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ANALYSIS OF MOBILE SINKS TECHNIQUES IN WIRELESS SENSOR NETWORKS: A REVIEW

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Abstract
Recently, a number of applications in military and environmental monitoring have made wireless sensor networks (WSNs) a research center. Data collection from mobile sinks is more popular due to many advantages, including increased network life, energy efficiency and minimizing isolated nodes. Mobile sinks have proven to be extremely useful in wireless sensor networks, especially in large networks. With a mobile sink, visiting each sensor node is complex and may result in data loss or delay. Several recent approaches have shown that data acquisition, routing and sink mobility in a controlled path can increase WSN energy efficiency. A review of some mobile sink (MS) techniques is presented in this paper that have been researched during the past six years, followed by an analysis based on factors such as methods used, research outcomes and limitations. Finally, this survey concludes with a summary and research challenges for the future.
Keywords - Wireless Sensor Networks (WSN), Mobile sink (MS), Sensor Nodes (SN), Multiple mobile sinks (MMS), Rendezvous Points.

1. INTRODUCTION

Usually, WSNs (Wireless Sensor Networks) consist of sink nodes and sensor nodes (SN). The processing power, bandwidth, memory, and energy of sensor nodes are limited. It is common to see WSNs in many aspects of our daily lives, such as monitoring of health, building structures, online medical diagnosis, home automation, precision agriculture, smart transportation, and smart grids. Sensor Nodes that sense environmental conditions and physical conditions (such as voice, pressure, movement, temperature and vibration) are distributed independently in space, and their data is transmitted to sink nodes. Each sensor node performs a variety of tasks, including as data gathering, processing, transmission, sleeping, and waking up. The biggest amount of energy is used during transmission. Sensor data is typically transmitted through a multi-hop communication system. Statistic WSNs, however, have fixed node locations, and default communications modes are hop-by-hop, many-to-one. Nodes located near sinks forward more data, consume more energy, and fail sooner. Often, this problem is known as hole problem in sink node or the wireless hotspot problem. Moving the sink node is implemented to address the issue. Recently, mobile sinks have been designed to cut down on energy use and connect split network areas. An unmanned aerial vehicle, a laptop/mobile mounted on a vehicle, or a person wearing a Personal Digital Assistant (PDA) are all examples of mobile sinks. To gather data, the mobile sink traverses around the sensor network. Therefore, the average length of the message path is shorter, which lowers the WSNs' overall energy usage. There are many methods available for scheduling MS to collect data from WSNs.

The typical clustered architecture of a WSN is shown in Figure 1. The network's data receiving centre is called the sink. Cluster Head transmits data from Cluster Members to sinks. The sink can be moved around.

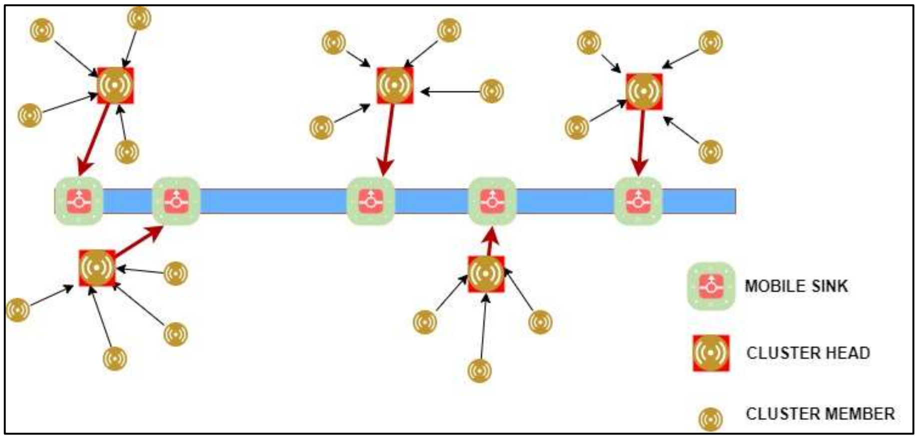

Figure 1 – Architecture of WSN

1.1 CONTRIBUTIONS

In this research study, we focus to explain the different existing methods for mobile sink WSNs. This survey's contributions are –

1. It informs readers of the current and most widely used MSWSN approaches.
2. It emphasizes the limitations, research outcome and approach employed by each protocol.
3. This article highlights the latest six-year surveys conducted for WSNs.

In this paper, we follow the following structure: Section 2 describes types of WSNs. Section 3 presents survey of mobile sink techniques for WSNs. The article is concluded in Section 4.

2. WIRELESS SENSOR NETWORK TYPES

According to the environment, WSNs are divided into six categories: underground, mobile, wireless body area, underwater, terrestrial and multimedia networks. In this regard, each Wireless Sensor Network type has its own data driven model mode, which involves transmission, computation and analysis. Land-based applications are terrestrial types of WSNs, which exist on the basis of data driven models and network application types. An illustration of an event-driven model is a forest fire. A forest fire sensor gathers data when a forest fire occurs, identifies the specific data, and transmits it to the sink node. Furthermore, weather forecasting can be either periodic or continuous (time-driven), where data is continuously collected on sensor nodes and sent to the sink node as a result of time slots. In the third model, the operator creates the query based on the specific data requirements in the healthcare process, which is mostly used in a query driven model. As a final point, hybrid data are dependent on environmental conditions and scenarios. An application can use more than one data-driven model.

There are various applications, routing protocols, and problems associated with each type of WSN. Various types of WSNs, applications, issues, and protocols for routing are shown in Figure 2.

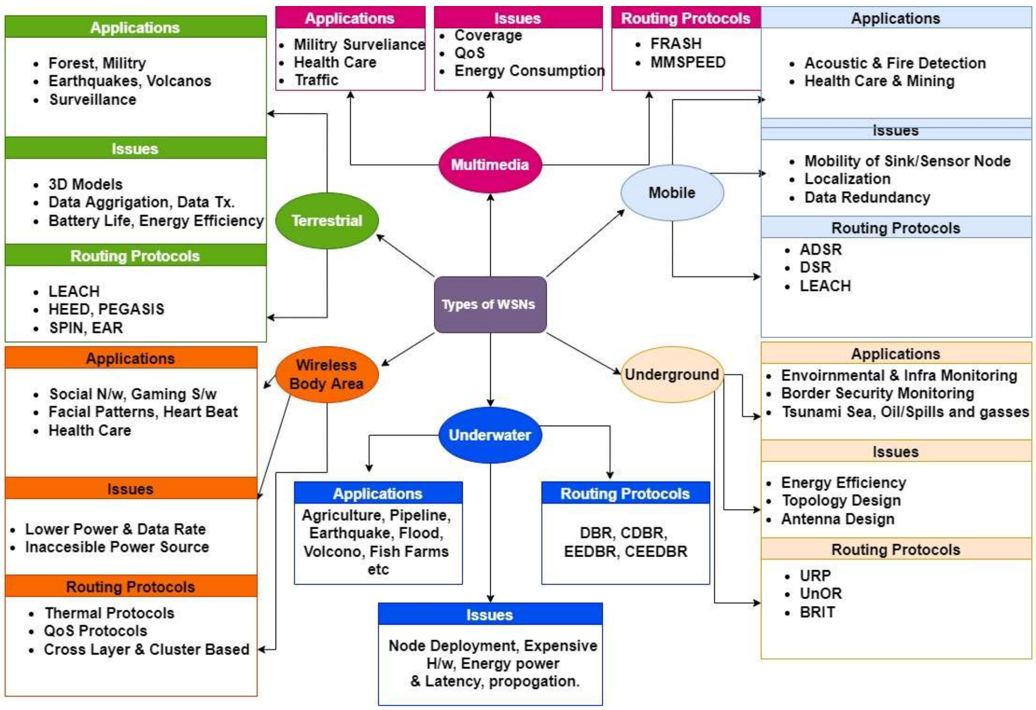

Figure 2 – Types of WSNs, applications, issues, and routing algorithms

3. SURVEY OF MOBILE SINK TECHNIQUES IN WIRELESS SENSOR NETWORKS

In this section, the existing mobile sink techniques are reviewed. Mobile sink techniques are reviewed in different categories based on mobile sink path finding, optimization techniques like Ant Colony Optimization, Particle Swarm Optimization, and Travelling Salesman Problem, Data Aggregation and Distribution Algorithms, Data Gathering Techniques, clustering based, routing based and Genetic Algorithms & Neural networks based.

Different mobile sink techniques based on mobile sink path finding are stated in below Table-1:

Table-1: Summary of Mobile Sink techniques based on mobile sink path finding for Wireless Sensor Networks

Author(s)	Year	Methods Used	Research Outcome / Scope	Limitations
Amar Kaswan, Md Azharuddin,	2017	Greedy Algorithm	The author of this research has proposed an algorithm for choosing a MS path in WSNs. According to the simulation	Those applications with a delay bound are not worth it.

Prasanta K. Jana [1]			findings, the suggested approach significantly decreased average waiting time, number of rendezvous points and MS path length.	
Kumar Nitesh, Prasanta K. Jana, Md Azharuddin [3]	2017	Voronoi Diagram	In this research, the authors present an approach for building a mobile sink's effective path in WSNs for cluster based applications. The proposed algorithm is performing better in terms of average waiting time, total path length, adaptability and fault tolerance than existing schemes.	Ineffective for gateways and dynamic sensor nodes. If the cluster heads are more than 110 then it will not work.
Ying Yang, Yisheng Miao [8]	2017	Path Planning Strategy	For Farmland WSN, a moving technique for MS and routing strategy for sensor nodes are suggested. The proposed approach improves the node energy usage rate and improves the network lifetime in order to lower the complexity of path computation.	The network will collapse when there are fewer than 70% nodes.

Different mobile sink techniques based on Ant Colony Optimization are stated in below Table-2:

Table-2: Summary of Mobile Sink techniques based on Ant Colony Optimization for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
Praveen Kumar D., Chandra Sekhara Rao Annavarapu and Tarachand Amgoth [21]	2018	Ant Colony Optimization	In this paper, authors propose a path determination algorithm for MS based on ACO method. Compared to existing algorithms, the	No method exists to determine the optimal number of ants to use.

			proposed algorithm performs better.	Not applicable in Extra large sensor node networks
Yong Lu, Xiuqin Pan, Na Sun [34]	2018	Artificial Bee Colony Algorithm	This paper presents artificial bee colony algorithms for path optimization for WSNs using MS. Proposed method is showing better performance for real time data collection and energy efficiency.	Sink mobile policy is not implemented for time delay constraints. Mobile data collection is not taken account for multi sink environment.
Muralitharan Krishnana , Sangwoon Yunb , Yoon Mo Jungc [41]	2019	Ant Colony Optimization	For efficient data collection, the authors introduced an enhanced clustering methodology that uses multiple mobile sinks (MMS). Based on simulation results, the proposed approach reduces data loss and improves network lifetime.	Sensor nodes are stationary in nature. Other bio-inspired algorithms are not used in the implementation of Mobile Sink.
Hong Zhang, Wanneng Shu, Zhanming Li, Jarong Chou [51]	2019	Ant Colony Optimization	This paper proposes a data collection strategy for industrial WSNs. The suggested approach can decrease latency and increase network lifetime.	The plan was not designed for obstacles and movable sinks.
Praveen Kumar Donta, Chandra Sekhara Rao Annavarapu, Tarachand Amgoth [62]	2020	Ant Colony Optimization	The authors proposed extended-ACO based MS path construction method in this paper. This algorithm increases the lifetime of wireless sensor networks while reducing data losses.	Embedded wireless energy transmitters are not used to recharge critical sensor nodes in WSNs through the Mobile Sink.

				Mobile sink has enough memory but memory of sensor node is limited.
Saugata Roy, Rajendra Pamula, Nabajyoti Mazumdar [82]	2021	Ant Colony Optimization	An innovative mobile sink-based data gathering protocol is presented in this paper. In terms of lifetime of network, consumption of energy, packet-delivery ratio, and end-to-end delay, the proposed protocol outperforms existing protocols.	Not useful for multiple Mobile Sink-based data gathering problems under storage constraints, as well as applications that are time constrained.
Kongara Mahesh Chowdary, Venkatanareshbabu Kuppili [93]	2021	Ant Colony Optimization	The authors of this study suggested the JayaX-LSM-CHS algorithm for choosing a productive group of Cluster Heads. According to the experimental findings, the Proposed Framework greatly lengthens the WSN's lifespan.	Useless for Mobile sensor nodes. Not practical for more than 250 nodes.
Xiaofeng Wu , Pingjian Zhang, Zhuangqi Chen, Hui Zhu and Yi Zhong [96]	2021	Ant Colony Optimization	The authors proposed an end-to-end strategy for collecting data. As a result of the experiments, it has been demonstrated that the proposed e-2-e strategy can improve lifetime of network and total consumption of energy, as well as the failure rate.	Not works if mobile sink moves at variable speed. Each sensor node's communication range is quite small.

Different mobile sink techniques based on Particle Swarm Optimization are stated in below Table-3:

Table-3: Summary of Mobile Sink techniques based on Particle Swarm Optimization for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
Shamineh Tabibi, Ali Ghafari [19]	2018	Particle Swarm Optimization Algorithm	This paper proposes a new method for selecting optimal rendezvous points using particle swarm optimization based selection (PSOBS). PSOB increases packet loss rates, according to simulation results.	One hop communication is used for data transfer. Each sensor node had limited memory for storage. It works only for randomly distributed sensor nodes.
Amar Kaswana, Vishakha Singha , Prasanta K. Janaa [20]	2018	Multi Objective Particle Swarm Optimization	The authors proposed an algorithm based on MOPSO for designing an energy efficient trajectory for the Mobile Sink. The proposed algorithm performs well on a variety of performance metrics.	An Energy efficient path was developed for single mobile sinks, not for multiple sinks.
Xialin He, Xiuwen Fu, Yongsheng Yang [46]	2019	MOPSO (Multi-Objective Particle Swarm Optimization)	In this study, a trajectory planning algorithm that is energy-efficient is proposed (EETP). The simulation results demonstrate that, in terms of energy usage, data delivery delay and network lifetime, the suggested EETP is superior than existing algorithms.	Need to apply multiple sinks to low-buffered networks to increase the frequency of RNs being visited by mobile sinks. Simulation is not performed for different

				topologies such as grid topology.
Hong Zhang, Zhang Li [67]	2020	Particle Swarm Optimization	The authors of this paper suggest a data collection method for mobile sinks in wireless sensor networks based on particle swarm optimization. According on the simulation results, the suggested mechanism performs better than the existing methods in terms of average energy exhaustion, running time and lifetime of network.	Not useful if transmission range is greater than 40m and target area is more than 400m * 400m.
Xiuwen Fu a, Xiaolin He [68]	2020	Hierarchical Clustering Algorithm and Particle Swarm Optimization	In this paper, a data collection algorithm is proposed to extend network lifetime by balancing inter cluster and inner cluster energy (BIIE). The suggested BIIE performs better than the existing algorithms in terms of network energy consumption, network lifetime, and the path length of the mobile sink, according to performance evaluation.	The suggested algorithm does not enable a multi-sink network, which will result in certain related issues, such as the load on each MS and how they cooperate.

Different mobile sink techniques based on Travelling Salesman Problem are stated in below Table-4:

Table-4: Summary of Mobile Sink techniques based on Travelling Salesman Problem for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**

Sanu Thomasa, Thomaskutty Mathew [26]	2018	Modified Travelling Salesman Problem	In situations where the sensors are heterogeneous and have varying communication ranges, the paper introduces a new technique for determining the best path for a mobile sink. When compared to other methods, this method can acquire more data.	Not useful for homogeneous Wireless sensor nodes with fixed communication range.
Tzung Shi Chen, Jen Jee Chen, Wei Qing Du [44]	2019	Travelling Salesman Problem	Two methods, B-ASAS and F-ASAS, were proposed in this study. In terms of reducing traversal length and saving energy, the proposed approaches outperformed the existing previous methods.	Due to the fact that it does not support multiple mobile sinks, the sink travels farther and takes more time.

Different mobile sink techniques based on other optimization techniques are stated in below Table-5:

Table-5: Summary of Mobile Sink techniques based on other optimization techniques for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
Niayesh Gharaei, Siti Zaiton Mohd Hashim, Kamalrulnizam Abu bakar, Suhail Ashfaq Butt, Ali Hosseingholi Pourasl [31]	2018	Sojourn Time Optimization Scheme for Mobile Sink	In this study, the Collaborative Mobile Sink Sojourn Time Optimization (CMS2TO) strategy is proposed. The output of the simulation demonstrates that the strategy is more effective for the network.	OMNET++ platform is used for the implementation. Not practical for randomly deployed sensor nodes.
Seema Dahiya, Dr.P. K. Singh [36]	2018	Optimization Algorithm	There is a new MSCOLER protocol proposed for Optimal Coverage restoration and Link stability estimation by the	The MATLAB platform is used for the implementation.

			authors. The suggested protocol can address the coverage restoration problem and shorten network lifetime, according to experimental results.	Not applicable in large sensor node networks.
Vinith Chauhan, Surender Son [42]	2019	Firefy-Optimization Algorithm	To enhance the network lifetime, the authors introduced a MS based energy aware clustering mechanism. In terms of communication and energy efficiency, the proposed work outperforms.	The sink mobility is used for 4 and 8 rectangular regions, but it can be implemented for 16 regions as well. Simulated for 200 nodes, but it can be simulated for more number of nodes.
Raj Anwit, Abhinav Tomar, Prasanta K. Jana [71]	2020	Shark Smell Optimization (SSO)	An algorithm based on Shark Smell Optimization is proposed in this article. The proposed algorithm is compared to existing schemes emphasizing that it is suitable for both delay lax and delay harsh DTNs.	Python is used for simulation. Limited number of nodes are mobile in nature.
Joohan Park, Jiseung Youn, Soohyeong Kim, Sunghyun Cho, Seyoung Ahn [76]	2020	trajectory optimization algorithm	In this research, authors suggested an iterative technique called ISCTO to reduce energy consumption of WSN components.	Not applicable in large sensor node networks.
Preeti Gupta, Samayveer Singh, Sachin Tripathi [90]	2021	Seagull Optimization and Salp Swarm (SOSS) Algorithm	For the energy-efficient routing in the HWSN model, authors proposed a hybrid SOSS that incorporates multiple MS. In comparison to other current Routing methods, the simulation results show that the suggested	Not useful for homogeneous WSN network. Not used any optimization technique.

			technique performs better in HWSN.	

Different mobile sink techniques based on Data Aggregation and Distribution Algorithms are stated in below Table-6:

Table-6: Summary of Mobile Sink techniques based on Data Aggregation and Distribution Algorithms for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
Prathima E G, S A Naveen, L M Patnaik, Laxmikant H, Venugopal K R, S S_Iyengar [5]	2017	Data Aggregation	A DAMS protocol for acquiring data from WSNs is proposed by the authors. At a comparable delay, DAMS has minimal energy dissipation per node and improved packet delivery ratio.	NS2 and C++ is used for simulation. Not practical for more than 500 and less than 100 nodes.
Mihaela Cardei and Catalina Aranzazu-Suescun [6]	2017	Distributed Algorithms	In this paper, various distributed algorithms are presented for detecting events in MS-WSNs.	WSNet simulator platform is used for the implementation. Not applicable in large sensor node networks. Security measures not taken care off.
Ammar Hawbani, Saleem Karmoshi, Xingfu Wang, Hassan Kuhlani, Rafia Ghoul, Yaser Sharabi, Esa Torbosh [7]	2017	Tree Based Data Dissemination Protocol	This paper proposes Sink-oriented Tree based Data-dissemination (STDD) for distributed sink-oriented dissemination of data. STDD outperforms existing approaches in terms of network-lifetime, delivery, latency and energy-consumption.	Useful for Homogeneous Sensors only. Mobile nodes are not supported by STTD.

Different mobile sink techniques based on Data Gathering Techniques are stated in below Table-7:

Table-7: Summary of Mobile Sink techniques based on Data Gathering Techniques for Wireless Sensor Networks

Author(s)	Year	Methods Used	Research Outcome / Scope	Limitations
Jin Wang , Hye-Jin Kim, Yu Gao, Xiang Yin and Feng Li [24]	2018	PEGASIS Algorithm	This paper proposes an algorithm to alleviate the problem of hot spots in sensor information systems called Enhanced Power Efficient Gathering in Sensor Information Systems (EPEGASIS). There are better performance results for EPEGASIS in terms of latency of network, energy-consumption and lifetime.	Hot spot problem is not solved. Simulated for 300 m network radius, but it can be simulated for larger area.
Chuan Z, G Han, Kangning Quan, J.J.P.C. Rodrigues [25]	2018	Location Predictive Data Gathering Algorithm	A location-based data collection scheme for mobile sinks with high availability is proposed in this paper. The proposed data gathering scheme performs better than existing schemes, according to simulation results.	Not useful for single sink. Implementation is done using the MATLAB platform.
Xiangping Gu, Baohua Yuan, Xiaofeng Zhou, Yanjing Sun [28]	2018	Bayesian Theory	The authors of this research introduced a novel Bayesian compressive data collection method. Compared to the random selection strategy, the proposed method can produce a uniformly distributed architecture of gathering nodes.	Obstacles are not avoided at the time of designing sink travel path. There is no practical application for a novel obstacle awareness compressive data gathering scheme.
Chih Yung Chang, I-Hsiung Chang, Shi Yong Chen,	2020	Multi Rate Data Collection	The authors propose a data collection algorithm called Multi Rate Data Collection (MRDC). It outperforms existing schemes in terms of	Not supported multiple mobile sink.

Diptendu Sinha Roy, Gwo Jong Yu [65]			the network lifetime, the energy consumption of each sensor, the path length, and both the effective and improvement indices.	Maximum transmission range of each sensor nodes is only 75m.

Different clustering based mobile sink techniques based are stated in below Table-8:

Table-8: Summary of clustering based mobile sink techniques for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
Jin Wang, J H Park, Sai Ji, Jiayi Cao [12]	2017	Cluster based dynamic routes adjustment approach with Energy efficient	In this study, authors suggested a cluster-based dynamic route adjustment method that is energy-efficient. Based on simulation results, the proposed approach performs well in the lifetime of wireless sensor networks.	Not practical for asymmetric link and heterogeneous sensor nodes.
Binit Saha, Gupta G P [14]	2017	Search Based Clustering with Improved Harmony	For mobile sink-based WSNs, this research suggests an improved harmony search-based clustering methodology. The results show that the improved HS algorithm with the improved objective function outperforms the existing protocols.	Energy consumption is more in proposed method.
Catalina Aranzazu-Suescun, Mihaela Cardei [16]	2017	Event Based Clustering	The authors of this research suggested a novel reactive routing system based on event-based clustering. The	WSNet is used for simulation. In big sensor node networks, not applicable.

			suggested protocol performs better.	
Areej Alsaa-fin, Zaher A A Ahmed M. Khedr [22]	2018	Cluster Based Method	For Mobile Sink, the authors propose a distributed data collection protocol. In terms of time complexity, energy and delay, the proposed protocol controls mobility in WSN efficiently.	MATLAB platform is used for the implementation. Not applicable in large sensor node networks. Not working for more that 500m * 500m Target area.
V. Saranya, G. R. Kanagachidambaresan, S. Shankar [23]	2018	The Markov model	The authors suggested an energy-efficient clustering approach using an MS-WSN. Based on lifetime and throughput, EECS outperforms MOD-LEACH.	Ineffective for heterogeneous sensor nodes. Initial Energy of All sensor nodes are 2J only.
A. Karimi, S. M. Amini [57]	2019	Hierarchical algorithm	For mobile sinks, authors presented a cluster-based routing method based on a number of predicted movement patterns. The performance of the simulation in terms of active nodes, lifetime of network, average residual energy and total consumption of energy is improved.	Not applicable in large sensor node networks. Wireless sensor nodes are static and homogeneous in nature.
Hailong Huang, Chao Huang , Dazhong Ma [59]	2019	Hybrid Compressive Sensing and Clustering	To calculate the energy usage of the suggested data collection method, the authors devised an analytical model. The	Packet loss and node failure are two concerns that the authors failed to take

			results show that the proposed technique can increase network lifetime.	into account, and as a result, they have an impact on the performance of the suggested solution. This strategy is ineffective for sensitive applications that require original data for analysis.
Govind P. Gupta, Binit Saha [69]	2020	Artificial Bee Colony and Differential Evolution	This study proposes a novel hybrid meta-heuristic method for the node clustering problem. The proposed method performs better, according to simulation results, in terms of average overall energy-consumption, residual-energy, energy-consumption and lifetime of network.	For cognitive radio-based sensor networks, no performance analysis has been carried out.
Raj Anwit, Prasanta K. Jana [74]	2020	Affinity Propagation Clustering	The authors of this research suggested an algorithm that creates a efficient path for the mobile sink. The suggested technique outperforms previous algorithms in simulations in terms of the number of path length and rendezvous-points.	The suggested approach uses a single MS, which causes a significant delay in data collecting, making it inapplicable for a large-scale WSN.

Gong Bencan, Chen Peng, Dong Panpan , Ren Dong [75]	2020	Fuzzy logic based clustering	In wireless sensor networks, an evolutionary game-based trajectory design approach is presented in this article. This algorithm balances load of network, reduces energy consumption of network, prolongs lifetime of network, and increases the number of data packets received by sinks.	Nodes have a finite amount of energy. Unable to support several mobile sinks.
Sercan Yalcin, Ebubekir Erdem [85]	2021	Adaptive Mobility Model	For burst traffic awareness, the paper presents a heterogeneous clustered WSN-based adaptive mobility scheme.	Implemented in NS-2. Not applicable for more than 500 nodes and 500x500 m^2 area
Qian Wei, Lin Zhou, Ke Bai, Yong Jin, Zhentao Hu, Junwei Li [89]	2021	Cluster Based Energy Optimization	"Cluster-Based Energy-optimization with Mobile Sink" is a new cluster-based energy optimization algorithm proposed in this paper. The simulation results demonstrate that the suggested CEOMS algorithm increases the self adaptability of the cluster head selection, increases the lifespan of the network, decreases data delay and balances network load.	Not supported multiple mobile sinks. Not useful for more than 100 sensor nodes and 300m * 300m simulation area.
S K Jain, Neeraj Shrivastava, M. V	2021	Hierarchical Clustering	For heterogeneous WSNs, the authors of this research presented the Non-uniform	Not useful for homogeneous WSN network.

katadari, R K Verma, Shubhra Jain [94]			Hierarchical-clustering with Dynamic-route Adjustment (NHCDRA) scheme. The results of the simulations demonstrate that the suggested algorithm enhances network lifetime and greatly cuts down on data delivery delays.	For single mobile sink, the proposed algorithm is useless.
Sercan Yalcin, Ebubekir Erdem [97]	2022	Mobile Clustering Routing Protocol	This study proposes a new clustering and routing scheme named TEO-MCRP. The simulation results demonstrate that the proposed protocol outperforms the existing ones in terms of consumed energy in the network, network life, packets received by base station and end to end delay compared to existing methods.	Not applicable in large sensor node networks. Not practical for more than 500 nodes
Madana Srinivas, Tarachand Amgoth [99]	2022	Hierarchical Clustering Approach	The article presents a method for identifying the optimal set of MS for scheduling data packets. A proposed routing algorithm achieves improved packet delivery ratio and throughput.	Implemented in Python. Not useful for more than 500 m^2 area.

Different mobile sink techniques based on routing algorithms are stated in below Table-9:

Table-9: Summary of Mobile Sink techniques based on routing algorithms for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
S-Wu, J-Niu, W-Chou, M-Guizani [32]	2018	Delay Aware Energy Efficient Routing	It is proposed in this paper that an energy-efficient routing algorithm can be designed for WSNs with path-fixed mobile sinks. Simulation result shows that proposed algorithm reduces the transmission cost.	Not practical for multiple path fixed sinks. As performance parameters End-to-End delay, the transmission cost and total amount of collected data are not taken into consideration.
Ayush Agrawala, Vinay Singha , Shubhra Jainb , Rajeev Kumar Gupta [33]	2018	Grid Cycle Routing Protocol	The authors of this research suggested a new Grid Cycle Routing Protocol (GCRP). At various network sizes, the suggested technique performs better than the existing methods.	Data distribution Strategies are not being developed for random and unpredictable sink mobility patterns.
Tran Cong Hung, P Thi The, Dang T Ngoc, L.N.T. Huynh, Le Ngoc Hieu, Le Dien Tam [43]	2019	LEACH and Dijkstra Algorithm	Dijkstra and LEACH-C based Routine method is presented by authors in this paper. The simulation's outcome demonstrates that working in homogeneous sensor environments is more effective.	Not efficient for working with heterogeneous sensor environment.
S Jain, R K Verma, A Shukla, K K Pattanaik [48]	2019	Query Driven Ring Routing Protocol	The authors of this study suggest a query-driven ring routing protocol (QRRP) that is built	The NS-2 is used for the implementation.

			on virtual ring architecture. When compared with existing methods, simulation results show a significant reduction in consumption of energy and data delivery delay.	Not useful for continuous, mobile sink movement.
Shayesteh Tabatabaei, Amir Mohsen Rigi [49]	2019	Distributed Clustering Reliable Routing Protocol	The authors of this work developed a novel, highly reliable distributed clustering routing protocol called DCRRP. It was discovered that the proposed protocol outperforms the NODIC protocol in terms of power usage and end-to-end delay.	The proposed method is simulated using OpnetModeler 11.5. Suitable for only random node distribution not suitable for fixed node distribution.
Sonam Mauryaa, Debanjan Roy Chowdhury, Vinod Kumar Jaina [52]	2019	Delay Aware Energy Efficient Reliable Routing	An innovative mobile sink routing strategy is suggested in this study. The simulation findings demonstrate that the suggested approach performs better in networks with dense deployment and high sink mobility.	The suggested energy-efficient routing is useless for large dense networks with multiple mobile sinks.
Saugata Roy, Nabajyoti Mazumdar, Rajendra Pamula [61]	2020	Cluster Based Routing Protocol	An energy-aware hierarchical routing protocol is proposed by the authors. Due to its distributed nature, the proposed	Simulated for 200x200 m^2 area, but it can be simulated for larger area.

			protocol offers reduced communication and computation overheads.	Proposed algorithm is of distributed in nature but we can also use static nature.
S Jain, S Bharti, R K Verma, A Shukla, K K Pattanaik [63]	2020	Delay Aware Green Routing Protocol	A virtual infrastructure based Delay-aware Green Routing Protocol (DGRP) is proposed in this paper. The simulation results show that DGRP is more efficient and has a higher throughput than existing routing protocols.	Not suitable for sparse sensor networks. Unable to support several mobile sinks.
M-Naghibi and H-Barati [64]	2020	“Energy efficient geographic routing protocol”	In this paper, Authors proposed a method of dividing the network into some cells in a geographic direction and applying two mobile sinks to collect the data sensed by the cells. Simulation results show that EGRPM significantly reduces average energy consumption, packet delivery rate, end-to-end delay, and network lifetime when compared to conventional methods.	Implemented in NS-2. Simulated for 500x500 m^2 area, but it can be simulated for larger area.

O Busaileh, W Xingfu, A Hawbani, L Zhao, Ping Liu and A Al Dubai [66]	2020	Distributed Routing Protocol	In this paper, Tuft is proposed as a novel hierarchical tree structure protocol for mobile sinks. According to performance evaluations, Tuft extends the life of the network and reduces energy consumption.	Proposed algorithm is of distributed in nature but we can also use static nature. Used only 1 mobile sink.
T C Hung, P Thi The [87]	2021	Ant Colony Optimization Routing Algorithm	For extending the life of networks, the authors propose combining colony-optimization algorithm, MS and ACO routing methods named as LEACH-CACO. LEACH-CACO saves energy and extends network lifespan, according to simulation results.	Implemented in MATLAB. Not useful for more than 100 sensor nodes and 100m * 100m simulation area.
Ying Yang, Huarui Wu, Wude Yang, Yisheng Miao [95]	2021	Distance Probability Transmission Strategy (DPTS) Routing	An approach for developing MS paths based on virtual potential fields is proposed by the authors of this paper. Excellent transmission efficiency and network lifespan were demonstrated by the simulation findings.	Unable to create rendezvous point selection criteria that take real-time requirements into account.

Different mobile sink techniques based on Genetic Algorithms & Neural networks are stated in below Table-10:

Table-10: Summary of Mobile Sink techniques based on Genetic Algorithms & Neural networks for Wireless Sensor Networks

Author(s)	Year	Methods Used	Research Outcome / Scope	Limitations
Raj Anwit, Prasanta K. Jana [29]	2018	Genetic Algorithm	A novel variable length Genetic Algorithm-based approach for data gathering by Mobile Sink is provided in this research study. Proposed algorithm is performing better in terms of data collection time and path length.	Python is used for simulation. Not applicable to more than 300 and less than 50 nodes
Jin Wang , Wei Liu, Yu Gao , Hye Jin Kim, Arun Kumar Sangaiah [39]	2019	Data Fusion using Neural Network	IDGS-DF is an intelligent data gathering schema with data fusion presented by the authors. Consumption of energy and lifetime of network are improved by the proposed algorithm.	There is a limitation in the training process of neural network in that great computational ability is required. Not applicable in large sensor node networks.
Anjula Mehto, Senior Member, Shashikala Tapaswi, K.K. Pattanaik [58]	2019	Greedy Algorithm	In order to obtain data for Mobile Sink, this work offers a rendezvous points-based delay efficient trajectory building algorithm. The no. of RPs and latency of data-acquisition are significantly decreased by the suggested	The suggested approach is unsuitable for applications that require delays. The amount of time that mobile sinks must spend collecting data is

			strategy, according to simulation findings.	little and the sensor nodes produce data at the same rate.
Samad Najjar Ghabel, Seyed Naser Razavi, Leili Farzinvash [60]	2020	Artificial Intelligence Algorithms	This paper proposes DGOB, an algorithm that provides effective data gathering in WSNs with obstacles. Based on the simulation results, DGOB outperforms in terms of parameters such as active-nodes, average exhaustion of energy and average lifetime of network.	Running time per round of DGOB is not compared for more than 500 sensor nodes.
Raj Anwit, Abhinav Tomar, Prasanta K. Jana [70]	2020	Christofide Algorithm	In this study, a novel plan for the trajectory design of a MS for data gathering is proposed. The proposed approach became more effective in terms of RPs, variance of RPs, path length and energy consumption.	Not applicable in large scale WSN. Not useful for heterogeneous WSNs. MATLAB is used for simulation.
Khalid A. Darabkh, Feras A. Al naimat, Enas N. AL zoubi, Ala F. Khalifeh [78]	2020	Genetic Algorithm	This article suggests a mobile sink-based efficient clustering strategy for effective data collection. The simulation findings of this work demonstrate considerable advancements over the techniques now in use.	Not applicable to more than 50m x 50m network size.
Chaya Shivalinge Gowda, P. V. Y. Jayasree [84]	2021	Neural Network	An innovative hybrid neural network-based routing technique using rendezvous points is presented in this study. The simulation findings demonstrate that, in terms of energy-use, throughput, packet loss ratio,	The MATLAB platform is used for the implementation.

			packet delivery ratio, delay, latency, jitter and network lifetime, the proposed methodology outperforms the prior approaches.	Useless for nodes that are more than 400.
Houriya Hojjatinia, Mohsen Jahanshahi, Saeedreza Shehnepoor [91]	2021	Gaussian Mixture Model	This study presents the GDECA algorithm, which uses the Gaussian Mixture Model (GMM). The proposed GDECA algorithm outperforms in terms of active-nodes, number of mixture-models and consumption of energy.	Not useful for single sink. For mobile nodes, the proposed algorithm is useless.

Different survey based mobile sink techniques are stated in below Table-11:

Table-11: Summary of survey based Mobile Sink techniques for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
Aparna Ashok Kamble , B.M. Patil [79]	2021	Survey Paper	Authors present a study on path optimization strategies in this paper. Authors conduct a thorough investigation based on a number of factors.	---
Vaibhav Agarwal, Shashikala Tapaswi, Prasenjit Chanak [80]	2021	Survey Paper	A survey of different path selection algorithms for mobile sinks is presented by the authors.	---
Sangdae Kim, Babar Shah, Beom Su Kim, Ki-Il Kim, Sana Ullah [88]	2021	Survey Paper	This survey article explains the significance of mobile sinks in WSNs.	---
S Jain, R K Verma, K K	2022	Survey Paper	Hierarchical routing protocols are presented in this paper for event driven and query driven	---

Pattanaik, A Shukla [100]			scenarios for data transmission.	

Different other mobile sink techniques are stated in below Table-12:

Table-12: Summary of other Mobile Sink techniques for Wireless Sensor Networks

Author(s)	**Year**	**Methods Used**	**Research Outcome / Scope**	**Limitations**
S. M. Amini, M. Esnaashari, A. Karimi[45]	2019	Hexagonal Cell Based Infrastructure	The paper proposes a data dissemination algorithm that uses minimal energy for sensing nodes. Compared to the existing schemes, the proposed scheme consumes less energy, costs less to update sink positions, and has a longer network lifespan.	The simulations were conducted using the NS2 simulator. Not useful for more than 400 sensor nodes and 200m * 200m deployment area.
Yu Sui, Mengze Yu, Xiaohui Zhang, Jiajia Huan [50]	2019	Markov Chain Process	A strategy for robot assisted sink node movement control is proposed in this paper. Simulation findings demonstrate that the approach saves more total transmitting power than a current approach.	not practical for multiple robot-assisted mobile sinks in large scale sensor networks.
Lei Tao, Xinming Zhang, Weifa Liang [54]	2019	Energy-Harvesting WSN	The authors of this research suggested an optimization methodology for data collecting. Using simulations, the proposed	The MATLAB platform is used for the implementation. Simulated for only 49 nodes and 180 x 180

			algorithms are shown to be efficient.	square meter area.
Jayavignesh Thyagarajan, Suganthi Kulanthaivelu [72]	2020	Quasi Mobile Sink	In this study, a joint hybrid OPSER design and path limited QMS for large scale, lossy WSN on the IoT were proposed. The proposed method performs better, according to simulation results.	It does not support dynamic deployment of nodes. Only takes into account lossy link behavior.
Jinghui Zhong, Liang Feng, Zhixing Huang, Ying Li, Wan Du [73]	2020	Heuristic Based Scheduling Strategy	The authors of this research suggested a hyper heuristic framework for the mobile sink. The simulation outcomes showed that the suggested strategy outperforms the existing method in terms of response time and lifetime of network.	The complexity and quality of H_2S is not optimize at the same time.
Zhang Lin, Ruikun Wu, Huan Chao Keh, Diptendu Sinha Roy [77]	2020	Minimum Spanning Tree	A data collection mechanism called DDCF is proposed in this paper. The suggested algorithm performs better in terms of network lifetime, fairness, and surveillance quality than existing studies.	For multiple mobile sinks, proposed algorithm is useless.
Craig Thomson, Zhiyuan Tan, Isam Wadhaj, Ahmed Al-Dubai [81]	2021	Carrier-Sense Multiple Access	The authors of this paper provide a simple MAC layer solution called	Not practical for more than 25 nodes and 200m

			"Dynamic Mobility and Energy Aware Algorithm (DMEAAL)". This approach, as opposed to earlier ones, balances energy consumption across individual nodes without increasing overall energy consumption.	* 200m grid topology size.
Omar Banimelhem, Eyad Taqieddin, Ibrahim Shatnawi [83]	2021	Principle Component Analysis	This paper presents a principal component analysis (PCA)-based algorithm for generating paths for the mobile sink. Based on simulation results, the proposed approach increases average remaining energy and live-nodes in WSNs.	Not supported multiple mobile sinks. Analyzed the results with one statistical tests
S.Jain, R.K.Verma, K.K.Pattanaik, A.Shukla [86]	2021	virtual wheel based data dissemination using Event driven	A novel "event-driven virtual wheel-based data dissemination scheme (EDVWDD)" is presented in this paper. EDVWDD performs better than existing techniques in terms of delay of data delivery and consumption of energy.	Data dissemination strategies are not implemented for multiple mobile sinks.
Anjula Mehto, Shashikala Tapaswi, K. K. Pattanaik [92]	2021	Squirrel Search Algorithm	This study suggests a method for choosing rendezvous point	The NS-2 platform is used

			based on a squirrel search algorithm (SSA-RPS). The simulation results show that in terms of network lifetime, data gathering ratio, energy consumption and dropped packets, the SSA-RPS performs better than the existing approaches.	for the implementation. Transmission range of sensor node is limited to 50m.
Rahul Kumar Verma, Shubhra Jain [98]	2022	Grid Based data acquisition Mechanism	In this paper, an energy and delay efficient data acquisition technique is proposed in the form of EDEDA. A proposed routing algorithm achieves higher throughput and energy efficiency than existing routing protocols.	Implemented in NS-2. Simulated for 200x200 m^2 area, but it can be simulated for larger area.

4. CONCLUSION

The field of mobile sinks is becoming increasingly interesting in WSNs. In recent years, a great deal of research work has been devoted to this field alone. There are many aspects of this field that have become important to every individual. The significance of MS in WSNs was discussed in this survey. We reviewed various mobile sink techniques that have been researched during the past six years. In addition, we briefly described and compared the operation processes of the studies. All the techniques are analyzed based on factors such as methods used, outcomes and limitations. Research outcomes and limitations of each approach are evaluated comprehensively in order to encourage and provide direction for future research.

CONFLICTS OF INTEREST

No author has disclosed any conflicts of interest.

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