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An Overview of Using Mobile Sink Strategies to Provide Sustainable Energy in Wireless Sensor Networks

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Abstract: The Wireless sensor networks (WSNs) can effectively address the issue with the static sink's sink-hole or hot spot brought on by multi-hop routing by data collecting using the mobile sinks (MS). The optimal path's design, however, is a famous NP-hard issue. Data transmission from source nodes to base station that is both successful and efficient while reducing energy consumption and data loss is what determines the architecture's overall performance. In WSNs, data collection is done via mobile sinks or static sinks (SS). However, the effectiveness of MS based data collection techniques is higher than that of techniques based on static sinks. Nevertheless, the MS-based data collection methods have a number of shortcomings and restrictions. Designing a trajectory is therefore an NP-hard task. In this work, we suggest a survey that utilizes the path optimization techniques. We also have an overview of different approaches for using SS and MS-based techniques to collect data from a sensor network, as well as different kinds of data collection using MS and some of the difficulties it encounters. Lastly, we offer a level-based categorization of the various trajectory techniques that were employed to gather the data. We divided the schemes into two categories at the first level: static and dynamic.

Keywords: Energy-efficiency, Mobile sink, Path planning, Static sink, Wireless sensor networks (WSNs)

1 Introduction and Overview

Recent years have witnessed a huge expansion of wireless sensor networks (WSNs) usage in many areas of our lives, including home automation, smart power grids, precision agriculture, habitat, structural health, and remote health monitoring [1], [2]. Many sensor nodes that are haphazardly placed throughout the monitoring area make up a WSN. The majority of research has presumed that sensor nodes have limited energy because they are battery-powered [3], [4].

Since sensor network nodes are battery-operated, it is typically not possible to replace or recharge them. To ensure that the network's limited energy reserves are used as efficiently as possible and prolong its lifespan, sensor nodes must modify their operations in a way that uses less energy. Furthermore to the importance of each use of energy by the sensor node, for a network to last longer, each sensor node's energy consumption must be balanced. Sensor nodes in traditional WSNs are dispersed throughout the sensing field. A node communicates with one or more static sinks via communication in several hops or in one hop when it detects an event of interest [5]. Energy use will be higher for the sensor nodes near the sink, which is a major drawback of these communication networks (in part to report data they have sensed and partly to relay data from their neighbors), which will cause them to exhaust energy more quickly. Consequently, the sink will become isolated as a result, and the network will stop working altogether. In wireless communication, this issue is frequently referred to as the sink-hole or hotspot issue. In order to address this issue, the concept of the mobile sink (MS) was created. It allows isolated network segments to be connected while also achieving balanced energy consumption across nodes. One more reason to include a WSN's mobile sink is that certain use cases specifically call for sink movement in the area of the sensor [1].

The past several years have seen a great deal of focus on the technique of collecting data using mobile sinks. In this section, we categorize the typical mobile data gathering in WSNs into two groups and provide a brief overview of them [6]:

- Direct Communicating Collection: using only single-hop communication, at least one MS visits every sensor node in order to collect data.

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- With a multi-hop communicating collection, other nodes must use a multi-hop path to transmit their data, and the MS only visit certain areas or parts of the sensor nodes.

Every sensor node was divided into multiple clusters, each of which had a single anchor serving as the root of a sub-tree. Every node in every sub-tree sent the sub-tree's topology and its sensing data to the root [7].

The structure of this paper is as follows: the methods used by a sensor network to acquire data via SS and MS are elaborated in Section 2, and the different types of data gathering using mobile sink are elaborated in Section 3. Section 4 discusses the review of related work, and Section 5 discusses the survey's conclusion.

2 Data Acquisition Strategies

Regarding WSNs, a sink refers to a specific node or device within the network that acts as a centralized collection point for data gathered by sensor nodes. The sink node is responsible for receiving, processing, and aggregating the information transmitted by the sensor nodes in the network, enabling efficient data management and facilitating the integration of WSNs with external systems or applications. The data acquisition strategies categorize based on static or mobile sink [8].

A. Data Gathering Using a Static Sink

The algorithms of static sink (SS) involve the introduction of a sink node in the network, separate from the base station (BS), that gathers data from all of the SNs and then sends it to the BS. In contrast to multi-hop and single-hop transmission strategies used in the past, this mechanism results in an increase in the network's overall lifetime. In reality, for data to be sent from source nodes to sink nodes, multi-hop communication is necessary. As a result, the communication distance affects energy consumption. A disadvantage of communication based on static infrastructure is the "energy hole" around the sink, when the SNs around the sink are become crowded and use up energy while forwarding data from parents' nodes. Additional data packets are not transmitted to the sink because of the energy hole [9]. This issue causes the network to split, which makes the network as a whole non-functional and reduces network lifetime and quality of services [10], [11].

One method to shorten the distance between SNs and SSs is to use multiple SSs and have each SN send data to the nearest sink based on its location. By doing this, the number of energy holes is decreased as the transmission distance between the source node and the sink is shortened as opposed to a single static sink case. The region is split up into more manageable sub-regions, each with a unique SS, by these SSs. Experiments have demonstrated significant improvements in energy dissipation and data delivery ratio when compared to a single static sink. Determining the ideal location for the sink within the monitoring region presents a challenge when dealing with multiple SS. This is in comparison to the widely recognized "facility location problem," in which the distribution of the number of facilities and customers is equal. But in many situations, it is not practically feasible to deploy SSs optimally; as a result, nodes that are close to a specific sink dissipate more energy than other nodes in their group [9], [12].

B. Data Acquisition Through Mobile Sink

Data collection using mobile sinks (MS) in wireless sensor networks (WSNs) is a useful method of addressing the "energy hole problem" [13]. The idea of MS is presented in order to address the problems associated with single or multiple SSs. MS provides network-wide energy consistency and load balancing, requiring no additional work. This occurrence is demonstrated in Figure 1. A mechanical device known as an MS travels throughout a network in a variety of ways to collect data [9], [14].

The network topology can be dynamically altered by the MS node, enabling data communication with the sink. The group of nodes surrounding the sink is no longer the center of the network load. A different sink node can also have the effect of achieving load balancing. The well-known hot spot issue for WSNs is mitigated by mobile sink nodes, which prevent the formation of bottleneck nodes [15], [16].

Since tracking MSs is far more difficult than tracking SSs, security is another key benefit of the MS. After all, its exact location is constantly shifting. In order to harm the sink or obtain any sensitive data, an attacker must pursue an MS across the network, which is far more challenging than chasing an SS because the SS's location is fixed. Nevertheless, nothing good ever comes for free, and MS's benefits are no exception. SNs must expend a lot of energy on this tiresome task in order to find the new location when the MS constantly advertises its new location throughout the network. Although this is an additional expense, it shouldn't be too great to outweigh the benefits of energy conservation over static sink methods. For WSNs with MSs, a unique set of routing protocols should be created that reduces various energy overheads while improving data collection latency, a prerequisite for many real-time applications [9], [17].

Any routing protocol that handles sink mobility must perform the following extra steps:

- Notify your neighbors if the mobile sink's link breaks.
- Spread the topological updates from the sink to maintain connectivity.
- Minimize the likelihood of packet loss as the sink travels between locations [1].

Especially in large-scale sensor networks, early research uses the MS to collect data from individual sensor nodes, but this results in a significant delay in data delivery due to the long trajectory of the mobile sink. To mitigate

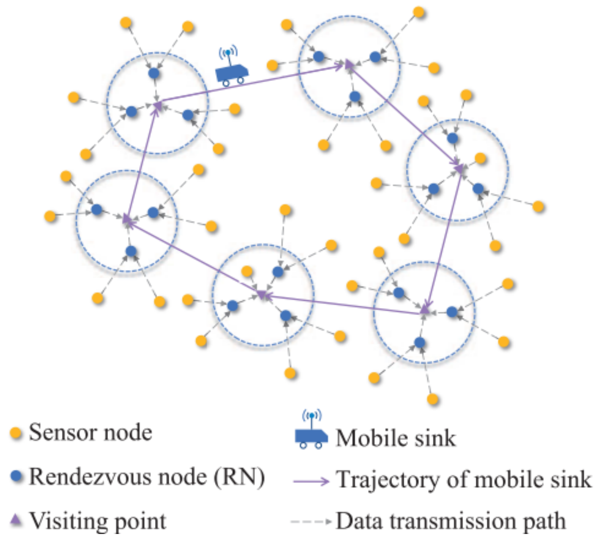

Figure 1. Data Acquisition through Mobile Sink.

this problem, according to the majority of recent research, non-RN nodes transmit data via rendezvous nodes (RNs), whereas the mobile sink can only gather data from a subset of nodes known as RNs. [13], [18].

1) Phases of Data Acquisition Through Mobile Sink

Three phases make up data transmission to incorporate MS-based WSNs: route planning, transmission of data, and sink discovery.

- Sink Discovery: finding MS's current location is the first step in the data forwarding process. SNs must monitor the sink's updated position on a regular basis as the MS moves around. A node notifies the entire network of the location of the MS and begins sending sensed data to it if it detects the presence of a sink and determines that the MS is within communication range. However, the connection time must be long enough to allow for full data transfer; otherwise, data delivery latency will rise [9].

- Route Planning: SNs will identify the best route to reach the MS when the sink is being found. SNs can take advantage of multi-hop or cluster-based communication in this situation. The primary goal of this route planning is to arrive at the sink for the least amount of money [9], [19].

- Data Transmission: connection time is crucial for the transfer of data from the environment that the SNs sense to the MS. In order to optimize throughput, it should be used effectively with the sink. It is important to select the connection time such that the data transfer is completed in the allotted amount of time. The variance the separation between the MSs and the source will have a significant effect on data transfer, in addition to channel condition [9].

2) Mobile Sink Challenge

In addition to presenting new opportunities and difficulties, the use of mobile nodes in WSNs can increase the nodes' positioning accuracy [15]. For a WSN to function effectively, numerous issues relating to the use of a mobile sink must be resolved. Using a mobile sink in WSN presents a number of major challenges, including:

1) Network Connectivity: ensuring continuous connectivity amongst the sensor nodes and the portable sink is a significant challenge. As the sink moves, it may encounter areas with poor or no network coverage, leading to communication disruptions. Effective routing protocols and mechanisms for sink mobility management are required to maintain connectivity and reestablish communication when connectivity is lost [1], [20].
2) Energy Consumption: there are new challenges with energy consumption due to the sink node movement. In order to stay in contact with the sink, the network's sensor nodes might need to boost their transmission power, which would increase energy usage. When there is a mobile sink present, it becomes imperative to manage the energy resources effectively and optimize the routing protocols to minimize energy consumption.
3) Sink Contact Detection: prior to initiating communication, the nodes of sensors must identify whether the mobile sink is within their communication range. Nodes in sleep mode cannot identify whether a moving sink is present, so the duty cycles of the nodes and the mobile sink's speed have a significant impact on sink contact detection. High packet loss ratios are caused by similar high sink mobility, which shortens the timing of communication with the sensor nodes.
4) Data Aggregation: with a mobile sink, data aggregation becomes more complex. Traditional data aggregation techniques, designed for static sinks, may not be suitable. Efficient algorithms and mechanisms for aggregating and compressing data from multiple sensor nodes while considering the sink's movement need to be developed to reduce the amount of data transmitted and conserve energy.
5) Scalability: scaling up the network size while using a mobile sink can pose scalability challenges. The complexity of effectively managing, routing, and gathering data grows with the number of sensor nodes and data sources. Designing scalable protocols and algorithms that can handle a large number of sensor nodes and effectively utilize the mobile sink's resources is a significant challenge.
6) Security and Privacy: the mobility of the sink can expose the network to new security threats. Security mechanisms need to be in place to protect the data transmitted between the sink and the sensor nodes, as well as ensure the integrity and authenticity of the sink's movements. Additionally, privacy concerns may arise if the sink collects sensitive data or its

movement patterns reveal sensitive information.

7) Increased Packet Loss Ratio: each sensor node forwards data to where the mobile sink was last seen because fixed contacts with the sink are not available. Nonetheless, there would be significant compromises to the message being forwarded successfully if the most recent mobility information was not distributed throughout the network. The last known sojourn point that a mobile sink departs from significantly ,this problem becomes even more complex and eventually leads to the message being dropped because of the lengthy traversal time [1].

Addressing these challenges requires careful design and optimization of the routing protocols, energy management techniques, data aggregation strategies, and security mechanisms in WSNs with mobile sinks. Researchers continue to explore solutions to these challenges to enable the effective use of mobile sinks in various WSN applications.

3 Types of Data Gathering

Both no data forwarding and partial data forwarding methods are the two most common types of data gathering used in WSNs.

A. No-Data-Forwarding

The no-data-forwarding solutions deploy a mobile sink to every sensor node in order to capture data packets; this eliminates the need for communication between sensor nodes and considerably lowers the network's overall energy usage. However, the mobile sink's touring path is excessively lengthy, which prolongs the network's delay [21].

B. Partial-Data-Forwarding

This category's basic idea is that, when many sensor nodes are deployed, it is impractical to visit every sensor. In order to get around this issue, the mobile sink only visits a portion of the sensor nodes while the visited sensors in the partial-data-forwarding category send their own data to them [3].

1) Cluster Based Approaches

With cluster-based techniques, a unique node serves as the Cluster Head (CH) of each small cluster within the network field. Many factors are taken into consideration when choosing the CH, including distance from the RP, hop count, and residual energy. The remaining nodes linked to various CHs as cluster members (CMs) are selected once the CH has been chosen. CMs send data to the CH, which forwards it to the MS after processing the data gathered from all CMs. Figure 2 presents a conceptual view of cluster-based approaches, and this section also covers the research that has been done in the following area thus far [9], [22].

There are three stages to these approaches: cluster formation, CH selection, RN selection, and MS trajectory formation. When it comes to cluster formation and CH selection, it's critical to choose carefully because CHs consume more energy because of the additional workload involved in receiving sensed data from other SNs, aggregating that data, and sending the combined data to the sink. Every other SN is regarded as a CM. When a CH's energy level drops below a set threshold, it is replaced [10]. The RN selection process frequently makes use of the weight function. The traveling salesman problem (TSP) is actually how to plan the trajectory for the set of selected registered nurses (RNs) after they have been chosen. Consequently, TSP algorithms are frequently utilized in trajectory planning [13]. The formation of the MS's trajectory: in order to gather sensory data from the network, the MS must visit every RP during this phase. The path of MS as a TSP on the chosen RPs [10], [23].

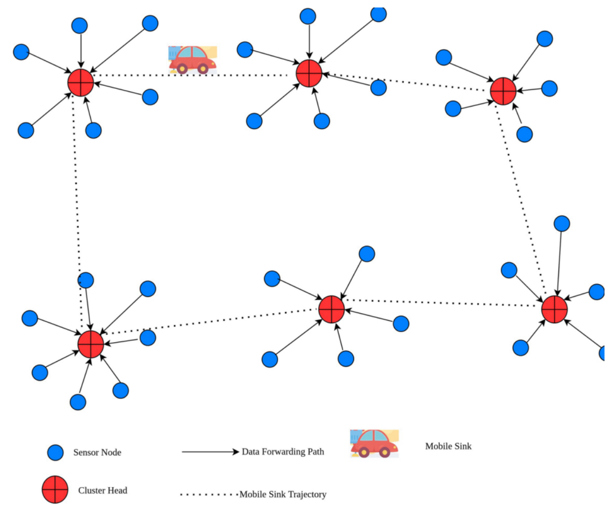

Figure 2. cluster-based approaches.

The primary factors used to choose cluster heads are the nodes' positions and the amount of energy left. A control plan is created so that mobile receivers can gather information from cluster heads [15].

2) Tree Based Approaches

When using tree-based methods, the SNs organize into a structure resembling a tree, from which they send data to the nodes at higher tiers and, ultimately, to a specific root node that serves as an RN. Next, in accordance with the implemented protocol, this RN sends the data to the MS. Figure 3 presents a theoretical perspective on tree-based methods [9]. This approach's methods choose RNs by either using a weight function or a pre-order tree traversal. Figure 3 presents a conceptual view of Fixed tree approaches [10].

3) Fixed track-based Approaches

The MS trajectory is predetermined in a fixed track-based system, and the placement of SNs is random in proximity to the MS trajectory. Social networks that are reachable by the MS —which could include CHs, cell headers, or just plain SNs—will function as RNs. Figure 4

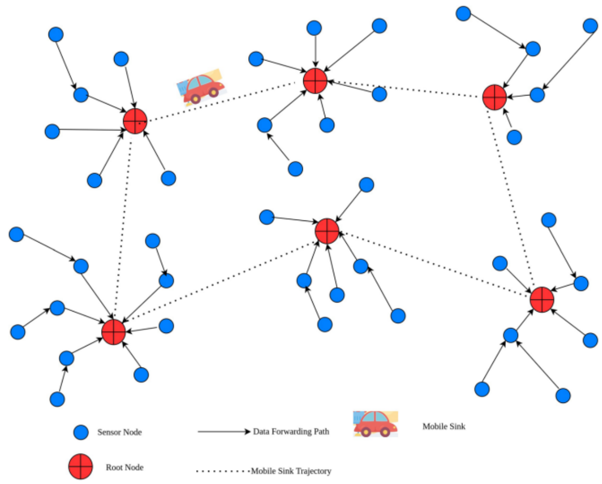

Figure 3. Tree-based approaches.

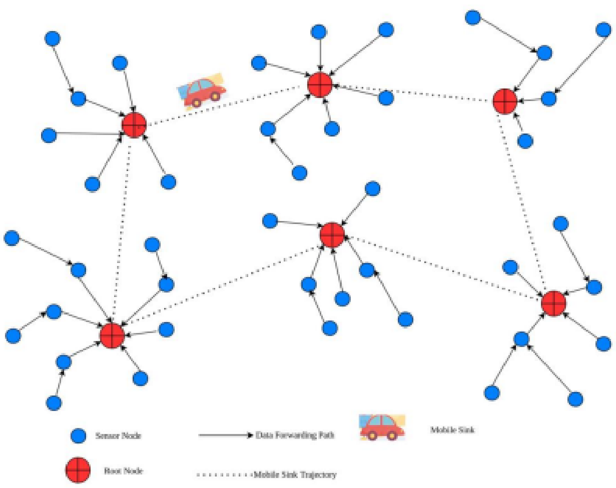

Figure 4. Fixed track-based Approaches.

presents a conceptual view of fixed track based approaches [10].

4 REVIEW OF RELATED WORKS

More RNs reduce the amount of energy used by multiple hops transmission and further balance energy consumption if the mobile sink's trajectory is long enough. However, the mobile sink's excessively long trajectory will cause a considerable delay in the data delivery. The majority of studies concentrate on choosing a sufficient number of RNs while keeping in mind the mobile sink's trajectory length restriction [15], [24].

A. Techniques for Path Optimization in WSN

Within this part, we've looked at a number of path optimization techniques. Figure 5 presents the classification of differentiating path optimization techniques. The primary types of methods based on path optimization strategies

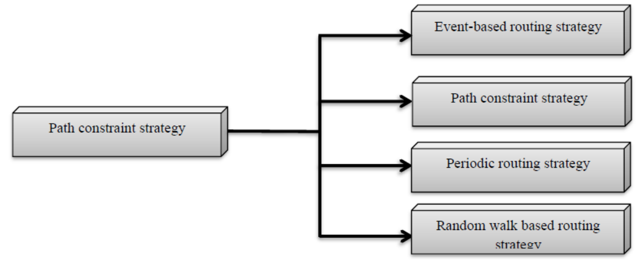

Figure 5. Classification of WSN route optimization techniques.

are path constraint-based, random walk, periodic walk, and event-based approaches. The following strategies are briefly illustrated in the Following subsections.

1) Event-Based Routing Strategy

In a single or multichip structure, the sensor node detects the data and transmits it to the sink node. The sink node gathers the data after the event has happened, much like when a cutoff point is determined. The event is started by the node. The different approaches based on event-based routing that we have examined in order to achieve successful the following describes path optimization in wireless sensor nodes:

In [25] the authors created a path optimization strategy (POSC) to charge the WSN nodes for path optimization. The clustering process was started during data transmission by the POSC algorithm using a clustered energy-efficient routing algorithm. The technique reduced each node's death time and balanced energy consumption.

In [15] the researchers used optimization of particle swarms (PSO) to optimize paths in wireless sensor networks (WSNs) with mobile sinks. Here, PSO was used in the routing process to create a virtual clustering strategy. Additionally, the cluster head selection process took into account the node position and residual energy. The technique extended the network's lifespan and demonstrated better energy utilization. Nevertheless, the approach neglected to account for the transmission nodes' energy.

In [26] the authors created an algorithm for WSN routing optimization that is based on equilibrium and achieves load balancing, increased network lifetime, reduced latency, and reduced packet loss. Here, data collection is done using the event-driven approach.

2) Path Constraint Strategy

Path selection is limited when using a path constraint strategy. There are instances when the mobile sink's data collection creates a path restriction. Every iteration of the data collection process must follow the same route for the mobile node.

The different approaches based on path constraints that are used to achieve efficient path optimization in WSN are reviewed here. Hedges, [27] created a continuum model, which makes use of the relay node density, to optimize paths. The technique offered an ideal relay path to start the WSN routing process. The model is intended to sustain constant connection densities indefinitely. The processing complexity was minimized and the end-to-end delay was decreased using this method. Nevertheless, the approach did not employ an optimization technique to provide the best possible sampling in models that are continuum.

[28] created the Fruit Fly Optimization Algorithm (FFOA) using several nodes while taking WSN into consideration. The greatest effective contribution from a node was provided by the method. In order to find the best nodes, the strategy achieved node capture attack and low energy consumption. Moreover, among various node capture techniques, the FFOA offers a high attacking efficiency.

[29] designed illumination that uses less energy. the reduction of energy usage across the nodes through data collection from scattered wireless sensors. Finding the sensors on neighboring nodes is the aim in order to identify the WSN path that uses the least amount of energy. Compared to other approaches, the method efficiently provided better results by optimizing energy consumption and communication.

[30] created a path planning and routing model for wireless network path optimization. Here, the randomly arranged sensor nodes were clustered using a dynamic clustering algorithm.

3) Periodic Routing Strategy

An alternative method of gathering data is the periodic routing strategy. Periodically gathering data is sometimes necessary. After a certain amount of time, periodic data collection becomes necessary. The sensor network is where this tactic is most helpful. The different approaches based on periodic routing that are used in WSN to achieve effective path optimization are reviewed below.

[31] created a technique for gathering data and utilizing mobile sink nodes to route data in WSNs, namely enhanced artificial bee colony (ABC) optimization. This technique combined the transmission path taking into account the set of sensor nodes with the variety of a cluster node. An enhanced ABC was produced by applying the differential evolution algorithm-aware search equation and the reverse learning initialization approach were generated. The technique overcame ABC's problems by improving convergence and boosting network efficiency. Nevertheless, the approach did not deploy nodes using a coverage optimization strategy.

[32] developed a strategy for path optimization that makes use of the mobile sink to gather data. The technique lengthened the network's lifespan and decreased hotspot problems. In this case, the mobile sink was used to select the best route using a trained neural network. Additionally, the stop points were marked to enable node-to-node communication via a portable sink. The technique resolved the hotspot problems and shortened the network's lifespan. These techniques worked well for gathering diverse data over large areas.

4) Random Walk-Based Routing Strategy

The sink node gathers data using a random walk-based routing strategy. In a wireless sensor network, the cluster head is selected at random by the mobile sink node for data collection [33].

The different approaches that we have surveyed using a random walk to achieve efficient path optimization in WSN are discussed below.

[34] created a Krill herd-based for large-scale networks in WSN, the traveling salesman problem (TSP) is used to optimize mobile sink paths. Both the computational effort and path length are decreased. Furthermore, it extends the node's lifespan.

[35] created a moving path planning algorithm for dynamic mobile sink nodes (DPPMSBT) employing precise WSN, which creates burst data in a specific area while periodically gathering data from the entire network. The method provided path length, network lifetime, and effective end-to-end latency. Additionally, the approach ensured that full network data would be collected intermittently and created dynamic sink path planning to gather burst traffic data during an incident. In this case, the technique increased the network's lifetime and reduced the loss rate of packets.

[36] developed a strategy to control the mobile sink in wireless networks by leveraging the hybrid model to enable path optimization. The mobile-sink node was used to create a moving pattern, and rendezvous points (RPs) were used to travel through every WSN node. In order to solve two problems, an adoptive rendezvous planning (WRP) was created. The first problem concerned path computation while moving through the mobile sink. The energy usage in the mobile sink to extend WSN lifetime was the second problem. WRP used the mobile sink path and traffic rate to determine the hop distance and assign a priority to each sensor node. Moreover, energy-aware local routing was applied to improve energy efficiency. But in energy-aware routing, the approach was unable to strike a balance between throughput rate and network lifetime.

[37] created a multi-path scheduling plan for WSN that includes mobile sinks. An enhanced PSO algorithm was used to choose the parking spot, and GA is employed to choose the moving path with the greatest efficiency.

Summary of Path optimization methodologies in WSN is shown in Table I.

B. The Trajectory of Mobile Sink

This part of the article delves into "The Trajectory of Mobile Sink," looking at how mobile sink devices move

TABLE I. An overview of WSN's path optimization techniques.

Article	Event-based	Path constraint	Periodic routing	Random walk based
[28]		✓		
[38]	✓			
[29]		✓		
[31]			✓	
[30]		✓		
[32]			✓	
[25]	✓			
[34]				✓
[35]				✓
[26]	✓			
[36]				✓
[37]				✓
[27]		✓		

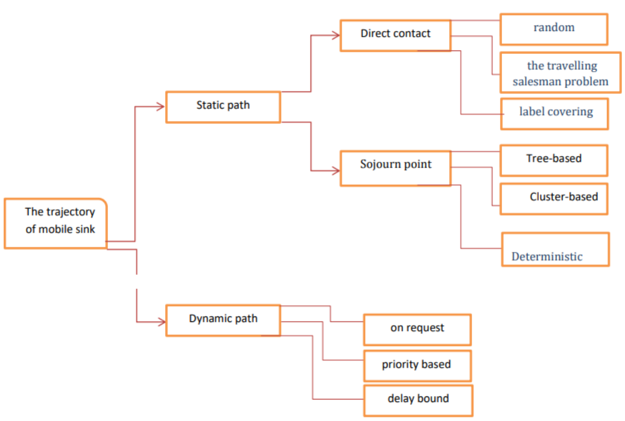

Figure 6. The trajectory of mobile sink taxonomy.

dynamically across wireless networks. A visual depiction of the main categories and traits will be included in the taxonomy figure 6, which will enhance the conversation.

1) Static Path Trajectory of Mobile Sink

Due to mobility patterns in a static path trajectory are primarily periodic, the mobile elements follow a fixed path that is repeated at predefined intervals. Because of the uniform path, only a single learning phase is required for the mobile elements after the deployment of static sensor nodes. There are two categories for this kind of trajectory: (i) direct contact and (ii) sojourn point.

- i. Direct contact Using a one-hop communication link at most, mobile elements are utilized in a trajectory based on direct contact to gather data from each node. The mobile elements transport the gathered data to a fixed base station (BS) if they are not IP enabled, in which case they communicate with the outside world directly. This kind of data collection strategy works well small-scale networks in general, but due to the considerable delays and lost data, it is unable to provide better performance when dealing with a big sensor network. Therefore, a solitary mobile element cannot gather data independently from every node in a large-scale sensor network. It is necessary to deploy multiple mobile elements in order to achieve better performance. The size of the sensing area and the applications will determine how many mobile elements are required. The manner in which the mobile elements move is another crucial component of a direct contact trajectory and needs to be covered in detail. Three distinct methods can be identified based on how the trajectory of the mobile elements is one of direct contact:
    1) Random In randomness the cellular provider roams In random order throughout the network, gathering information from various polling locations and sensor nodes. The locations where mobile carriers gather data are known as polling points. With sensing devices mounted on the animal's body, this kind of trajectory is

best suited for wildlife monitoring [9].

2) The Travelling Salesman Problem A traditional graph theory algorithm for visiting every node on the shortest path is the travelling salesman problem (TSP). Several WSN researchers have used this algorithm to collect data using mobile sinks.
3) Label Covering Data delivery delays are decreased when label covering eliminates the need to visit every node during data collection. In essence, the mobile sink moves from vertex to vertex when label covering, where the implied trajectory path reduces the search space for the data collection. Analogously to the rendezvous points, the data collection points are selected according to the vertex degrees. Vertices with higher degrees are given priority in acting as sojourn points during the data collection process.

- Sojourn Point In a WSN, the centroid point of the sub networks is known as a sojourn point (SP), which is the location where the mobile data collector stops to gather data. Most of the sensor nodes in each sub-network are thereafter covered by single-hop communication. This lessens the requirement for the cluster heads (CHs) on the left and right of each level to be visited by the mobile data collector. In this case, SPs are fixed on both sides of a rectangular area at every level. The chosen CH uses a round number to determine the level at which it transmits its aggregated data to its neighboring CH. Transferring the data is finally aggregated and sent to the mobile mule when it reaches the left- or right-most CH. While traveling a predetermined route, the mobile mule stops for a predetermined period of time at each SP on a regular basis to visit both sides. This plan boosts throughput while decreasing the likelihood of energy holes. The fundamental flaw in this plan is centralized CH selection.
  1) Tree based In tree-based methods, every tree's root nodes are known as the SPs, and multiple trees are created, the node density being the basis. These trees are created using multi-hop routing, which also transmits data to the roots [10].
  2) Cluster based When collecting data using cluster-based methods, the CH acts as the data supplier's node, and every cluster, or cluster group, performs the role of an SP. The mobile element follows a predetermined path, but for that round, it modifies its path according to the position of the CH. The mobile element stays on the same path for that round. Similar to grid-based techniques, centralized clustering fixes clusters for the duration of the network, which means that since the SPs in a cluster remain the same, the trajectory path will likewise remain fixed. But since most clusters in distributed clustering shift with each round, the trajectory path likewise varies because different SPs are used [10].
  3) Deterministic The mobile data collector visits each SP along a predetermined route while maintaining controlled mobility in data collecting based on deterministic SP. This data collection scheme is efficient due to the mobile collector's controlled and basic mobility. Finding SPs, choosing a straightforward route, and controlling movement speed are the main obstacles in this method [1].

- Dynamic Path Trajectory When following A trajectory with a dynamic path, mobile elements change their usual path and select a new one in response to limitations, such as a delay bound during data collection. In data collection trajectories, the mobile elements' path is typically predetermined; The mobile elements' path, however, can be altered at any moment in dynamic path planning in response to a particular demand or priority. Consequently, this trajectory type can be divided into three different subtypes based on the limitations that necessitate the use of dynamic path planning:
  - On Request When on-request trajectory control protocols get a request from a source node, they usually alter the default route. The terminal node notifies the mobile element to visit it in the event of any unusual events.
  - Priority-based When using a priority-based dynamic trajectory, mobile elements typically follow a default path and alter it in response to high-priority data messages. This method operates on a predefined data priority.
  - Delay Bound For each time interval, the mobile element adjusts its default trajectory in a delay-bound dynamic manner. A set amount of time is given for the entire trip in these kinds of situations. The mobile element must gather data during that time and send it to the BS [45].

In [39] for industrial wireless sensor networks, a mobile sink and ant colony optimization-based data collection technique is suggested. First, the entropy weight method is introduced to select rendezvous nodes according to their density relative residual energy, and degree of distribution uniformity, thereby reducing the quantity of nodes that sink can directly access while cutting down on the path's length. Secondly, an algorithm based on ant colonies is suggested to determine the best access path for mobile sinks. This algorithm can balance the network's energy usage and transmission latency. The simulation results demonstrate that the suggested algorithm can reduce latency and increase the network's lifetime when compared to the current algorithms.

TABLE II. Summary of Path optimization methodologies in WSN.

Ref.	Method	Type of trajectory	Target	Sensor Node deployment	Energy Consump-tion
[39]	A mobile sink and ant colony optimization data collection method	Static/direct/ the travelling salesman problem	-Reduce latency and extend the lifetime of the network. -find the best route of access for the mobile sink	Randomly	Minimize
[7]	A data gathering algorithm known as DEDC that takes into account both balanced and unbalanced deployments to choose the anchors as much as possible.	Dynamic/ delay bound	with the goal of reducing the quantity of hops that separate each sensor and the corresponding anchor in order to increase the WSNs' network lifetime.	Balance and unbalance deploy-ment.	Minimize
[40]	An event-driven WSN approach to mobile sink path construction based on extended ant colony optimization (ACO)	Static /Direct / label covering	- the most effective mobile sink traveling path and optimal set of RPs are identified; - To maintain an equilibrium of energy among the nodes, the RPs re-selection mechanism is also incorporated.	Randomly	Minimize
[41]	Using a virtual grid to select the rendezvous point (VGRSS) Fuzzy interference system for random point selection and reselection	Static/ Sojourn point	Long network lifetime, low control overhead, low energy consumption, and low data acquisition latency are all features of VGRSS. RPs are distributedly reselected, reducing the overhead of topology reconstruction.	Randomly	Minimize
[42]	A productive cluster-based data gathering technique is developed, and the optimal path for the mobile sink (MS) is determined by the Ant Colony Optimization (ACO) algorithm.	Static/ Sojourn point/Cluster-abased	Enhanced data aggregation effectiveness and efficiency - Decreased data transmission energy consumption	-	Minimize
[13]	a multi-objective particle swarm optimization (MOPSO)-based energy-efficient trajectory planning algorithm (EETP)	Static/ Sojourn point	Reduce the mobile sink's trajectory length and among the rendezvous nodes, distribute the load equally. - EETP seeks to increase network lifetime and decrease data delivery latency.	Randomly deployed	Minimize
[21]	An end-to-end data collection strategy based on ant colony optimization to carry out the touring path planning and collection point selection concurrently.	Static/ Sojourn point / tree-abased	Extend wireless sensor network lifetime	Randomly	Minimize
[43]	utilize the Hilbert curve to maximize as a useful data collection trajectory, the sink travels in the sensor field.	Static/direct/ the travelling salesman problem	extends considerably over the network's lifespan. -extends considerably over the lifetime of the network.	Deployed randomly	Minimize
[44]	heuristic algorithm for artificial bee colonies that can be used	Static/ Sojourn point/Cluster-abased	maximizing data collection, minimizing mobile path length, and optimizing network reliability.	Randomly deployed	Minimize

In [7] aims to choose as many suitable anchors as possible under the path length constraint in order to extend the network lifetime. It does this by putting forth the DEDC algorithm for data collection is a joint density-aware and energy-limited path construction method. First, the monitoring region is divided into several grids by the proposed DEDC, which then classifies the grids as balance or unbalance grids according to the path length constraint. The recommended DEDC adjusts the path segments for these unbalanced grids after constructing a regular path based on the partitioned grids. A path that passes through as many anchors as possible is built through regular path construction and path adjustment work to balance the forwarding loads and extend the life of the network.

To expedite the process of gathering data, a simulated rendezvous points selection is first conducted, as detailed in [40]. After that, the optimal collection of meeting locations and the most effective path across MS are chosen using an enhanced ant colony optimization (ACO)-based technique.

In [41] the VGRSS method, which minimizes data acquisition latency and saves energy and delay in wireless sensor networks, selects the random point (RP) using a virtual grid and fuzzy interference system.

In [42] The study suggests a cluster-based data collection approach based on the Ant Colony Optimization algorithm for choosing the best path and collecting data in wireless sensor networks. It is limited. There is a significant risk of data loss, and performance and efficiency suffer.

[13] this paper presents an energy-efficient trajectory planning algorithm for mobile sinks in wireless sensor networks which is based on multi-objective particle swarm optimization. By distributing the load among rendezvous nodes and choosing possible visiting locations within the overlapped sensor node communication ranges, the algorithm seeks to decrease data delivery delays and increase network lifetime.

In [21] the study suggests an end-to-end data collection approach for wireless sensor networks based on ant colony optimization that combines touring path planning and collection point selection at the same time. Particularly in the case of uneven sensor distribution, this tactic can lengthen the wireless sensor networks' network lifetime. The suggested end-to-end data collection strategy's specific limitations are not mentioned in the paper. It is crucial to remember that the suggested algorithm may not work in every situation and is predicated on a number of assumptions. The algorithm, for instance, makes the assumption that each sensor node generates a single, fixed-size data packet during a round and that the energy usage is proportionate to the size of the packet. Furthermore, the algorithm's performance in real-world scenarios may differ from that of simulations used to evaluate it. Consequently, more investigation and testing are needed to confirm the suggested algorithm's efficacy in various situations.

In [43] the paper focuses on optimizing energy consumption and data collection in wireless sensor networks(WSNs) using the Hilbert curve as an efficient data collection trajectory. The authors suggest using a virtual rendezvous point (VRP) and clustering techniques to allow the Sink to move between VRPs and gain energy. This paper's limitations include the fact that the ILP optimization might not be appropriate for wide clusters and that it only looks at one particular kind of cluster organization. In order to achieve energy gain, the paper suggests a virtual rendezvous point (VRP) and a clustering strategy for the Sink to move between. Unfortunately, the ILP optimization takes too long for the wide cluster, and the paper only takes into account the cluster that is arranged in a grid. The authors propose developing a Hilbert curve-inspired heuristic to account for the randomly distributed WSN within the cluster.

[44] In order to solve energy hole and communication overhead issues in large-scale WSN, the paper suggests an algorithm for collecting data from multiple mobile sinks using artificial bee colonies and energy-balanced clustering. The suggested algorithm successfully lowers data transmission, conserves energy, increases the reliability and efficiency of network data collection, and lengthens the network's lifespan.

Comparison of path trajectory of mobile sink illustrated in Table II.

5 Conclusion

In WSNs, path planning for an MS is emerging as a fascinating field. Numerous researchers have focused solely on this area of study. All of the most recent developments in mobile sink path planning were covered in this survey. The paper initially proposed a few SS and MS-based data acquisition strategies for sensor networks. Additionally, we demonstrated a kind of mobile sink data collection. There was also a thorough discussion of the difficulties the Mobile Sink faces. Many strategies are being adopted to achieve better path optimization in WS; based on specific criteria, they have categorized strategies such as strategies based on random walks, periodic walks, path constraints, and events. The review's objective is to classify traditional methods according to adopted methodologies, software tools, and performance metrics values derived from path optimization. We also introduced level-based categorization of the various trajectory schemes applied in the data gathering process. We divided schemes into two categories at the first level: static and dynamic.

References

[1] A. W. Khan, A. H. Abdullah, M. H. Anisi, and J. I. Bangash, "A comprehensive study of data collection schemes using mobile sinks in wireless sensor networks," *Sensors*, vol. 14, no. 2, pp. 2510–2548, 2014.

[2] A. M. K. Abdulzahra, "A clustering approach based on fuzzy c-means in wireless sensor networks for iot applications," *Karbala International Journal of Modern Science*, vol. 8, no. 4, pp. 579–595, 2022.

[3] W. Wen, S. Zhao, C. Shang, and C.-Y. Chang, "Eapc: Energy-aware path construction for data collection using mobile sink in wireless sensor networks," *IEEE Sensors Journal*, vol. 18, no. 2, pp. 890–901, 2017.

[4] I. D. I. Saeedi, "An energy-saving data aggregation method for wireless sensor networks based on the extraction of extrema points," in *AIP Conference Proceedings*, vol. 2398, no. 1. AIP Publishing, 2022.

[5] H. M. Salman and A. A. R. Finjan, "Important extrema points extraction-based data aggregation approach for elongating the wsn lifetime," *International Journal of Computer Applications in Technology*, vol. 68, no. 4, pp. 357–368, 2022.

[6] C. Zhu, S. Wu, G. Han, L. Shu, and H. Wu, "A tree-cluster-based data-gathering algorithm for industrial wsns with a mobile sink," *IEEE Access*, vol. 3, pp. 381–396, 2015.

[7] W. Wen, C. Shang, C.-Y. Chang, and D. S. Roy, "Dedc: Joint density-aware and energy-limited path construction for data collection using mobile sink in wsns," *IEEE Access*, vol. 8, pp. 78 942–78 955, 2020.

[8] W. B. Nedham, "An improved energy efficient clustering protocol for wireless sensor networks," in *2022 International Conference for Natural and Applied Sciences (ICNAS)*. IEEE, 2022, pp. 23–28.

[9] V. Agarwal, S. Tapaswi, and P. Chanak, "A survey on path planning techniques for mobile sink in iot-enabled wireless sensor networks," *Wireless Personal Communications*, vol. 119, pp. 211–238, 2021.

[10] A. Mehto, S. Tapaswi, and K. Pattanaik, "A review on rendezvous based data acquisition methods in wireless sensor networks with mobile sink," *Wireless Networks*, vol. 26, pp. 2639–2663, 2020.

[11] H. M. Salman and A. A. R. Finjan, "Bigradient neural network-based quantum particle swarm optimization for blind source separation," *IAES International Journal of Artificial Intelligence*, vol. 10, no. 2, p. 355, 2021.

[12] M. K. Jabar, "Human activity diagnosis system based on the internet of things," in *Journal of Physics: Conference Series*, vol. 1879, no. 2. IOP Publishing, 2021, p. 022079.

[13] X. He, X. Fu, and Y. Yang, "Energy-efficient trajectory planning algorithm based on multi-objective pso for the mobile sink in wireless sensor networks," *Ieee Access*, vol. 7, pp. 176 204–176 217, 2019.

[14] A. L. N. Al-Hajjar, "An overview of machine learning methods in enabling iomt-based epileptic seizure detection," *The Journal of Supercomputing*, pp. 1–48, 2023.

[15] J. Wang, Y. Cao, B. Li, H.-j. Kim, and S. Lee, "Particle swarm optimization based clustering algorithm with mobile sink for wsns," *Future Generation Computer Systems*, vol. 76, pp. 452–457, 2017.

[16] S. A. Abdulzahra and A. K. M Al-Qurabat, "Data aggregation mechanisms in wireless sensor networks of iot: a survey," *International Journal of Computing and Digital System*, 2021.

[17] W. B. Nedham, "A review of current prediction techniques for extending the lifetime of wireless sensor networks," *International Journal of Computer Applications in Technology*, vol. 71, no. 4, pp. 352–362, 2023.

[18] Z. J. Hussein, Z. A. Mohammed, and H. Q. Gheni, "Routing information protocol (rip) for wired network," in *AIP Conference Proceedings*, vol. 2787, no. 1. AIP Publishing, 2023.

[19] H. M Salman and A. A. R. Finjan, "Solve cocktail party problem based on hybrid method," *International Journal of Computing and Digital Systems*, vol. 15, no. 1, pp. 1–9, 2024.

[20] A. M. K. Abdulzahra, "An energy-efficient clustering protocol for the lifetime elongation of wireless sensors in iot networks," in *IT Applications for Sustainable Living*. Springer, 2023, pp. 103–114.

[21] X. Wu, Z. Chen, Y. Zhong, H. Zhu, and P. Zhang, "End-to-end data collection strategy using mobile sink in wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 18, no. 3, p. 15501329221077932, 2022.

[22] W. B. Nedham, "A comprehensive review of clustering approaches for energy efficiency in wireless sensor networks," *International Journal of Computer Applications in Technology*, vol. 72, no. 2, pp. 139–160, 2023.

[23] A. M. K. Abdulzahra, "A clustering approach based on fuzzy c-means in wireless sensor networks for iot applications," *Karbala International Journal of Modern Science*, vol. 8, no. 4, pp. 579–595, 2022.

[24] M. Al-Qurabat and A. Kadhum, "A lightweight huffman-based differential encoding lossless compression technique in iot for smart agriculture," *International Journal of Computing and Digital System*, 2021.

[25] S. Zhang, "Path optimization strategy for charging nodes in wireless sensor networks," 2019.

[26] L. Tang, Z. Lu, J. Cai, and J. Yan, "An equilibrium strategy-based routing optimization algorithm for wireless sensor networks," *Sensors*, vol. 18, no. 10, p. 3477, 2018.

[27] D. A. Hedges, J. P. Coon, and G. Chen, "A continuum model for route optimization in large-scale inhomogeneous multi-hop wireless networks," *IEEE Transactions on Communications*, vol. 68, no. 2, pp. 1058–1070, 2019.

[28] R. Bhatt, P. Maheshwary, and P. Shukla, "Application of fruit fly optimization algorithm for single-path routing in wireless sensor network for node capture attack," in *Computing and Network Sustainability: Proceedings of IRSCNS 2018*. Springer, 2019, pp. 129–136.

[29] M. B. Ghorbel, D. Rodriguez-Duarte, H. Ghazzai, M. J. Hossain, and H. Menouar, "Joint position and travel path optimization for energy efficient wireless data gathering using unmanned aerial vehicles," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 3, pp. 2165–2175, 2019.

[30] A. Pang, F. Chao, H. Zhou, and J. Zhang, "The method of data collection based on multiple mobile nodes for wireless sensor network," *IEEE Access*, vol. 8, pp. 14 704–14 713, 2020.

[31] G. Ren, J. Wu, and F. Versonnen, "Bee-based reliable data collection

for mobile wireless sensor network," *Cluster Computing*, vol. 22, pp. 9251–9260, 2019.

[32] R. Kaur and A. K. Narula, "Mobile sink path optimization for data gathering using neural networks in wsn," *International Journal of Wireless and Microwave Technologies*, vol. 4, pp. 1–13, 2017.

[33] A. A. Kamble and B. Patil, "Systematic analysis and review of path optimization techniques in wsn with mobile sink," *Computer Science Review*, vol. 41, p. 100412, 2021.

[34] T. Suriya Praba, T. Sethukarasi, and V. Venkatesh, "Krill herd based tsp approach for mobile sink path optimization in large scale wireless sensor networks," *Journal of Intelligent & Fuzzy Systems*, vol. 38, no. 5, pp. 6571–6581, 2020.

[35] L. Zhang, C. Wan *et al.*, "Dynamic path planning design for mobile sink with burst traffic in a region of wsn," *Wireless Communications and Mobile Computing*, vol. 2019, 2019.

[36] A. Kumar, M. Anuppalle, S. Maddirevula, T.-L. Huh, J. Choe, and M. Rhee, "Peli1b governs the brain patterning via erk signaling pathways in zebrafish embryos," *Gene*, vol. 694, pp. 1–6, 2019.

[37] J. Wang, Y. Gao, C. Zhou, S. Sherratt, and L. Wang, "Optimal coverage multi-path scheduling scheme with multiple mobile sinks for wsns," *Computers, Materials & Continua*, vol. 62, no. 2, pp. 695–711, 2020.

[38] J. Wang, Y. Cao, B. Li, H.-j. Kim, and S. Lee, "Particle swarm optimization based clustering algorithm with mobile sink for wsns," *Future Generation Computer Systems*, vol. 76, pp. 452–457, 2017.

[39] H. Zhang, Z. Li, W. Shu, and J. Chou, "Ant colony optimization algorithm based on mobile sink data collection in industrial wireless sensor networks," *EURASIP Journal on Wireless Communications and Networking*, vol. 2019, no. 1, pp. 1–10, 2019.

[40] P. K. Donta, T. Amgoth, and C. S. R. Annavarapu, "An extended aco-based mobile sink path determination in wireless sensor networks," *Journal of Ambient Intelligence and Humanized Computing*, vol. 12, pp. 8991–9006, 2021.

[41] A. Mehto, S. Tapaswi, and K. Pattanaik, "Virtual grid-based rendezvous point and sojourn location selection for energy and delay efficient data acquisition in wireless sensor networks with mobile sink," *Wireless Networks*, vol. 26, pp. 3763–3779, 2020.

[42] B. M. Sahoo, R. K. Rout, S. Umer, and H. M. Pandey, "Ant colony optimization based optimal path selection and data gathering in wsn," in *2020 International Conference on Computation, Automation and Knowledge Management (ICCAKM)*. IEEE, 2020, pp. 113–119.

[43] K. Fellah and B. Kechar, "New approach based on hilbert curve for energy efficient data collection in wsn with mobile sink," *IET Wireless Sensor Systems*, vol. 10, no. 5, pp. 214–220, 2020.

[44] R. Vijayashree and C. Suresh Ghana Dhas, "Energy efficient data collection with multiple mobile sink using artificial bee colony algorithm in large-scale wsn," *Automatika: časopis za automatiku, mjerenje, elektroniku, računarstvo i komunikacije*, vol. 60, no. 5, pp. 555–563, 2019.

[45] S. K. Singh and P. Kumar, "A comprehensive survey on trajectory schemes for data collection using mobile elements in wsns," *Journal of Ambient Intelligence and Humanized Computing*, vol. 11, pp. 291–312, 2020.