A Survey on Deploying Mobile entities to Enhance the Lifetime of Wireless Sensor Network

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Abstract— Deployment of mobile sinks for data collection has been well recognized in various recent research papers. Mobile sinks are used in order to collect the data from the sensor nodes in the network. Mobile elements are deployed are entities used for data collection from the sensor nodes in the network. Rather than placing the sink as static which may lead to an earlier demise of the network the mobile sinks in contrast are made to move along the network area. In this paper we propose usage of multiple mobile sinks that changes their location accordingly to our proposed pathway. The pathway is engineered in a way so that it tries to distribute the load fairly among the sensor nodes in the network thereby intensively increasing the network lifetime. We have considered both constant and adaptive stopping time for sinks and have also formulated a Linear Programming Model which optimizes the sensor network lifetime

Keywords— Sensor Network, Mobile sink, Wireless Network, Sensor network lifetime, Predestined pathway., Style, Styling, Insert (key words)

I. Introduction

Sensors have become a very trendy research area during the last few years covering a wide range of applications such as habitat monitoring, military surveillance, information collecting etc. Sensors exploited for these purposes needs to be deployed very densely and in a random fashion. They should also be able to operate without human intervention. Many techniques are employed to increase the various capabilities of a sensor network. Wireless sensor networks (WSN) comprises of a large number of sensor nodes possessed with sensing and routing capabilities and are able to communicate with each other. Since clustering provides numerous benefits over flat network, the nodes are clustered in to various groups where each group is under the control of a cluster head. The cluster members should communicate the sensed data to the cluster head for further processing. In such a kind of scenario nodes that are closer to the cluster head or sink tend to consume more energy compared to other sensors nodes. This is because; sensor nodes that are located far away cannot communicate their data directly to the sink. So, multi hop communication is used for forwarding the data. Due to this, the nodes that are nearer to the sink besides transmitting their own packets, they forward packets on behalf of other sensors that are located farther away. As a result of this, the sensors closer to the sink will drain their energy resources soon, resulting in formation of energy holes in the network. Energy hole represent a scenario where nodes around the sink deplete their energy completely thus making it impossible for the rest of nodes to communicate with the sink. Due to this reason the area around the cluster head or sink is termed as hotspot.

A critical issue for data gathering in wireless sensor networks is the formation of energy holes near the sinks. Sensors near the sinks have to participate in relaying data on behalf of other sensors and thus will deplete their energy very quickly, resulting in network partitioning and limitation of the network lifetime. The proposed work aims to improvise the lifetime of wireless sensor network by utilizing mobile entities in the network. The work recommends usage of mobile sinks rather than a static sink for data collection. Usage of mobile sinks helps in frequently changing the fair distribution of load among the sensors thus decreasing the chances for energy hole formation..

II. Design Issues and Challenges

Implementing cluster based architecture requires a significant amount of work to be done. Clustering offers a wide range of advantages for a sensor network but still it has its own drawbacks, issues and challenges. In this section we outline several concrete design and implementation issues involved in the development of cluster based network architecture

A. Node Mobility

Most of the network architectures assume that nodes are stationary. But sometimes it is compulsory to support the mobility of base stations or CHs. Node mobility makes clustering a very challenging task since the node membership will dynamically change, forcing clusters to evolve over time.[4]

B. Traffic Load

Events that are monitored by a sensor network can either be continual or intermittent. Intermittent monitoring generates traffic in the network only when detecting the event of interest, whereas continual monitoring generates traffic at frequent intervals as they continually sense information. Since intermittent events requires only occasional sensing it does not reflect any change in the CH, whereas intermittent events unevenly load CHs relative to the nodes in the cluster and a rotation of CH role may be required if the CH is randomly picked from the sensor population[4].

C. Overlapping Clusters

As stated earlier the cluster head CH may be predesigned by the network designer or elected by the sensors in the network. If the later one is opted there is a possibility that a member of one cluster may become the member under another CH. This makes the overlapping clusters also to be considered in the design issues. It is therefore important to establish necessary mechanisms for detecting the existence of overlapped clusters and coordinating between clusters to avoid unfairness, starvation or deadlock during resource competition [7]

D. Load Balancing

Load balancing is one of the most pressing issues in sensor networks where CHs are picked from the available sensors. The member sensor nodes needs to be evenly distributed among the different CHs available which if fails will overload a particular CH leading to the failure of that head. So in such cases it is necessary to design equal sized clusters for a fair balancing.

E. Dynamic Cluster Control

It is necessary to configure a self-configuring clustering mechanism with a sensor network. The clustering mechanisms are responsible for the formation of initial clusters which needs to adapt to its location. The clusters are formed based on several metrics like data accessibility, node capacity, network connectivity etc. One of the important design issues in clustering is the cluster head has to dynamically determine the membership of the nodes as the phenomenon moves. It has been noted in [7], that when the target is beyond the sensing range of the CH, another round of head election is necessary to find a new CH.

F. Inter-cluster Coordination

To achieve the desired goal CH's needed to communicate with each other. They might need to communicate for sharing of information and to achieve coordination. Further data gathered by one cluster can be requested by base station or other CH across the network. So the self-configuring clustering mechanism should be capable of handling inter-cluster communication overheads.

G. Data Aggregation

The CH needs to perform the task of aggregating and transmitting the data from the nodes in the cluster to the CH and hence consumes more energy. So there should be a proper care taken while deciding the CH. One way of conserving the energy of the CH's is by rotating the roles between different nodes, at periodic intervals. Another option is to have the powerful node that can handle the additional energy requirement, to act as the CH.

H. Fault Tolerance

Fault tolerance is the ability to sustain sensor network functionalities without any interruption due to sensor node failures. Some sensor nodes may fail or be blocked due to lack of power, have physical damage or environmental interference. The failed node might be a CH or a member of the cluster. Such failures should not affect the overall task and performance of the sensor network. So it is therefore necessary to have a mechanism which will adapt to these types of failures.

I. Scalability

After the initial formation of clusters, the CH should be able to adapt to either increase or decrease in its cluster member's count. The member count of a cluster may change due to various factors. For example a cluster member may fail due to environmental threat. During this time the CH should adapt t a decrease in its member count. On the flip side, increase in the member count may also happen during circumstances like addition of new sensor nodes, failure of an existing CH etc. Similarly the sensor network itself should be capable of adapting to either increase or decrease in the number of clusters.

J. Number of Clusters

Total number of clusters or cluster count is another important design issue to be considered. It is necessary that the cluster count should be very optimal, which if fails leads to network complexity and management overhead. Formation of optimal number of clusters will make the network energy efficient.

K. Cluster Formation Time

The time taken by the network to form the initial cluster should be very minimal. Events including the choice of cluster count, selection of CH, allotment of cluster members to a CH should be done with in minimum period of time.

L. Single hop Vs Multi hops Network.

Communication in clustering can be either single hop communication or multi hop communication. As the transmission energy varies directly with the square of distance therefore a multi –hop network is suitable for conserving energy [8]. But Multi hop network raises various design issues regarding to topology management and media access control. This is another issue to be considered.

M. Node Heterogeneity

Some applications of sensor might require a diverse mixture of sensor nodes with different types and capabilities to be deployed. Data from different sensors can be generated at different rates; network can follow different data reporting models and can be subjected to different quality of service constraints. Such a heterogeneous model will make clustering a difficult one and making the job of CH as a tougher one. [8]

N. Cluster Formation

The cluster formation has to consider in to account several things like whether the cluster formation is centralized or localized, whether the number of clusters is assigned a priori or is it formed distributed etc. the cluster based routing protocols should address to such kind of design issues in sensor networks. To distribute energy load evenly among the sensors, each sensor in a cluster randomly becomes the cluster head. However the percentage of cluster heads in a network is pre assigned by the network designer.

O. Self-Configuration and Reconfiguration

One of the most important phases of cluster formation is the self – organization phase. The clusters should have the capability self-configuring themselves. How fast the network self-organize in did to functional unit is one of the important issues in wireless sensor network. To maximize the network life time the self-organizing phase should be short and energy efficient. Another issue is Reconfiguration or Replenishment. Replenishment can be defined as the process of adding new fresh sensor nodes with full energy reserve to replace old and energy depleted sensors. Reconfiguration is the process of self – organization after the loss or addition of new sensor nodes.

III. MOBILE DATA COLLECTORS APPROACH

In this approach a special node is destined for data collection. The data collector move around the network area to visit the sensor nodes. Sensor nodes usually buffer their sensed data until the data collector visits them. As soon as the data collector approaches the sensor node, the data is transferred over a single – hop communication. This method minimizes the energy consumption as it eliminates the expensive multi – hop communication. In this method as the nodes are aware of the data collector trajectory, they are able to enter in to sleep mode for a specific time period thereby minimizing the energy consumption.

The work by Chatzigiannakis et al (2002) exploits few of the sensor nodes in network to act as forwarding agents. The forwarding agents move around the network to collect data from the sensor nodes and carry those packets to the destination nodes. The sensor nodes communicate their sensed data to the agent when the agent and the sensor node are within the vicinity of each other. The data received from the sensor nodes is then delivered to the destination node when the agent node passes near the destination node.

The idea of using “data mules” was introduced by Shah et al (2003) in their works. Here special nodes termed as mules are utilized as forwarding agents. The primary goal here is to save the energy consumption by allowing single-hop communication rather than an expensive multi – hop communication. Sensor node ready with the sensed data communicates it to the passing by mule. The mule will carry the data collected from all the sensors and communicate it to the sink. This approach increasing the network lifetime by reducing the energy expenditure incurred to propagate the sensed data to the sink.

The approach of using forwarding agents was further enhanced by Kim et al (2003) which suggest a dissemination protocol named SEAD (Scalable Energy-Efficient Asynchronous Dissemination). The protocol constructs and maintains a tree-like communication structure which will be exploited by the mobile sinks to access the sensor nodes. In another work proposed by Chakrabarti et al (2003) data is collected by vehicles when they pass near the sensors. Here the sensor nodes are aware of the trajectory of the vehicles. Based on the knowledge about the trajectory, the sensor nodes predicts the data transfer time and would enter in to a sleep mode until that time.

Somasundara et al (2004) proposed the concept of using data collection nodes called mobile elements (MEs). The MEs are programmed to visit the sensor nodes for data collection such that no buffer overflow occurs at the sensor nodes. A node with maximum buffer usage is allotted the high priority for the ME to visit next. This is termed as Earliest Deadline First (EDF) category. The drawback with EDF is nodes with approximately equal buffer usage suffer heavy data loss. So to eliminate this shortcoming, a variant of EDF termed as Minimum Weight Sum First (MWSF) was proposed. MWSF considers not only the buffer usage but also the distance between the nodes to identify the visiting schedule.

In Wang et al (2005) the authors consider heterogeneous network composed of few energy rich mobile nodes and a set of static nodes. The authors investigate the performance of using mobile nodes and mobile relays and suggested two joint mobility and routing algorithms. They experimented with a network encompassing three different scenarios. (i) Static network (ii) Network with one mobile sink (iii) Network with one mobile relay. It is proved that utilizing mobile sink enhances the network lifetime to a great extent and also concluded it is not always possible to use mobile sink in hostile terrains. They also state that to prolong the network lifetime the mobile relay should stay within two hops away from the sink.

Vupputuri et al (2010), focused on enhancing the network lifetime by utilizing the concept of mobile data collectors (DCs). A heterogeneous WSN is considered which comprises of a set of sensor nodes, set of few DCs, and a static Base Station (BS). The sensor nodes are assumed to be fixed and are deployed uniformly in the environment. The DCs are assumed to be mobile and it is possible to control their mobility. A sensor node in the network passes its sensed data to its nearest DC. The DCs in turn aggregates the data received from the sensor nodes and communicates the received packets periodically to the BS. This strategy tries to delay the hotspot formation thus increasing the network lifetime to a large extent. The sojourn points are chosen in such a way that the load is equally distributed over the network.

IV. MOBILE BASE STATION APPROACH

In this approach instead of using data collectors for data gathering from the sensor nodes, the base station (BS) itself is relocated. The base station is allowed to move along the network area for collecting sensed data from the sensor nodes. The movement of the base station can either be on a predetermined trajectory or on a random trajectory. In predetermined trajectory, the base station moves along a predestined pathway for data collection. The drawback with such kind of method is the predetermined pathway is not energy conscious. As the BS repeatedly visits the same set of nodes along the pathway, the energy level of those nodes will deplete soon. An alternative to this approach is to make the BS to move towards energy rich zones. Network lifetime will be enhanced in the later approach as the pathway of BS is energy conscious and different set of nodes are visited along the trajectory.

Maximizing the lifetime of Wireless Sensor Network with mobile elements has been well recognized in various recent research papers. Many research works has focused on the usage of mobile base stations. The work in Gandham et al (2003) was one of the pioneering researches in the utilization of multiple mobile base stations. The authors attempted in minimizing the energy consumption of sensors by determining specific base station movements. The authors presented an ILP (Integer Linear Programming) model to determine the feasible sojourn positions of multiple base stations and exploited a flow based protocol by allowing multi-hop routing to the base stations. The ILP model targets at reducing the energy consumption per node and the total energy consumption in the course of a given time. For obtaining better results on energy parameter the authors permits the presence of multiple base stations in the network. The authors argue that utilizing multiple base stations yields minimization of energy consumption thus leading to network longevity.

Kansal et al (2004) proposed the concept of using rendezvous points (RP) for data collection. In this method the sink moves along the network in a straight line path. The sink issues a beacon message containing a hopcount value which indicates the number of hops the sink has travelled. Sensors receiving this beacon message will rebroadcast it after incrementing the hop count by one. At the end of this phase clustering trees are formed across the network with sink as root. This root is considered as a RP. The sink visits the RP during its tour for data collection.

Baruah & Urgaonkar (2004) address the concept of using mobile sink which follows a fixed pattern for data collection. Initially the sink tour is divided in to number of time domains with a weight assigned for each domain. At the beginning, all the neighbours have equal weight assuring every location is best for the sink to sojourn. In the subsequent rounds, the weight assigned for each domain will vary according to the energy consumed. The goal of the algorithm is to find the best sojourn point and optimal way to forward data from the sensors to the sink.

The next prominent work that focused on the same area is Wang et al (2005). Here the authors exploited a single base station to move along a square grid of sensors. The paper is concerned with the combined problems of determining the movements of the sink as well as the sojourn time of the sink at various locations in the network. A simple elegant novel linear programming formulation is presented for maximizing the network lifetime in terms of sink sojourn time at the nodes. Contrarily from the linear programming formulation in Gandham et al (2003), the model proposed by Wang et al (2005) concerns the overall network lifetime directly, instead of indirectly inferring it from the greedy minimization of the energy consumptions at the nodes. Simulation experiments of Wang et al (2005) shows very good improvements concerning with the results which are almost five-fold when compared to the static sink case.

Subsequently, another significant and refined work was proposed by Papadimitriou et al (2005) by explicitly citing the various shortcomings in Wang et al (2005). Papadimitriou et al declares that Wang et al (2005) considers only a specific type of network and the initial energy and the data generation rate are considered to be alike for all the sensor nodes. Differently from the Linear Programming Formulation proposed by Papadimitriou, the optimization model in Wang et al (2005) determines only the sink sojourn time, separating the routing problem outside the optimization. Although it employs a shortest path algorithm to route data packets to the sink, it does not considers the residual energy of sensors, thus ensuing in an overall network lifetime which is not optimal. Elegantly quoting such drawbacks with Wang et al (2005), Papadimitriou proposed another linear programming formulation taking routing inside the formulation and alleviating the drawbacks said by Wang et al.

Luo & Hubaux (2005) proposed another work where the lifetime maximization has been formulated as a min-max problem. They consider mobility of the sink and data routing together, and obtained a solution that has a very good balance on the load, while keeping the sink mobile on the perimeter of the network. Simulation results achieves 500% higher lifetime than when the sink stays in the centre of the network.

In Jea et al (2005) multiple mobile sinks are used for data collection. Here the network area is divided in to equal sized areas and each area is assigned with a sink. Each area forms a communication structure to pass the data to its allotted sink.In order to eliminate unbalanced load along the sink trajectory a load balancing algorithm is framed which will confirm approximately equal number of sensors.

Accepting the opinions of Papadimitriou and Georgiadis about the drawbacks in Wang et al (2005), Basagni et al (2006) proposed another Mixed Integer Linear Programming formulation which identifies sink route and sojourn time at the sink sites. Different from their previous research work in Wang et al (2005), more realistic parameters and constraints of a WSN are considered in Basagni et al (2006). Cost of moving the sink from a sink site to another, both from data latency point of view and from the energy consumption point of view is focused in this work. Quoting that their ILP produces centralized solution to the problem of finding sink routes which is not suitable for most WSN applications, a second contribution is proposed by them. The second contribution of their work which is termed as the Greedy Maximum Residual Energy (GMRE) protocol is a completely distributed and localized protocol for sink mobility. Here the sink is drawn towards energy rich areas of the network.

The works in Azad & Chockalingam (2006) and Somasundara et al (2006) focused on the idea of dense deployment of sensors around the base station in order to reduce the formation of energy holes near to it. But such a deployment may result in a sensing coverage which is unbalanced. In Wu et al (2006) the authors consider a WSN with one mobile sink which frequently changes its location to reduce the formation of holes in the network. The mobile sink moves towards the nodes that have highest residual energy to distribute the load fairly among the sensors.

In Mir & Ko (2006) the authors proposed a protocol termed as Quad tree-based partitioning. In this approach, when a sensor node senses a new event, it computes a set of rendezvous points by consecutively partitioning the sensor field into four equally logical quadrants, and the data reports are sent to the nodes which are closer to the centroid of each successive partition. The mobile sink follows the same strategy for the query packet transmission. The main drawback of this approach is that few static nodes will be selected as rendezvous points inducing a hot spot problem which may decrease the network lifetime and reliability.

Lin et al (2006) proposed a clustering protocol named The Hierarchical Cluster-based Data Dissemination (HCDD) protocol. The protocol defines hierarchical cluster architecture which tracks the position of mobile sinks and also establishes routing patterns for data dissemination from the sensors to the sink. The nodes are grouped in to clusters with each cluster assigned to a cluster head. The cluster head are within the vicinity of each other and maintains a backbone structure. A mobile sink moves around the network for data collection. During its movement the mobile sink records itself to the cluster head within its vicinity. A notification message regarding the sink's positions is broadcasted to all other cluster heads. The cluster head that receives this notification message stores the sink id and sender's information for future data transmission. The shortcoming of this protocol is high traffic concentration over the cluster heads which will induce the formation of hotspot. Another drawback is the difficulty involved in maintaining the backbone structure comprising of cluster heads.

Jarry et al (2006) examine the mixed data gathering scheme in WSNs. Under the mixed data gathering scheme, an intermediate node either transmits its data to one of its neighbours or directly to the sink, so an implicit assumption is that each node is able to communicate directly with the sink. They propose a distributed data gathering algorithm for evenly distributing the energy consumption among all the nodes in WSNs. They prove that an energy-balanced mixed data gathering scheme could be better than any other possible routing schemes. They argue that the lifetime maximization, data flow maximization, and balanced energy consumption among the nodes are equivalent. However, the assumption that each node is within the direct reach of the sink might be unfeasible.

The frequent variation in the location of mobile sink should be communicated to the sensor nodes for further data communication. As the sink location is propagated continuously through the sensor nodes, the energy of the sensors might drain out soon resulting in decreased network lifetime. To assist in propagating the sink's location Shim & Park (2006) proposed locators which are used to identify and communicate sink's current location to the sensors. Sensor wishing to communicate data should inquire to the locator. The proposed dissemination model containing locators track the sink locations and reply sinks' location query from sensors. Theses locators are distributed evenly throughout the sensor field by using a deterministic geographic hash function. When a sink moves to another location, an update message is sent to the closest four locators. Likewise for obtaining a sink's location, a sensor node queries to the locator and communicates the data to the sink.

Luo et al (2006) proposed a routing protocol termed as MobiRoute which is specifically targeted for WSNs with mobile sinks. In the protocol, the authors have proposed three primary mechanisms for handling node mobility. The first approach exploits beacon messages and timeouts to notify a node when it is disconnected from sink due to mobility. The next mechanism is for notifying the whole network about topological changes due to mobility. Third mechanism for minimizing the data loss generated due to sink mobility. Through simulations the authors prove that sink mobility in varying deployment scenarios increases network lifetime to a large extent.

Nesamony et al (2006) designed the sink movement problem as a modified version of Traveling Salesman Problem (TSP) and the new algorithm is termed as Traveling Salesman Problem with Neighbourhood (TSPN). Here the sink should visit the neighbourhood of each sensor exactly once. Likewise in Nesamony et al (2007), the authors again presented a novel algorithm to find the optimal sink tour. In this algorithm sensors with low battery power are given preference for data collection to prevent the data loss.

Xing et al (2007) allows the sink to move along a predetermined trajectory with the assumption that the sensors are densely deployed with same transmission range. In such networks the energy consumed for sending a message is proportional to the Euclidean distance between the sensor and the sink. The concept of minimum spanning tree is exploited to connect all the sensors to the sink track in the Euclidean domain.

In Bi et al (2007) the authors consider one mobile sink that traverses proactively towards the node that has the highest residual energy in the network, as an effort to balance sensors' energy consumption. When the sink reaches a new location, it broadcasts a notification message to the sensor nodes to form data collection trees to gather data from the network. So, sink mobility can improve network performance in parameters like energy efficiency and throughput.

In another work, Bi et al (2007) proposed an autonomous moving strategy for mobile sinks. The network lifetime is increased by utilizing one mobile sink that is capable to deciding the sojourn point. In order to balance the energy consumption throughout the network, the sink nodes moves towards the node with highest residual energy. After reaching a new location the sink broadcast a message in order to notify the sensor about its current location. The sink then receives the messages from sensors through multi-hop communication. This type of data collection suits well for delay tolerant networks. The sink traveling time will be more as there is only sink to cover the whole network area.

In Rao & Biswas (2008) the authors proposed a framework for exploiting mobile sink for data collection from the sensor nodes. The framework is designed by combining the concepts of few existing algorithms. In this framework, a minimum dominating set is constructed where each node in the dominating set is termed as navigation agents. The navigation agent constructs a tree positioning itself as the root. Apart from constructing tree, the agent also find the shortest path for reaching other navigating agents. The mobile sink uses exploits the navigating agents to collect data from the network.

Banerjee et al (2008) proposed the concept of using multiple mobile sinks where multiple clusters are formed across the network. The clusters are formed in such a way that the entire network is covered without any cluster overlapping. The mobile sink moves within their allotted clusters and prefer to choose energy rich zones for data collection. Selecting energy rich zones results in increased network lifetime. The drawback with this concept is, the algorithm requires more number of mobile sinks if large network area is to be covered.

Hamida & Chelius (2008) propose an idea of dividing the network area in to parts. Here the authors use a vertical line or strip which divides the sensor field into two equal parts. Sensor nodes that lie within the boundaries are called by the term inline-nodes. The vertical line is considered as rendezvous area for data storage and lookup. When a sensor deployed in the field senses a new event, it communicates the sensed data towards the virtual line. This data will be received and stored by the first inline-node encountered. To perform data aggregation and further processing for generating reports, the sink sends its query towards the rendezvous area. The query is then received by any arbitrary node along the vertical line and propagated until it reaches the node that holds the requested data. Friedmann & Boukhatem (2009) exploit the concept of multiple mobile sinks and presented a centralized brute-force algorithm. Initially the sinks are destined to specific locations and the brute force algorithm is run periodically to check if the sink needs to be relocated. The sink will be relocated only if the new position guarantee reduced total energy cost.

In Marta et al (2009) the authors have considered multiple mobile sinks for improving the lifetime of the network. Algorithms are framed by considering both predetermined and autonomous moving strategies. In the predetermined strategy, the sink moves along the perimeter of hexagonal tiling and for every time period T, the sink stops at various positions for data gathering. The authors argues that 6 stopping position sink movement resulted in 3.48 times improvement in network lifetime over static sink and 12 stopping positions of the sink, shows 4.86 and 1.39 times improvement over static sink and 6 stopping position sink movement case respectively. The drawback recognized in this paper is, when the network area becomes very large there is a need for more number of sinks and it becomes impossible to compensate, if there are only fewer sinks available. Similarly in Pradeepa et al (2009) the authors experimented with usage of multiple mobile sinks to enhance the network lifetime. Multiple sinks are allowed to move along a predetermined trajectory to reduce the formation of energy holes near the sink. Simulation results show a good improvement over the static sink case.

A mobile sink introduces many challenges to data dissemination in wireless sensor network. Identifying the exact locations of the mobile sink is a significant issue which should be handled efficiently to improve the network lifetime. In particular, a stationary dissemination path may no longer be effective in mobile sink applications, due to sink mobility. Jeon et al (2009) propose a Sink-oriented Dynamic Location Service (SDLS) approach that provides solution to handle the mobility of sink and energy conservation. The authors contribute a global grid structure which helps to reduce overall energy expenditure. The authors also suggest an Eight-Direction Anchor (EDA) system that acts as a location service server. EDA prevents intensive energy consumption at the border sensor nodes and thus provides energy balancing to all the sensor nodes. Another contribution is a Location-based Shortest Relay (LSR) which minimizes the delay during data transmission between source sensor node and the sink. Simulation experiments shows that SDLS is efficient in providing scalable location service and minimizes the data communication overhead in network with multiple mobile sinks.

In the works of Alsalih et al (2010), Yi Shi et al (2012) the infinite possible locations for base station placement are transferred to finite set of locations. In Yi Shi et al the authors showed that for an optimality of $(1 - \varepsilon)$, the infinite points are reduced to a finite set of locations by using several constructive steps (i.e., discretization of energy cost through a geometric sequence, division of a disk into a finite number of subareas, and representation of each subarea with fictitious cost point (FCP)). A novel algorithm is designed by Alsalih et al for converting the infinite solution space to finite thus making the linear programming as discrete rather than a continuous one.

Most of the previous research works have concentrated in running the optimization model on a continuous search space. Only few have focused on discrete optimization. For the base station placement problem the solution space is considered to be each and every single point in the network. The first challenge in the proposed placement problem is converting the infinite solution space to finite without compromising on the quality and quantity parameters of the final solution.

Table 2.1 provides a comparative analysis of the various related works that are discussedIt should include important findings discussed briefly. Wherever necessary, elaborate on the tables and figures without repeating their contents. Interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. However, valid colored photographs can also be published.

V. Conclusion and Future Scope

The main conclusions of the study may be presented in a short Conclusion Section. In this section, the author(s) should also briefly discuss the limitations of the research and Future Scope for improvement.

Work	Mobile Entity	Network Model	Contribution	Model Determines	Discretization	Base Station Placement
Gandham et al	Multiple BSs	Random	ILP	Optimal locations for Base Station	No	At Predefined Spots
Z.M.Wang et al	Single BS	Grid	LPP	Sojourn time	No	At Predefined Spots
Pappadimitriou et al	Single BS	Random	LPP	Sojourn time	No	At Predefined Spots
J.Luo et al	Single BS	Random	MILP	Sojourn time	No	At the boundary
Basagni et al	Single BS	Random	MILP &GMRE Protocol	Sojourn time	No	Predefined Spots
W.Alsalih et al	Multiple	Random	Discretization Procedure &ILP	Optimal locations for Base Station	Yes	Anywhere in the sensing field
Yi Shi et al	Multiple	Random	Discretization Procedure & MILP	Sojourn time and Optimal locations for Base Station	Yes	Anywhere in the sensing field
Marta et al	Multiple	Random	Algorithm for Sink Placement	Predetermined Trajectory Autonomous movement	No	On a Predetermined Trajectory
Pradeepa et al	Multiple	Random	LPP	Sojourn Time	No	Predetermined
Hamida and Chelius	Single	Random	Algorithm	Sojourn Points	No	Predetermined
Friedmann and Boukhatem	Multiple	Random	Brute Force Algorithm	Optimal Locations for Sinks	No	Random Trajectory
Chatzigiannakis et al	Multiple Data Collectors	Fixed	Data Collection Algorithm	Data Collection points	No	Random Trajectory
Shah et al	Multiple Data Mules	Heterogeneous	Data Collection Algorithm	Sojourn points for Mules	No	Predetermined
Kim et al	Forwarding Agents	Heterogeneous	SEAD (Scalable Energy-Efficient Asynchronous Dissemination)	Tree communication Structure	No	Predetermined
Wang et al	Mobile Relay and Mobile Sink	Heterogeneous	Joint Mobility and Routing algorithm	Data collection points and routing path	No	Random
Somasundara et al	Mobile Elements	Heterogeneous	Earliest Deadline First (EDF) Algorithm	Data Collection points for MEs	No	Random
Vupputuri et al	Data Collectors	Heterogeneous	Data collection and aggregation algorithm using DCs	Sojourn points for DCs	No	Random
Nesamony et al	Mobile Sink	Heterogeneous	Traveling Salesman with Neighborhood (TSPN).	Algorithm for Sink tour	No	Random
Kansal et al	Mobile Sink	Heterogeneous	Algorithm for Data Collection	Identifying rendezvous points (RP) for the sink to sojourn	No	Predetermined
Jea et al	Multiple Mobile Sinks	Heterogeneous	Sink Load Balancing Algorithm	Sojourn points for the sink	No	Predetermined
Xing et al	Mobile Sink	Heterogeneous	Algorithm for Minimum Spanning tree	Data Collection Points	No	Predetermined
Rao and Biswas	Mobile Sink	Heterogeneous	Framework for Data Collection	Minimum Dominating Set(MDS) and Navigating Agents	No	Random
Banerjee et al	Multiple Mobile Sinks	Heterogeneous	Algorithm for Data Collection	Construction of Clustering Tree	No	Random
Friedmann and Boukhatem	Multiple Mobile Sinks	Heterogeneous	Centralized Brute Force Algorithm	Relocation Points for the sinks	No	Random
Baruah and gaonkar	Mobile Sink	Heterogeneous	Algorithm for Data Collection	Sink tour divided in to several time domains	No	Predetermined
Mir and Ko	Mobile Sink	Heterogenous	Quad tree-based partitioning Protocol	Rendezvous Points for data collection	No	Fixed
Bi et al	Multiple Mobile sinks	Heterogeneous	Algorithm for Data Collection	Highest energy zone for the sink to sojourn	No	Random
Jarry et al	Single Mobile sink	Heterogeneous	Mixed Data gathering algorithm	Sojourn point for sink with routing patterns	No	Random
Luoet al	Single Mobile Sink	Heterogeneous	MobiRoute- routing protocol	Routing pattern and sojourn point for sink	No	Random
Shim amd Park	Locators	Heterogeneous	Data Collection Algorithm	Dissemination model with locators to track the sink locations	No	Random

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