many defects. However, the method failed to use a fusion algorithm for testing simulation to predict the performance of each method.

Maity C. et al. [22] devised a method for path optimization considering clustering strategies. Here, the power consumption of the network was employed for distributing the clusters by dynamically revolving the cluster head considering every iteration of the cluster. Here, the simulation was done to select the cluster head for performing the path optimization and decide the iteration count for allowing another node to become a cluster head. This method assists the applications to reduce power consumption significantly, wherein a huge number of nodes is deployed. However, the method failed due to some variations which caused performance degradation.

Jiang A. and Zheng L. [24] devised an ant colony optimization (ACO)-based WSN routing method by considering certain attributes like network load, energy constraint, and network topology. Here, a hybrid routing algorithm was devised by combining the ACO minimum hop count strategy. The method was capable to detect the best routing path with less energy consumption on each node. The algorithm was effective and increased the lifetime of the network.

Ghafoor S. et al. [24] devised a method using mobile sink trajectory in WSN. The method was devised using a Hilbert Space-Filling Curve. The method was processed by considering node density with changes in curve orders. Here, network size was considered using the mobile sink trajectory and Hilbert Curve Order. The Hilbert Curve Order was computed to re-dimension the trajectory of the mobile sink. The method evaluated the efficiency of the method using scalability and network coverage. However, the method offered poor results when the density of the node is high.

D. Deepika and R. Prabha [25] analyzed different methods for implementing the optimization of paths in mobile sinks for minimizing the consumption of energy amongst nodes by minimizing the reconstruction cost. The method yields that mobile sink speed and fixed path generate a high data delivery ratio. However, the method failed to precisely select the stop points of the mobile sink.

Sun Z. et al. [26] devised a method for addressing the optimization issue in the barrier coverage and the area coverage using an ant colony algorithm. Here, an improved ant colony algorithm was devised for path optimization in order to attain effective energy consumption. Additionally, an effective covering algorithm was devised using optimization. The method also utilized the coverage area probability function and Gaussian normal density function in the optimization of the point set. The method improved the network QoS and reduced the overhead of the network.

Mamalis B. et al. [27] devised clustering and data forwarding protocol using the MS solution for effective data accumulation in WSN using delay constraints. The devised cluster formation method was based on 'residual energy' and was correctly modified for inter-cluster communication and data forwarding. Moreover, the opposite data gathering protocol was devised using the TSP route, which fulfills the length constraint that poses the ability to handle energy holes around cluster heads. However, the MS-oriented clustering method did not apply to heterogeneous WSN environments.

Dhamdhere S. et al. [28] devised a method, namely Optimal Terminal Assignment based Path (OTABP) for path optimization in a wireless network. The method significantly improved the collection of data and reduced the consumption of energy and optimization of sensor nodes in sub sinks. The method was devised for assigning the member nodes to sub sinks. The method was adapted for addressing the subs inks selection and member node assignment issue. The goal was to accumulate maximum data in WSN by using minimal energy with OTABP. However, the method failed to solve the dynamic sub sink selection problem.

Pang A. et al. [29] devised a routing model and path planning for path optimization in wireless networks. Here, a dynamic clustering algorithm was utilized for clustering the sensor nodes which are arranged randomly.

C. Periodic Routing Strategy

Periodic routing strategy is another way of the data collection method. Sometimes data need to be collected periodically. In the application, where the periodical data collection is needed after some time interval, this strategy is most useful in the sensor network.

We have surveyed the various methodology based on periodic routing practiced for attaining effective path optimization in WSN, as deliberated below.

Ren G. et al. [30] developed a method namely improved artificial bee colony (ABC) optimization for feasible data collection using mobile sink nodes for routing data in WSN. This method integrated the assortment of a cluster node and the transmission path considering the set of sensor nodes. An improved ABC was devised using the initialization technique for reverse learning and devises a search equation considering the differential evolution algorithm. The method overwhelmed the issues of ABC with improved convergence and to enhance the efficiency of the network. However, the method failed to use a coverage optimization strategy for node deployment.

Kaur R. and Narula A. K. [31] devised a method for path optimization using the mobile sink for collecting the data. The method reduced the hotspot issues and increased the network lifetime. Here, a trained neural network was employed for selecting the optimal route using the mobile sink. Moreover, the stop points were spotted to permit the communication between the nodes using a movable sink. The method reduced the lifetime of the network and effectively handled the hotspot issues. These methods were suitable for huge areas and for collecting heterogeneous data.

Hong S. et al. [32] designed a Sensor Networks for an All-IP World (SNAIL) approach for path optimization. Here, certain attributes like security, web enablement, mobility, and time synchronization were employed for optimizing the path to provide efficient routing. The interoperability and feasibility of the method were significantly improved thereby provided effective management of network, service discovery, and high quality-of-service in routing.

D. Random Walk Based Routing Strategy

Random walk based routing strategy is another data collection method used by the sink node. The mobile sink node is randomly choosing the cluster head for the data collection in Wireless Sensor Network.

We have surveyed the various methodology based on a random walk for attaining effective path optimization in WSN, which are deliberated below.

Vijayashree R. and Suresh Ghana Dhas C. et al. [33] designed a method named multiple mobile sinks based data collection algorithm, which used ABC and energy balanced clustering for routing data to target nodes. Here, the choice of cluster heads was devised based on residual energy. The method enhanced the reliability of the network and improved the path optimization process. However, the method failed to integrate the data fusion method in the sensor node for improving the performance.

Yue Y. et al. [34] designed a heuristic algorithm to provide path optimization considering cluster heads and routing paths in WSN. Here, the data collection algorithm was devised for mobile sinks considering the ABC algorithm. The method improved the rate of data transmission and saved the energies and enhanced the efficiency of data collection. However, the method failed to provide improved network performance.

Dongyao J. et al. [35] developed an adaptive multi-path method using an improved leapfrog algorithm for addressing transmission-congestion problems in WSN. Here, the path-satisfaction model was considered for predicting the congestion degree and the residual energy with lesser hops.

Wang J. et al. [36] devised an energy-efficient competitive clustering algorithm for WSN with inhibited mobile sink. The method significantly enhanced the performance of sensor networks. Here, the clustering of nodes was done to systematize sensor nodes and the utilization of controlled mobile sink nodes was adapted for mitigating the hot spot or energy holes issue. The choice of optimal moving trajectory from a set of sink node is considered an NP-hard issue. Moreover, the clustering algorithm was adapted in which the cluster head is rotated in each round and was chosen using residual energy. However, the method failed to delay in data transmission to optimize the algorithm.

Salarian H. et al. [37] devised a hybrid moving pattern using mobile-sink nodes and rendezvous points (RPs), considering all nodes. The sensor nodes send their sensed data through multi-hopping using the nearest RP. The issue occurs while computing tours that visit these RPs using the provided delay bound. The identification of an optimal tour was considered as an NP-hard problem. Here, weighted rendezvous planning (WRP) was devised in which each sensor node was allocated a weight based on the hop distance and count of data packets which forwards the data to the sink node. However, the method failed to provide analysis using different performance measures.

Wang J. et al. [38] devised an improved ACO strategy for WSN using mobile sinks with CH distances. Here, the network was partitioned into different clusters and each cluster poses one cluster head. Here, the distance between the cluster head was computed using the classical ACO algorithm. In addition, the mobile sink node determines an optimal mobility trajectory for communicating with the cluster head using an improved ACO algorithm. The analysis of the method was done which revealed that the algorithm can enhance the performance of the sensor network, but the improvement of network lifetime was not considered in the WSN.

Kushal B. Y. and Chitra M. [39] devised a method for optimizing the energy dissipation using the enhanced cluster head selection strategy. Here, Low Energy Adaptive Clustering Hierarchy (LEACH) strategy was adapted to address the energy-hole issue by considering sink mobility and of nodes which eventually helped to increase the network lifetime. The method increased the overall network lifetime, but failed to minimize the rate of packet loss.

Chen H. et al. [40] devise a clustering energy-efficient transmission protocol using ant colony path optimization (CEETP-ACPO) for path optimization in WSN. Here, the distributed cluster computing energy-efficient routing scheme (DCCERS) was adapted for choosing the cluster heads based on gravity center and the nodes energy using the accessible range of nodes and then the nodes are effectively clustered. Moreover, the improved ant colony path optimization algorithm was utilized for choosing the optimal path using the next-hop range considering the ring-angle search model. The method was effective against attacks, but it did not consider energy in WSN.

Zhang L. and Wan C. [41] devised a dynamic mobile sink node moving path planning algorithm (DPPMSBT) using precise WSN that accumulates periodic data from the complete network and the single area produces burst data. The method provided effective end-to-end delay, network lifetime, and path length. Moreover, the method assured intermittent collection of complete network data and made dynamic sink path planning for accumulating the burst traffic data while there is an incident. Here, the method minimized the rate of packet loss and extended the lifetime of the network.

Kumar A.R. and Sivagami A. [42] devised a method for regulating the mobile sink using the hybrid model for facilitating path optimization in wireless networks. Here, the moving pattern was devised using the mobile-sink node and employed rendezvous points (RPs) for traversing each node in WSN. Here, an adoptive rendezvous planning (WRP) was devised for addressing two issues. The first issue was regarding the calculation of paths while traveling in the mobile sink and the second issue was the consumption of energy in the mobile sink to improve WSN lifetime. In WRP, each sensor node was allocated a priority based on the hop distance using the mobile sink path and traffic rate. Furthermore, energy-aware local routing was utilized for increasing the efficiency of energy. However, the method failed to balance throughput rate and network lifetime in energy-aware routing.

Prabha M. et al. [43] devised a method for computing the WPSN performance in mobile sink nodes by accumulating information. Moreover, the prioritized sensor nodes are employed with PSN using minimum traveling distances and energy conservation. The method proved that the efficiency of weighted-energy aware sensor selection reduced the delay and energy. However, the method failed to minimize nodes which degraded the performance of the system.

Wang J. et al. [44] devised an energy-efficient routing method using sink mobility and clustering methodology. Here, the method was partitioned using the whole sensor field, and each cluster head was computed by members' weight. The member nodes computed the energy consumption of various routing paths by selecting the optimal case. The cluster heads were devised in the chain using a greedy algorithm for initiating inter-cluster communication amongst nodes. The method showed improved performance in path optimization but failed to add different parameters for evaluating the effectiveness of the method.

Siriwardana J. and Halgamuge S. K. [45] devised a mathematical model for simulating the intellectual foraging behavior of plasmodium in a network. The method utilized shuttle streaming for analyzing the performance in order to get the shortest path. However, the method failed to address computationally hard issues and real-world engineering issues.

Chen Y. et al. [46] addressed an energy hole issue in WSN by devising a strategy namely a lifetime optimization algorithm with mobile sink nodes (LOA-MSN) for path optimization. Here, the hybrid positioning strategies were devised for RSSI positioning and satellite positioning to save energy. Moreover, the Network optimization model was formed and the lifetime optimization model was devised using grid movement paths. The method improved the lifetime of the network and minimized latency and energy consumption.

Sharma D. and Kulkarni S. [47] designed routing protocol, namely Improved Energy Efficient Chain Based Routing (IECBR) for path optimization in wireless networks. Here, the selection of an optimum node was done using IECBR. Moreover, the HBO method was utilized for autonomous localization using an energetic selection algorithm which corroborates that nodes present in the network are not empty. This method improved the lifetime of the network but failed to provide WSN security and disaster management based issues for addressing extreme energy consumption.

Xiao W. et al. [48] devised a method considering the features and properties of the algorithm using an improved ant colony algorithm in WSN. The method was adapted for determining the shortest path amongst the set of paths using the ant pheromones. The basic principle was that the ant leaves pheromone in the path using volatile secretions for path optimization.

Baroudi U. et al. [49] devised a genetic algorithm (GA-TBR) in the sensor nodes for collecting the state information in the WSN environment of smart grids. The method optimized the routes for ensuring the quality of service. The method showed improved efficiency but needed additional processing and memory.

Wang W. et al. [50] devised a method for recuperating the malfunction cluster by choosing different static sensor nodes and cluster heads for accumulating packets and fed to the sink node. Here, a Simulated Annealing algorithm was used for attaining standardized deployment of cluster heads. The obtained cluster heads were enthusiastically changed for balancing the energy consumption. The method transmitted the packets using Dijkstra's algorithm for multihop routing. The paths were updated using the energy cost of the path and present node energy.

III. RESEARCH GAPS AND ISSUES

Despite many path optimization methodologies, there subsist many drawbacks, which should be solved for acquiring effectual techniques. Here, issues of the conventional methods based on different existing methods for path optimization are presented as follows.

The path optimization methodologies pose certain drawbacks that must be addressed for designing an effective path optimization strategy in WSN. Generally, the path optimization strategies pose huge computational complexities, which could escort obstruction of the channel when data required for communication is huge. The challenges confronted by the existing methods are two-fold. The first was that the method was incapable to make redundant nodes boundary dormant, and the second was the inconsideration of overlying amidst the areas between node coverage that lead to unnecessary functioning nodes thereby affect network lifetime [6]. The issue of sink's motion was considered as a linear programming problem [2] wherein the optimal motion sequence issue was addressed based on the position of nodes present in the WSN.

However, there exist issues for balancing the data acquisition providing improved energy consumption between sink nodes [5]. In addition, there exists an opposition between the low energy consumption in networks due to lower transmission delay and huge access paths. Moreover, the motion of the sink and path selection strategy affected the data collection efficiency and destructed network performance [21]. WSN are commonly suffered from foreseeable problems, as these resources controlled SN are organized in an antagonistic environment, which makes it complicated for changing and replacing the batteries. Thus, lifetime enhancement is considered as a major issue while developing the WSNs despite the application type [30]. The major challenge faced by the WSN is two-fold, which involves energy and communication bandwidth that tends to be limited with respect to the tethered network environment [21].

Table 1 portrays the analysis of limitations, considering each category of classified methods.

Table 1
Analysis of Limitations

Classified Method	Limitations
Event-based routing technique	• Message overhead: The overhead is detected on the network while transmitting and receiving messages. The message overhead is evaluated using overlay hops, which indicate a number of nodes that are navigated by an event alongside propagation. Here, an event routing algorithm must need nodes in a single hop. However, the messages in transmission are considered as an overhead in routing [3]. • Memory overhead: The information accumulated at each process becomes a major overhead in the network. Even the increase in the number of nodes may degrade the performance causing memory overhead [8]. • Subscription language limitations: The routing mechanism may incorporate drawbacks on the supported subscriptions, for instance, based on the kind of constraint. Based on the resource, the issues of WSN like elevated traffic loads and high-data-rate applications lead to network congestion which is a major obstacle in event routing [4].
Path constraint-based routing technique	• The malfunction of sensor nodes may cause failure in topologies and might need re-routing of packets [4]. • Some methods are supposed to be homogeneous having similar computation, power, and communication. However, the applications of the sensor node may have a diverse role which may lead to technical issues [1]. • Many sensor nodes fail due to deficiency of power, corporal damage, or ecological interference. The failure of sensor nodes should not effect the task of the sensor network [11]. • The majority of network models suppose that sensor nodes are motionless. However, the mobility of the base station and sensor nodes becomes an imperative issue in WSN [12].
Periodic routing technique	• There are different factors, like link load, node reliability, and route hops, which are responsible for route efficiency, making the routing algorithm more challenging [30]. • The existing routing protocols consider that each node work in a compassionate manner, which results in susceptible behavior of the network against suspicious attacks, in which suspicious nodes are considered. The attackers consider data, bandwidth, battery power, and routing protocols for initiating the attack [31]. • The establishment of routes and data transmission is prone to various types of attacks while considering network setup, in which the misbehaving of nodes affects the overall path discovery process using impersonation or response to information that governs the false route. Thus, the information transfers the whole control of the network to the intruder [32]. • Various protocols are designed for networks, which are subjected to deal with several issues, such as more power consumption, large rates of errors, and less bandwidth [30].
Random walk based routing technique	• Despite many methods of random walk theory, the precise random walk theory was performed under restrictive conditions like network periodicity and system homogeneity. However, the issue of a random walk on the finite lattice is not much explored [33]. • The major issue of the random walk is to devise how long does walk evolve in the future under different conditions [34]. • As random walking doesn't need communication while sending the data and require less energy for transmission. However, simple grid topology provides a huge lifetime in WSN but is an enviable issue while designing topologies [35].

IV. ANALYSIS AND DISCUSSION

The evaluation is done using numerous strategies adapted for path optimization using the year of publication, adapted methodologies, evaluation measures, software tools, and performance evaluation values.

A. Analysis Based on Strategies

The analysis using adapted path optimization strategies is elaborated in this subsection. The strategies utilized for effectual path optimization is shown in Figure 3.

Based on Figure 2, it is noted that 12% of the research papers utilized event-based routing, whereas 46% of researcher works employed path constraints for providing path optimization. It is observed that 36% of research works are covered by a random walk and the remaining 6% of the research works utilized the periodic routing strategy for initiating routing in WSN. From the analysis, it was noted that path constraints are the commonly employed measure for path optimization in WSN.

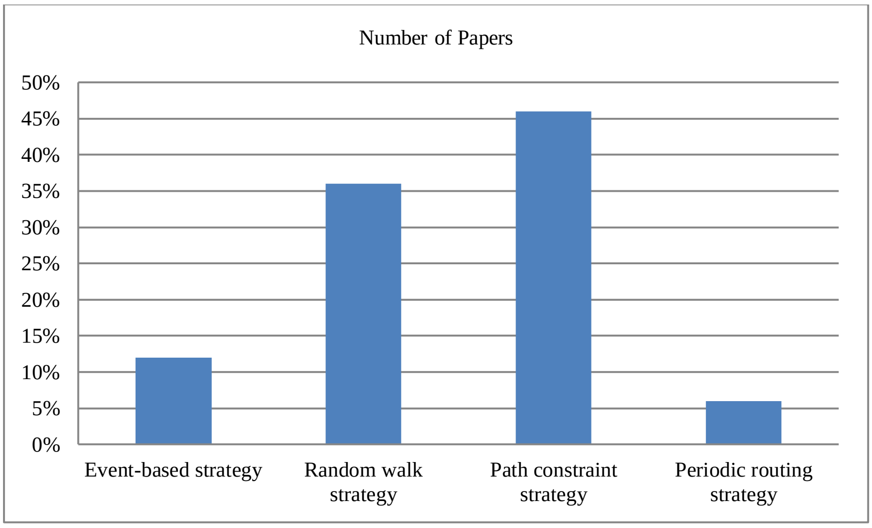

Figure 2: Analysis based on strategy

B. Analysis On The Basis Of Implementation Tool

The analysis of conventional techniques using an implementation tool adapted in the literary works is described in this part. Figure 3 elaborates the software tools employed to perform effectual path optimization. The software tools adapted in different path optimization strategies are C++, MATLAB, Omnet++, and network simulators 2, and 3. From Figure 4, it is observed that MATLAB is a commonly adapted software tool for performing path optimization considering WSN.

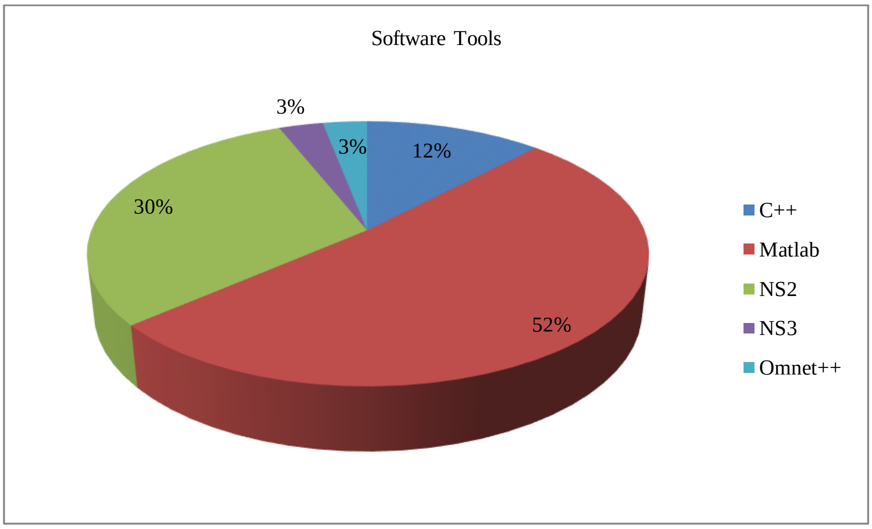

Figure 3: Analysis devised on the basis of implementation tools

C. Analysis Of Energy Consumption

The analysis of energy consumption (mJ) is reviewed with three ranges below 0.2, 0.2-0.3, 0.3-0.4 and above 0.4. It is evaluated that the author Vijayashree et al. [33] and author Sharma et al. [47] had acquired minimal energy consumption i. e below 0.2 (mJ) for data transmission. Whereas researcher Ren G. et al. [30], Yue et al. [34] and Mamalis et al. [27] observed energy consumption in the range of 0.2-0.3 (mJ). The author Gao et al. [12] observed energy consumption between 0.3-0.4 and Wang et al. [36], Salarian et al. [37], Zhang et al. [41] and Wang et al. [50] observed above 0.4 (mJ).

D. Analysis On The Basis Of Throughput

The analysis of throughput is reviewed with three ranges as below 70%, 70-80%, and 80-90%, respectively. It is observed that researcher Arti et al. [18] had acquired better throughput within the range 80-90%. The researcher Radhika et al. [3] acquired 70%-80% and researcher Tang et al. [5] below 70%.

E. Analysis Using Runtime

The analysis on the basis of values of the runtime is elaborated in this subsection. The evaluation of runtime is reviewed with three ranges below 1sec, 1-2 sec, and 2-3 sec. It is evaluated that researchers Baroudi et al. [49] and Siriwardana et al. [45] required minimal running time for data transmission below 1 sec then Xiao et al. [48] between 1-2 sec and Dongyao et al. [35] D. Deepika et al. [25] between 2-3 sec.

F. Analysis Using Delay

The analysis on the basis of values of delay is elaborated. The evaluation is based on the delay parameter with three ranges 0.1-0.2, 02-0.3, and above 0.3. It is evaluated that researchers Sun et al. [21] Hong et al. [32], Vijayashree et al. [33] and Wang et al. [14] acquired minimal delay while performing data transmission. The researcher Wang et al. [9] and Arti et al. [18] observed 0.2-0.3 and above 0.3 respectively.

G. Analysis On The Basis Of Evaluation Measures

The analysis based on evaluation measures for path optimization in WSN is illustrated in the Ffigure . The frequently employed evaluation measures are delay, energy consumption, packet delivery ratio, network lifetime, and runtime. Other metrics include SNR, path length, energy utilization, network connectivity, BER, the average tour length, node density, and network coverage which are employed in the path optimization strategies for computing the performance of each method.

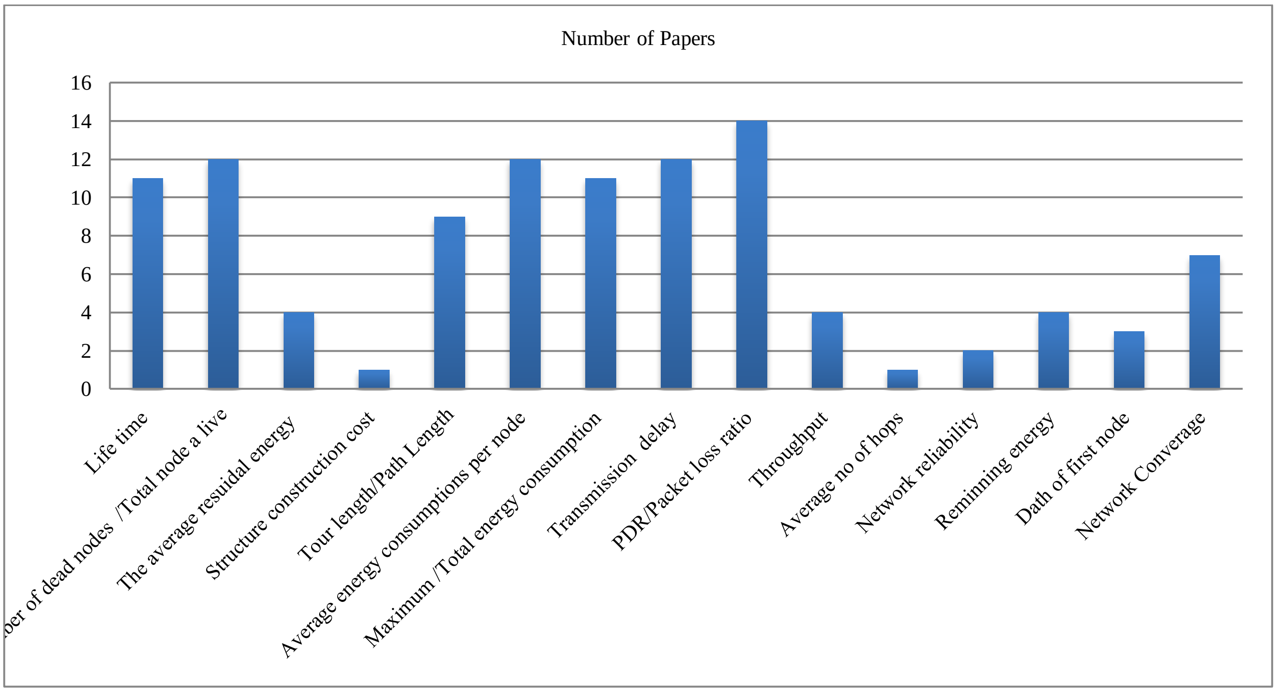

Figure 4: Analysis based on evaluation measures

Table 2
Study of the Performance Analysis with Methodology

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Multi-hop route optimization	Path constraint										✓								
2	ACO	Event-based strategy		✓									✓	✓			✓			
3	ACO	Event-based strategy								✓	✓							✓		
4	Fruit Fly Optimization	Path constraint																		
5	Improved artificial bee colony algorithm	Periodic routing technique							✓	✓						✓				
6	Harmony search algorithm	Path constraint	✓																	
7	Maximum Amount Shortest Path (MASP) Genetic Algorithm (GA)	Path Constraints	✓								✓									
8	Artificial bee colony algorithm	Random walk based									✓	✓								
9	Distributed Wavelet Compression Algorithm	Path constraint																		
10	Energy-Efficient Route Optimization	Path constraint								✓										

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
11	Survey Paper	Event-based strategy																		
12	Path Optimization using Unmanned Aerial Vehicles	Path constraint								✓										
13		Path constraint																		
14	NN	Periodic routing technique	✓						✓											
15	PSO	Path constraint		✓									✓							
16	Artificial Bee Colony Algorithm	Path constraint		✓		✓			✓									✓		
17	Heuristic Artificial Bee Colony Algorithm	Random walk based							✓		✓	✓				✓				
18	Path optimization strategy (POSC)	Event-based strategy							✓											
19	Artificial Bee Colony Algorithm	Path constraint										✓	✓	✓						
20	Dij-Huff Method	Path constraint	✓								✓	✓	✓							
21	Sensor Networks for an All-IP World (SNAIL)	Periodic routing technique										✓								
22	Virtual grid margin optimization	Event-based strategy		✓									✓	✓						
23	Improved genetic algorithm and binary ant colony algorithm	Path constraint																	✓	
24	Particle swarm optimization	Path constraint																	✓	
25	Improved Ant Colony Algorithm and Genetic Algorithm	Path constraint																	✓	
26	Power Optimization,	Path constraint									✓									
27	an improved leapfrog algorithm	Random walk based																	✓	✓
28	Ant Colony Optimization in combination with Hop Count Minimization	Path constraint	✓								✓									
29	Hilbert Space Filling Curve	Path constraint								✓			✓						✓	
30	Energy-efficient competitive clustering algorithm	Random walk based		✓							✓						✓			
31	Weighted rendezvous planning	Random walk based	✓								✓									
32	improved ACO algorithm	Random walk based	✓	✓									✓							
33	I-LEACH	Random walk based		✓		✓						✓			✓					
34	A clustering energy-efficient transmission protocol for wireless sensor networks based on ant colony	Random walk based		✓		✓												✓		

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
	path optimization (CEETP-ACPO)																			
35	Dynamic path planning for mobile sink	Random walk based							✓			✓	✓							
36	A heuristic called adoptive rendezvous planning	Random walk based							✓				✓							
37	PSN based mobile sink model	Random walk based							✓				✓							
38	Energy efficient routing schema combined with clustering and sink mobility technology.	Random walk based		✓							✓									
39	Physarum Optimization with Shuttle Streaming (POSS)	Random walk based							✓										✓	✓
40	Lifetime optimization algorithm with mobile sink nodes for wireless sensor networks (LOA MSN)	Random walk based	✓			✓				✓		✓								
41	Modified HIECBR (MH-IECBR) Improved Honey Bee Optimization based Routing Protocol	Random walk based	✓							✓			✓	✓			✓			
42	Particle swarm optimization based clustering algorithm	Event-based strategy	✓							✓		✓	✓							
43	Review	Path constraint										✓								✓
44	An improved basic ant colony algorithm	Path constraint		✓															✓	
45	modified clustering and data forwarding protocol combined with a MS	Path-Constrained	✓																	
46	Optimal Terminal Assignment based Path (OTABP)	Path constraint								✓			✓							
47	Path equalization algorithm (PEABR)	Path constraint											✓							
48	Improved Ant Colony	Random walk based								✓										✓
49	Genetic algorithm-Ticket based Routing	Random walk based						✓				✓								✓
50	A Balanced Energy Consumption Solution	Random walk based		✓													✓			

Table 2 describes the various methodologies used by the researchers with the evaluation parameters. In Table 2, Methods, Path Strategy, lifetime, Number of dead sensor nodes/Total node alive, Total energy dissipations in the system, The average residual energy, Variance of energy across the network, Structure construction cost, Tour length/Path Length with increasing transmission range, Average energy consumptions per node, Maximum /Total energy consumption, Transmission delay A11, PDR/Packet loss ratio A12, Throughput A13, Average no. of hops A14, Network reliability A15, Remaining energy, Death of the first node, Network Coverage, and Run-Time are represented as A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, and T, respectively.

H. Discussion

From the analysis of the existing path optimization techniques, we have noted the following points:

Most of the techniques used the performance measures, such as packet delivery rate, network lifetime, energy consumption, delay, and distance. They discarded the analysis of messages and the time complexity of their techniques. There are several metrics, such as control messages, scalability, QoS, complexity, load balancing, and reliable delivery should be analyzed to evaluate the performance. The transformation of existing simulations into real-world applications is also a significant challenge. Hence, it is necessary to build a technique, which considers the above metrics. Also, the scheduling of sensor nodes increases the performance of the network. In this scheme, only the sensor nodes, which participate in monitoring a target area, must be selected. So, the number of nodes that transmit data is reduced, which decreases the energy consumption of the network. Therefore, in future work, a minimum number of nodes is selected for routing, which reduces energy consumption and improves the network lifetime. Also, we need to improve the performance of the path optimization strategy by selecting the best clustering algorithm for cluster head selection. After the selection of the best clustering algorithm, a major challenge is to focus on the best optimization strategy to improve the QoS parameters in WSN using the mobile sink.

V. CONCLUSION

In this survey, many techniques are being adapted for acquiring improved path optimization in WSN, and they are classified as an event-based strategy, path constraint-based strategy, periodic strategy, and random walk based strategy based on certain criteria. The review aims to categorize the conventional techniques on the basis of methodologies adapted, evaluation measures and software tools, and values of performance metrics based on path optimization. Additionally, the gaps and issues of the research works based on path optimization are elaborated to suggest effectual future scope. The frequently employed strategy for acquiring effective path optimization is path constraints. The major challenge faced by the path optimization models is that the majority of the conventional methods cannot be determined due to energy constraints. These are some of the main limitations, which should be resolved in the future by employing novel path optimization strategies by the researchers.

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