JCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol.-7, Issue-6, June 2019 E-ISSN: 2347-2693

Review and comparison of Mobile Agent Itinerary Planning Algorithms in WSN

Shivani Chaudhary[1*], Umesh Kumar[2], Mohit Gambhir[3]

[1]Department of Computer Engineering, J.C. Bose University of Science and Technology YMCA, Faridabad, Haryana, India
[2]Department of Computer Engineering, J.C. Bose University of Science and Technology YMCA, Faridabad, Haryana India
[3]Verispire Technologies Pvt. Ltd. India

Corresponding Author: shivanichaudhary522@gmail.com

DOI: https://doi.org/10.26438/ijcse/v7i6.209219 | Available online at: www.ijcseonline.org

Accepted: 10/Jun/2019, Published: 30/Jun/2019

***Abstract* -** Wireless sensor networks used the idea of mobile agent to reduce load on network and less energy consumption in comparison to client server based models and obtain effective data gathering. To alleviate the problem of significantly increased latency, data crowding and increased energy consumption in wireless sensor networks, mobile agents (MA) have been proved as the credible substitute to the basic client- server data gathering model. Particularly, in data gathering based on mobile agents, it is very essential to discover the optimal itinerary for the mobile agent dispatched by the sink. In this paper, the existing Mobile Agent based algorithms have been reviewed to address the issues related to data gathering. More significantly, the review showed the advantages and disadvantages of different algorithms and eventually it has also been noted that most of the planning approaches has not considered the security of the collected data by the mobile agent and authentication of the sensor nodes.

***Keywords*:** Data Gathering, Mobile Agent, Mobile Agent Itinerary, Wireless Sensor Networks, Sensor nodes

I. INTRODUCTION

The advent of wireless sensor networks (WSNs) have fascinated many of the researchers and became a vigorous area for research in the wide range of applications. WSNs consist a huge number of locally distributed tiny autonomous nodes that collaboratively sense and respond to the environmental or physical conditions and transmit the collected data to the sink node [1]. These small autonomous nodes are called as sensor nodes and comprised of small microcontroller, sensor, communication device and energy source. Generally, these devices are resource constrained in most of the applications. Many applications make use of WSNs in fields such as, industrial process monitoring, battlefield surveillance, habitat monitoring, home automation, environmental monitoring, traffic control and healthcare monitoring [2].

The sole purpose of these sensor nodes in any application is to sense and transfer the data to the sink node and then send it to the remote users who requires it. Each of the sensor node is resource constrained i.e., memory, energy, processing speed, communication bandwidth and computational power and also an individual sensor battery is limited, and it is almost impossible to replace or recharge the battery in some applications due to human unreachable environments. Therefore, In WSNs dealing with the energy consumption of sensor nodes is essential. In a WSN, node energy depletion is due to various factors like data gathering, multi-hop communication and data processing.

As few SNs are located far off from the sink node that is why these nodes generally have to communicate through multi-hop as they cannot directly transmit the data to distant sink node. In the case if distant nodes transmit the sensed data directly to the sink, energy of these far nodes will be exhausted earlier than those which are closer to sink. Therefore, to deliver the data to sink every sensor node has to send its sensed data to the neighbor nodes via multi hop. This process of collecting sensed data by sampling and transmitting it from source nodes to the sink node is called data gathering, which is known to be as one of the challenging task in WSNs.

In WSNs, managing the power consumption to prolong network lifetime is the challenge So many researchers adopted data gathering as one of the area to minimize power consumption. Many protocols such as SPIN, LEACH, PEDAP, PEGASIS [4] have been suggested to reduced energy consumption and prolong the sensor nodes lifetime, these protocols used basic client server model to transmit the data between sensor nodes and sink. In the network, huge amount of data is being transmitted among vast number of nodes, it results in increased latency, much energy consumption and data congestion. It becomes a challenging task to balance the network and avoiding these issues. It is evident that data processing is done using minimal amount of energy while data transmission consumes more energy. Therefore, data aggregation is essential to improve data accuracy, remove data redundancy and to limit the large data transmissions.

Data aggregation leads to improved energy and bandwidth consumption which prolong the nodes lifetime as communication accounts for seventy percent of total energy of nodes. Hence, data broadcasting is the basic and essential task for wireless sensor networks. Data dissemination is a process encircling in-network processing and routing. To sort out the dissemination problem many protocols based on various norms and theories have been inferred for WSNs. Based on the criteria that whether source nodes transmit their data to sink or computational process goes to the source nodes for further processing Mobile Agent based and non-mobile agent based protocols has been classified. In non-agent based traditional scheme, which follows client-server model, as soon as an event occurs all the sensor nodes collect data and forward it towards sink node, by following a particular data routing algorithm which is generally energy inefficient as all sensed data is forwarded to sink, and it is indicated in paper [6] that transmission is the process which consumes the energy most. In agent based approach [6], a mobile agent has been employed for data aggregation in WSNs.

An autonomous code that is capable of migrating from one node to another node for the completion of a specific task is known as mobile agent. A MA carries a software logic for determining the operation to be processed on each sensor node. The resultant data after the local processing is then integrated with the MA's state and forwarded to the other SN, and MA resumes its execution there and do data aggregation upon the data retrieved. This mobile agent based paradigm offers numerous benefits as instead of sending all the sensed data by transmitting the processing code only.

Firstly. it can reduce bandwidth consumption considerably by sending the computational code to the sensor nodes located for sensing phenomena else more energy will be consumed if transmission of raw data is done. Additionally, since MA can be dispatched when the network connection is alive and return results when the connection is re-established the mobile agent based computing paradigm also provides stability and fault-tolerance. Hence unreliable wireless links does not much affect the network performance [7].

Finally, in contrast to non-agent based computing, MA can also be designed such that they can carry adaptive codes for processing a particular task which extend the quality of the network. Consequently, when specific computational code being processed locally on nodes it has been proved as more energy efficient.

For using mobile agents as the data aggregation migrators, sensor nodes set and order for visiting sensor nodes is required to be determined, i.e., scheduling of an itinerary. Selected itinerary mainly affects the important parameters i.e., aggregation cost and energy consumption. As a result, for the purpose of data aggregation many solutions have been provided by researchers in order to reduce the cost.

MA should follow a path to visit the sequence of nodes which is known as MA itinerary. In MA based paradigm for WSN classification of mobile agent itinerary planning mainly is done as Static, Dynamic and Hybrid. Static itineraries are those wherein sink node has predetermined order of source nodes to be followed by agents for the data aggregation. The problem with the static itinerary based agent migration approach is that agent may not be able move according to its predetermined itinerary due to link failures or node exhaustion and also at sink periodic collection of network topology information experiences substantial additional cost. However, in dynamic approach around node or link failures flexibility is there to select itinerary on the fly [8]. While static approach makes the agent's size larger but in dynamic approach MA does not carry a pre-computed itinerary list. Which helps in reducing the agent size.

Itinerary planning for mobile agent can be done by employing two approaches: (SIP) Single Agent Itinerary Planning and (MIP) Multi Agent Itinerary planning. For data gathering, SIP uses single agent only for migrating in the whole network which is inefficient for large scale networks. There are many drawbacks introduced by the SIP scheme such as increased MA packet size, long delays, packet loss probability and low reliability because of the agent visiting very large number of source nodes.

On the other hand, [10] MIP have been introduced to overcome the disadvantages of SIP, In MIP multiple mobile agents are dispatched into the network in such a manner that each MA visits a certain set or partition of sensor nodes concurrently that is actually like one MA is allotted to visit particular set of source nodes. Due to concurrent task distribution for aggregation, this process obviously reduces overall task duration, drops the MA packet size, which further helps to preserve the energy as small size packet transmission consumes lower energy. Although SIP limitations are sorted by MIP introduction but it comes with a new challenge of finding ideal number of mobile agents and itinerary to be followed in non-deterministic polynomial time. It will be considered as inefficient network performance if we get suboptimal solution.

Energy efficient agent migration is of major concern but besides that another serious problem is the security of MAs against compromised or malicious nodes in the dynamic network. In mobile agent based model, each Mobile agent has been providing an execution environment by the sensor nodes in the particular itinerary. Unknowingly, when sensor nodes are gets compromised by any internal or external malicious node, that malicious adversary node can severely spoil the execution of an agent by accessing the security keys and actual information can be affected by modifying or corrupting mobile agent's state information or code, by preventing the agent's processing code execution, or denying agent service requests [11].

In order to prevent the intrusion of such malicious node, basic such as integrity protection and symmetric key authentication only are not enough, because we are never aware which legitimate node has been compromised node now and even the compromised nodes know the secret keys [12]. Considerable storage and computation is required for the implementing computation-intensive traditional cryptographic mechanisms So it cannot be employed in WSNs because sensor nodes are resources constrained i.e., memory, computational power, battery power, and communication capabilities.

In order to overcome these attacks and providing an efficient solution, reliability of nodes should be determined and avoid the compromised nodes during the agent's visit to source nodes. This way mobile agents can be prevented to get affected by malicious activities. An Energy and Trust Aware Mobile Agent Migration (ETMAM) distributed approach [11] which takes trust and energy of nodes as the itinerary deciding criteria dynamically for mobile agent to accomplish the task of data aggregation. For sensitive applications of WSN, in presence of faulty and compromised nodes ETMAM perform more nominally. Particularly, agent's round trip success rate, energy utilization also overall response time is improved by deploying ETMAM.

The paper proceeds as follows: Section II contains Related work surveys several recent papers related to itinerary planning algorithms for mobile agents in WSN. Section III describes the Models for data gathering in WSN and Section IV explains MA itineraries in WSNs. In section V ‘‘MA itinerary planning algorithms’’ are classified as SIP and MIP, with their almost all the further proposed algorithms. Challenges and future work have been discussed in the section VI. Then eventually ‘‘Conclusion’’ concludes this article.

II. RELATED WORK

In wireless sensor network, for MA based paradigm discovering an efficient itinerary or route for MA migration is the major research area for the efficient data collection from large number of source nodes or sensor nodes. Extensive research has been done in recent years for the same. The selection of set of SNs and sequence to be visited in an itinerary plays very crucial part and affects noticeably the accuracy and quality of data aggregation. In this section we survey various proposed algorithms related to mobile agent itinerary planning. [1-4].

Min Chen et al. [13] has given routing protocols in Wireless Sensor Networks and concludes that in wireless sensor networks, client-server model is the most commonly used for data aggregation from sensor nodes, in which every node transmits the sensed data itself to sink node via multihop. Due to the reason that data transmission takes place in huge amount to the sink, this model becomes inefficient with the growing network size. Then Mobile Agent based model has been proposed by many authors as the energy efficient solution. But it has been noticed that in this model to plan the route or itinerary for agent is the challenging issue.

First solution for this issue was given by K. Akkaya et al. [5] and Qi H et al. [14]. Two heuristic algorithms been proposed, in LCF an agent been dispatched by the sink and then agent looks for the next node which can be selected on the criteria that distance between the current node and next node to be selected must be the shortest and so on for remaining nodes. Whereas GCF works as, initially mobile agent dispatched from sink and checks for the next sensor node closest to the sink every time. GCF choses the source nodes in its itinerary based on global network distance matrix not ased on local location of nodes.

An algorithm almost similar to LCF has been designed by T Kwon et al. [15] called (MADD)Mobile Agent-based Directed Diffusion algorithm which is almost similar to LCF but differs only when selecting the first node after sink, it is done in such a way that chose the farthest node as the initial one after the sink instead of considering the nearest one.

In [16], Wu Q et al. has given an approach for determining the itinerary for a mobile agent based on Genetic algorithm. To design a static itinerary using GA, global knowledge of network topology must be known prior. In terms of energy consumption, LCF and GCF can be defeated by this Genetic

Algorithm in performance. Approaches in [14] and [16] perform adequately for normal size networks but for the maintenance of global topology information each node has to report its state to sink which leads GA to suffer loads of communication overhead.

Konstantopoulos C et al. [8] and Ioannis E. Venetis et al. [17] proposed two efficient approaches, first as (IEMF)Itinerary Energy Minimum for First-source-selection and second, Itinerary Energy Minimum Algorithm (IEMA). IEMF employs as after sink it selects the first source node in itinerary as the one with the lowest estimated energy cost of its subsequent route among other routes and then uses the LCF approach for further remaining route planning. When IEMF gets iterated k times for energy efficiency enhancement, it is then considered as IEMA approach. In general, IMEF signifies the prominence of selecting the first node to be visited. Energy costs of different alternatives are estimated for the selection of first node and decision is made on the basis of minimum energy cost. IEMA iterations are performed on the basis of choosing the next node with optimal energy from remaining nodes.
Single agent data gathering faces many issues in large scale networks i.e., large delays, unbalanced load, unreliability. Therefore, to resolve these issues, multiple MAs may be dispatched, which further comes up with a new challenge of deciding itineraries for multiple agents.

To have the solution of multi agent itinerary planning (MIP) as a substitute to single agent itinerary planning (SIP), Centre Location-based Multi agents Itinerary Planning (CL-MIP) algorithm has been given by X. Wang et al. [18], MIP is completely central algorithm implemented at the central node sink and to define different subclasses by grouping the sensor nodes deployed in network. To determine the mobile agent itineraries for each subclasses already discussed SIP algorithms e.g., LCF, GCF, or GA can be used

After CL-MIP Gonzlez S. et al. [19] proposed another MIP algorithm Directional Source Grouping Based Multi-Agent Itinerary Planning (DSG-MIP) which is considered as centralized. Number of mobile agents and their corresponding itineraries can be found by the execution of this algorithm on sink node. The main concept of this algorithm is to split the Network to form sector zones in such a manner so that each sector zone's center be the direct neighbor of the sink node.

Itinerary for mobile agent can be determined in each sector zone using any of the SIP algorithm.

Table1: Comparison Table for mobile agent itinerary planning algorithm

S.No.	Model Name		Advantage	Disadvantage
1	Client Server based model	Data Aggregation Routing Protocol [13]	• Easy to understand • Maintenance ease	• Unbalanced energy consumption • Increased delay
2	Mobile agent based model (Single agent itinerary planning)	A. Local Closest first (LCF) [5]	• Adequate for small size networks. • Predetermined itinerary	• High migration cost. [benchmarking] • Uses greedy approach.
		B. Global Closest first (GCF) [14]	• Does not rely on greedy approach. • Lower computational complexity than LCF.	• Messier routes than LCF. • Long route paths.
		C. Mobile agent- based directed diffusion (MADD) [15]	• Cost efficient paths are followed. • Assumes partial aggregation model	• Uses only spatial location of the nodes. • Not energy efficient.
		D. Genetic algorithm [16]	• Uses global knowledge of topology • Better performance than LCF and GCF.	• Incurs lot of communication overhead.
		E. Itinerary Energy minimum for first-source-selection (IEMF) [8]	• Lowest estimated energy cost itinerary.	• Deemed to have n times the complexity of LCF.
		F. Itinerary Energy minimum algorithm (IEMA) [17]	• Good estimation of the minimum cost for all iterations.	• Un-scalable with large network due to single agent.

3	Mobile agent based model (Multiple agent itinerary planning)	A. Centre location-based multi agents itinerary planning (CL-MIP) [18]	• Reduced delay than SIP • Limited visiting central location point used (VCL).	• VCL grouping is not a generic solution. • Optimal value analyzed implicitly
		B. Directional source grouping based multi-agent itinerary planning (DSG-MIP) [19]	• Covers a larger transmission range • Incremental cost minimized.	• Unable to find the optimal gap threshold. • Inefficient when isolated nodes are farther.
		C. Tree based itinerary design (TBID) [20]	• Minimizes the total aggregation cost. • Determines optimal number of mobile agents.	• Uses greedy approach to form the binary tree. • Interference due to huge amount of branches.
		D. Genetic algorithm-based multi-agent itinerary [21]	• Better performance regarding the issues of delay and energy consumption.	• High computational complexity.

Cai W. et al. in [20] given a Tree Based Itinerary Design (TBID) algorithm. This algorithm employed itself at sink node i.e., it is a centralized algorithm which is used to compute number of mobile agents required for data gathering and agent itineraries. An assumption made in this algorithm is sink has the global knowledge of network topology. For making groups of sensor nodes and planning the optimal itineraries TBID uses greedy approach.

A Genetic algorithm, which is a type of multi- gent itinerary planning algorithm, (GA - MIP) is designed by Cai W. et al. [21]. The authors support the given GA method by determining that what number of MAs have been dispatched and where or to which nodes it have been dispatched. Mainly to find the ideal number of MAs deployed GA-MIP approach was proposed.

III. MODELS FOR DATA GATHERING IN WSNS

In this section, we mainly focus on the data gathering models in WSNs [22]. Data gathering models are those which are used to collect the precise data from sensor nodes and send back to sink. These models are discussed in this section as follows:

A. Data gathering using client–server model

Main objective of WSNs is to collect and send the sensed data from sensor nodes to the sink node or processing element (PE) for the processing purpose. Basic approach for data transmission is done via multi-hop communication in the network nodes until it eventually delivered to the sink mode. Figure 1 [22] demonstrates that in the client-server model, sensed data is sent to the sink node from all source nodes in the network. The nearest nodes to sink send and receive more data on behalf of other nodes and their energy may be deplete

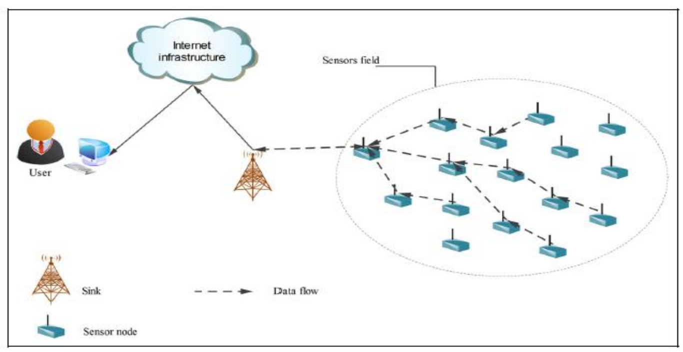


Figure 1. WSNs data gathering based client-server model [22]

completely before the other source nodes. Hence, this could lead to unbalanced energy consumption of the nodes. The transmission of bulky data entails likewise a huge amount of unnecessary traffic, and because of common shared bandwidth large delays are caused. In particular, it can be noted that data flow is directly proportional to the number of nodes so this paradigm consumes large amount of energy and bandwidth in large scale networks. Thus, to counter the above drawbacks of client–server model, data gathering model based on mobile agent has been proposed. High bandwidth consumption is reduced by using this model with the help of moving the processing code in mobile agent and data aggregation is performed at the node itself.

B. Data gathering model based on mobile agent

The mobile agent based model has improved data gathering in WSNs with efficient energy consumption. The mobility model's data collection strategies are as : Mobile sink, mobile node and mobile software agent. In the mobile sink and mobile node data collection strategy, the sink or node can roam the data collection network from different sources, while only the processing code is migrated to different source nodes using mobile agent strategy for data collection. We further explain Mobile software agent strategy in following section:

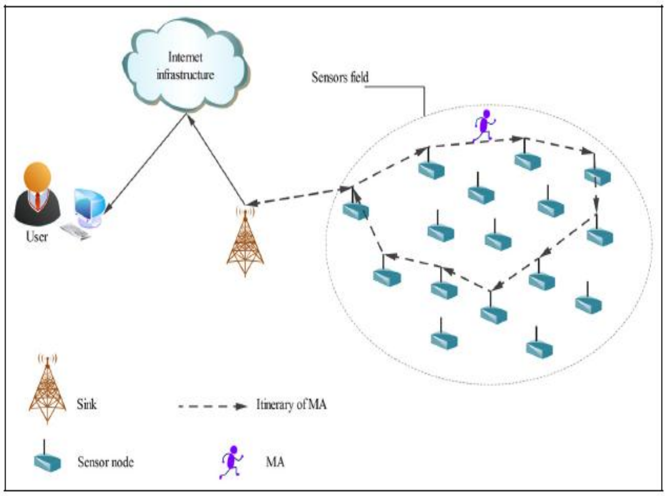


Figure 2. Data gathering model based on mobile agent [22]

Mobile agent : Restraints mentioned above are relieved by the advent of MA in WSNs. A small code or a function is sent inside a data packet from the sink node to the source nodes is known as mobile agent. At each node, this code itself gets executed locally to perform data aggregation, thus in contrast to the client–server model this strategy achieves computational flexibility. This code, in addition to autonomous, interactive, and intelligence, has assisted to reduce the cost of energy consumption and transmission as well as the probability of collisions and transmission errors. The Mobile Agent follows an itinerary assigned by sink to visit the nodes sequentially as shown in figure 3 [22]. An itinerary is the route that the MA should follow to collect data. In some applications, where sensor nodes generate a large amount of sensory data, the MA visits the sensor nodes and performs a local data reduction process at each source node. This local reduction process is generally used to eliminate the redundant sensed data where the nodes are spatially located closely and senses spatially correlated data (density deployment).

IV. MOBILE AGENT ITINERARY

Itinerary can be defined as the route to be followed by the mobile agent for the data gathering process. Particularly these two issues are addressed by the mobile agent or sink node regarding itinerary planning autonomously.

• Selection of the source node's set to be visited
• Sequence Determination to be visited by MA in an energy efficient manner.

The order of sequence which is followed by a mobile agent to form an itinerary, significantly affects energy consumption therefore Finding the best source-visiting sequence is a (NP)-complete, non-deterministic polynomial-time problem. The sequence can be fixed, dynamic, or a combination thereof based on the information of one hop neighbors or the information from previously visited nodes piggybacked by the mobile agent. Itinerary planning can be categorized as:

1) Static planning, where the agent itinerary is completely defined by the sink node before the agent is dispatched to source nodes
2) Dynamic planning, where the mobile agent autonomously determines the source nodes to be visited and the route of migration according to the current network status.
3) Hybrid planning, where the set of source nodes to be visited is decided by the sink and the source visiting sequence is determined dynamically by the mobile agent.

V. MOBILE AGENT ITINERARY PLANNING

Itinerary planning is procedure to determine the sequence of the sensor nodes which is to be followed by the MA. Itinerary planning has been classified for single Agent i.e., SIP and for multiple agents (MIP). Single MA is dispatched by sink throughout the network to all source nodes in SIP however, several MAs are dispatched from the sink to source nodes in MIP. Although finding the optimal route for MA in a large-scale network is of major concern regarding task duration and energy efficiency.

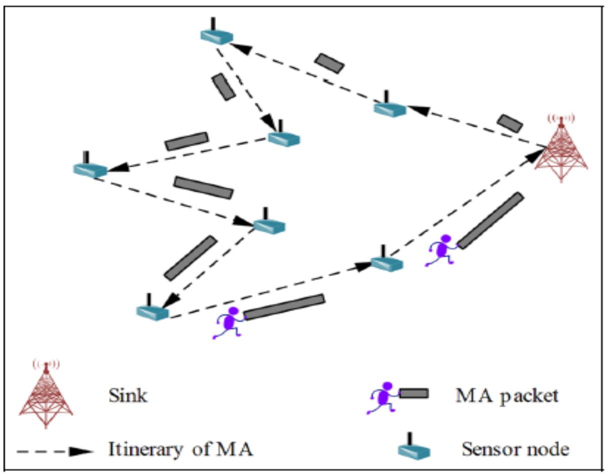
It is notable that the MIP is actually many SIPs working concurrently to visit subgroups of source nodes i.e., based on the SIP algorithms, the MIP algorithms were developed. Accordingly, an outline of the SIP as well as MIP is presented.

1) Single MA itinerary planning

Earlier in WSNs, LCF and GCF two SIP approaches have been presented using MA. In LCF, MA migrates to the next hop with the shortest distance from the current node, while in GCF, MA migrates to the next hop with the closest distance from the monitoring zone center. Directed diffusion based on MA (MADD) was proposed MADD is similar to LCF but differs as MA selects the node as the first source that has the farthest distance from the sink. Itinerary energy minimum for first-source-selection (IEMF) and itinerary energy minimum algorithm (IEMA) are two algorithms has been proposed to achieve energy-efficient itineraries. In the IEMF algorithm, MA selects the first source node based on estimated LCF-extending communication costs. In addition, the IEMF considers the impact of data aggregation and energy efficiency in order to obtain an energy-efficient route. The second IEMA algorithm-an iterative version of IEMF-selects an optimal source node as the next source on the basis of estimated energy cost. Conversely, all the previous work in large - scale sensor networks do not perform well and they have several major disadvantages. The disadvantages include:

1) Extended delays in visiting hundreds of sensor nodes by single MA.

Figure 3. Single itinerary planning [22]



2) Sensor nodes in the itinerary of the MA exhausted of energy faster than other nodes.
3) In SIP, the size of MA packet grows during the aggregation of data from node to node.
4) Reliability not ensured when the MA accumulates upsurge amount of data.
5) In large scale networks, When the MA migrates to several source nodes, the chance of being lost increases.

2) Multi MA itinerary planning

In the multi-MA itinerary, several MAs were sent from the sink and worked parallel to the network. Each MA follows its allocated route and visits a subset of source nodes. Unlike SIP, MIP overcomes the weaknesses of using SIP, particularly on a massive WSN scale. Figure 4 shows that multi-MAs are sent with two different routes to the network area. Mainly due to the distribution of tasks that assign an individual itinerary to each MA, the reduction in the size of the MA packet is managed to achieve. In addition, each MA visits a sequence of nodes (a group of nodes) when multiple MAs migrate to the network and then minimizes the duration of the task (lower delay).

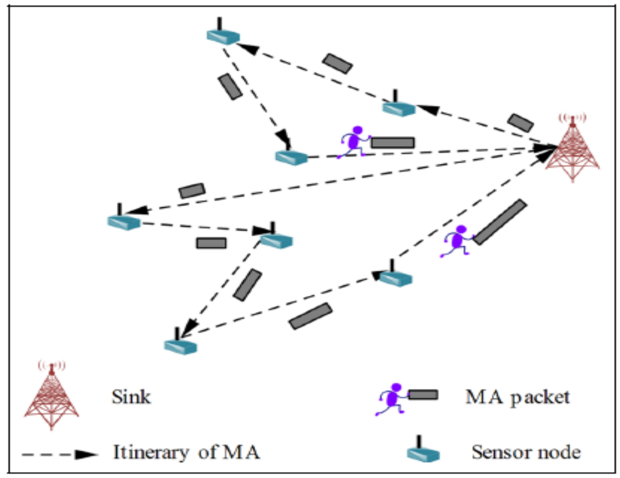


Figure 4. Multiple agent itinerary planning [22]

1) SINGLE AGENT ITINEARY PLANNING ALOGRITHMS

A. *LOCAL CLOSEST FIRST ALGORITHM (LCF)*

Algorithm uses static planning where current global network information is obtained and an efficient agent path is derived from the dispatcher just before mobile agents are sent

Assuming each algorithm begin at constant sensing element node nearest to the dispatcher, LCF searches for future node with the shortest distance to the present node. Local Closest First (LCF), the mobile agent begins its itinerary from a node and looks for the next target with the shortest distance to its location.

This algorithm has the running time complexity of $O(n^2)$ because by comparing the distances with the remaining nodes at each step, the closest neighbor node is obtained. .

B. GLOBAL FIRST SEARCH ALOGRITHM

As in case of the Global Closest First (GCF) algorithm, the MA starts its route from a node and selects the next destination nearest to the monitoring zone center. When source nodes are intended to form multiple clusters with a similar distance from the sink, GCF tends to cause zigzag routing due to the perturbations in the route between them. In order to calculate the MA path, the distances (between the sink and other sources) are essentially used.

Its time complexity is O(n log n) if using a comparison-based sorting algorithm (e.g., quick sort). An ideal list of L(i, j) nodes is searched so that the cost of the calculation time and the overall power consumption for each node itself reaches the minimum.

C. MOBILE-AGENT BASED DIRECTED DIFFUSION ALGORITHM

Mobile agent - based direct diffusion (MADD) is proposed in a hybrid planning scheme. If the sources in the target region detect an event of interest in MADD, they individually start flooding exploratory packets to the sink. On the basis of these exploratory packages, the sink statistically selects the sources visited by a mobile agent, which decides autonomously on the source - visiting sequence as it migrates between the nodes in the source - visiting set. The mobile agent therefore follows a cost - effective path between MADD target sensors. When visiting each target source, the MA aggregates individual sensed data. Although this type of aggregation technique is generally used in clustering or aggregation tree based protocols for the dissemination of data, the aggregation in MADD does not need an overhead to build these special structures.

D. ITINERARY ENERGY MINIMUM FOR FIRST-SOURCE-SELECTION ALOGRITHM

We focus on the development of energy - efficient route planning algorithms while relaxing the above assumption. We first propose an Itinerary Energy Minimum for First-source-selection (IEMF) algorithm, which extends LCF by taking into account the estimated cost of communication. In IEMF, in order to achieve an energy - efficient route, the impact of both data aggregation and energy efficiency is taken into account [17]. The strategy is quite specific since it does not rely on a particular network design. The LCF performance could be enhanced by carefully selecting the first source node on the route, which is one of the reasons why we design the IEMF algorithm. The IEMF is considered to be n times as complex as LCF, i.e., O (n^3).

While our proposed IEMF approaches have higher energy efficiency as compared to the existing solutions, the shortcoming of the use of a single agent to carry out the entire task makes the algorithm un-scalable with a large number of source nodes.

E. ITINERARY ENERGY MINIMUM FOR FIRST-SOURCE-SELECTION ALOGRITHM

An Itinerary Energy Minimum Algorithm (IEMA), which is an iterative version of IEMF, is being proposed. IEMA selects the best node according to IEMF as the next source to visit from the rest of the source nodes during each iteration. We show that the suboptimal route can be gradually improved with more iteration and that the average energy consumption for the first few iterations is significantly reduced. Therefore, we can trade between energy efficiency and computational complexity based on specific requirements for the application. IEMF selects the first source as the one whose corresponding itinerary is estimated to have the smallest energy cost among n candidate itineraries. When it is determined, the LCF criterion actually takes into account the corresponding itinerary [24]. In this section, an iterative version of IEMF called IEMA is proposed. As compared with IEMF, IEMA seeks to optimize the remaining itinerary to a certain degree. Although IEMA approach exhibit higher performance in terms of energy efficiency, compared with the existing solutions, the limitation of utilizing a single agent to perform the whole task makes the algorithm un-scalable with a large number of source nodes to be visited. The complexity of IEMA with k iterations is O(k .n2 log n).The estimation of communication energy of a node itinerary is given by

F**.** *ADVANTAGES AND DISADVANTAGES OF SINGLE-AGENT ITINEARY PLANNING*

In this section, itinerary planning algorithms [24] for single agent applications have high efficiency with the following characteristics:

a) The source nodes are distributed geographically close to each other.

b) The number of source nodes is not large. For large scale sensor networks, with many nodes to be visited, single agent data dissemination exhibits the following pitfalls:

1) Large Delay: When a single agent works for networks consisting of hundreds of sensor nodes, extensive delay is required.

2) Unbalanced load: When using a single agent, there are two kinds of unbalancing problems. First, the entire traffic load is placed on a single flow from the perspective of the whole network. Sensor nodes in the agent route will therefore quickly reduce energy than other nodes. Secondly, from the point of view of the itinerary, the size of the agent continually increases as it visits the source nodes, so that the agent transmissions consume more energy back to the sink node on its itinerary.

3) Insecurity with large accumulated size: The growing amount of data that the agent accumulates during its migration task tends to increase its chances of being lost due to noise in the wireless medium. Therefore, the longer the itinerary, the riskier the migration based on the agent will become.

2) MULTIAGENT ITINERARY PLANNING ALOGRITHMS

The existing algorithms reviewed include tree-based MIP, central location based MIP (CL-MIP), genetic algorithm based MIP (GA-MIP), directional angle based MIP, and greatest information in the greater memory based MIP (GIGM-MIP).

A. TREE-BASED MIP ALGORITHM

In [25], the algorithm for near - optimal itinerary design (NOID) was proposed to address the problem of calculating the number of near - optimal routes for MAs, which incrementally fuse the data when visiting the nodes in a distributed sensor network. NOID algorithm adapts a technique that was designed for the constrained minimum spanning tree (CMST) problem in network designing. The NOID algorithm groups the sensor nodes in the network iteratively to segregate sub - trees that are gradually connected to the processing element (PE) or sink. Finally, an individual MA is assigned to each sub - tree.

Authors in [26] proposed another tree based algorithm named second near-optimal itinerary design (SNOID). This algorithm improves the NOID algorithm by considering the communication costs of the nodes. The number of Mas is determined by SNOID and their routes by dividing the area around the sink or PE into concentrated areas. The number of nodes in the first the zone radius includes the PE representing the starting points of the MAs itineraries (or the number of MAs). The first zone radius can be calculated by aRmax, where a is an input parameter in the range [0, 1] and aRmax is the maximum transmission range of any sensor node. The trajectory of the MAs itineraries begins from the inner zones (close to the PE) and goes to the outer zones. An improvement to the basic algorithms, NOID and SNOID, has been obtained by a tree-based itinerary design (TBID) algorithm not only finds the optimal number, but also creates low cost itineraries for each individual MA. TBID can be suitable for WSNs with dynamic network conditions due to its low computational complexity. Authors in [26] proposed a novel algorithm for energy-efficient itinerary planning of MAs. This algorithm uses a meta-heuristic method called iterated local search (ILS) to generate the hop sequence of multiple traveling MAs across the source nodes deployed. Like other tree-based MIP algorithms (e.g. NOID and TBID), ILS is executed at the sink and the number of itineraries (MAs) is determined by taking into consideration a circular area around the sink. The nodes which are positioned in the sink zone will be the start points of each MA itinerary. However, the difference from other previous MIP algorithms based on the tree is that the ILS algorithm takes into account the increase in size of the MA as well as the energy used to migrate to intermediate nodes along its itineraries.

B. CL-MIP ALGORITHM

Centre location-based multi agent itinerary planning (CL-MIP) is another algorithm being introduced by [27] to determine the suitable number of MAs. An algorithm to create MIP solutions was presented by the author. The CL - MIP's main idea is to regard the MIP solution as an

iterative variant of the SIP solution. CL-MIP algorithm comprises of the following four parts:

1. Visiting central location (VCL) selection algorithm
2. Source grouping algorithm for each MA
3. Determining the source visiting sequence using SIP algorithm
4. An iterative algorithm to guarantee that all source nodes have been covered by an MA.

In CL-MIP, the VCL algorithm is often used to categorize all originating nodes according to the density of the node (gravity algorithm) [27]. The fundamental idea of the VCL algorithm is to disseminate the impact factor of each source node to other source nodes. Let n represent the source node number; then each source node will receive (n-1) impact factors from other source nodes, and one from itself. The location of the source with the largest accumulated impact factor is selected as a VCL after calculating the cumulative impact factor. The source nodes in the VCL radius are then randomly assigned to the MA. The process above is repeated until all other remaining source nodes are assigned to an MA.

C. GA-MIP ALGORITHM

In [21], a GA-MIP was enacted to find the optimum number of MAs to MIP. In Figure 6, [22] GA-MIP is about gene that comprises of source-ordering-code (sequence array) and source grouping code (group array). A source ordering code is an array containing segments; each segment has a number of source nodes that a specific MA visits. Even while the source grouping code is an array of numbers, each number in the source order code specifies the number of source nodes in each segment. The results show that the proposed GA-MIP performs better on delay and energy consumption issues. This greedy approach can, however, lead to a substantially under - optimal MIP solution and high computational complexity.

D. DIRECTIONAL ANGLE BASED-MIP algorithm

In this algorithm, an angle gap based MIP (AG-MIP) is used for grouping all the source nodes in a particular direction as a single group. [28] The main idea of direction-based MIP is to establish AG-MIP to divide the network into sectors as shown in [22]. A particular angle gap threshold determines each sector. Then, all nodes around one central location (VCL) within this sector must be included in the same group. Therefore, the source grouping algorithm is direction oriented. The two nodes with minimal angel gap determine the VCL here, which differs from the previous algorithm of VCL that presented in section ‘‘CL-MIP.’’ As a comparison with VCL, direction-based MIP more efficiently groups the source nodes, but this algorithm may result in few isolated source nodes that are located near the group. These isolated source nodes will finally be considered as a new sector after several iterations. Moreover, how to find an optimal angle gap threshold in this approach is still an open issue.

Work in [29] improves the previous work presented in [28] by proposing an algorithm entitled directional source grouping based MIP (DSG-MIP). This algorithm partitions the network area into sector zones whose centers are the sensor nodes within the radius of the sink node or PE. Figure 7 shows that the size of the PE zone can be determined by the same algorithm presented in SNOID algorithm, aRmax where R is the maximum transmission range, and a is an input parameter in the range [0, 1]. Then, the sensor node within this zone represents the starting points of each MA.

VI. CHALLENGES AND FUTURE WORK

Dynamic itinerary of MIP: In MIP planning algorithm, most of the proposed solutions assume that the itinerary of each MA is determined at the sink node, which means the MA is carrying a static itinerary. In this case, any change in the network topology due to node mobility or node failures (energy depletion) could affect the migration of MA. The migration of MA has to be dynamic and more intelligent, such that the MA migration is decided at each visited sensor node. Therefore, it is recommended that the MA packet carries an alternative source nodes list together with the list that is predetermined at the sink. The alternative source nodes list will contain the nearest neighbour node of each next hop node. This proposed solution might increase the MA packet size slightly. The added alternative source nodes list (to the MA packet) could increase the time of MA hop migration at each node. While this solution consumes energy and time, on the other hand, however, it is beneficial and applicable for dynamic migration (such as target tracking applications).

MA data security: The data carried by the MA are assumed to be secure with the MA migration. Since the migration of the MA is done by several hops among the sensor nodes, the limited available energy at these sensor nodes will affect the MA migration and the data carried by the MA may be lost. Therefore, it is recommended to use any of the compression algorithms to compress the data accumulated by each MA. The compression code with an encryption key should be carried by the MA so that once the MA reaches the source node, it compresses the accumulated data and then later when the MA finishes its task, the encrypted data accumulated will be decrypted at the sink.

Source Nodes authentication : As none of the reviewed protocols consider security issues. They only focus on how to decide efficient itineraries for mobile agents. A malicious or compromised node can disrupt the operations of mobile agent by modifying its code, state, or itinerary, denying requested services or terminating it absolutely. To overcome these challenges, we can propose an authentication mechanism for sensor nodes which would be participating in itinerary, by using that malicious or compromised nodes can be detected at an early stage and bypassed during migration.

VII. CONCLUSION

This article explains the use of the mobile agent based paradigm for data aggregation in WSNs. We focus our discussion on literature survey of itinerary planning approaches for the mobile agent. Various mobile agent based algorithms are proposed to compare with the performance of the optimal itinerary. In this paper, we addressed the problem of itinerary planning for agent based data dissemination, facilitating concurrent sensory data collection to reduce task duration extensively. To conclude, the main objective of this paper is to provide an understanding of the merits and demerits of the proposed algorithms for Itinerary planning. We have presented a review with the help of Table , Many Mobile Agent Itinerary planning approaches have been classified on the basis of Single agent and Multi agents.

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Authors Profile

Miss Shivani Chaudhary pursued Masters of Technology from YMCA University of Science & Technology, Faridabad, India in 2019 and Bachelors of Technology in 2017 from BSA college of Engineering & Technology Mathura, U.P. India. Her main research work focuses on Network Security, Wireless Sensor Networks.

Mr. Umesh Kumar is working as an Assistant Professor in the Computer Engineering department of YMCA University of Science and Technology, Faridabad, India since 2012. He pursued his M.Tech. degree in Computer Engineering from same University. His research interests include Wireless Security, Mobile Agent, Distributed Computing.

Dr Mohit Gambhir is Founder & CEO of Verispire technologies Pvt Ltd, currently on an assignment as Director, Innovation Cell, Min. of HRD, Govt of India. His major thrust at present is to drive the innovation culture across the country. His research interests include network security, WSN, technology management and IPR.

