International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol-6, Special Issue-3, Apr 2018 E-ISSN: 2347-2693

A Comparative Analysis of Itinerary Planning Algorithms for Single Mobile Agent and Multi Mobile Agent

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Available online at: www.ijcseonline.org

Abstract— Using Mobile Agents (MAs) every conventional distributed system work can be performed efficiently, robustly and easily within a single and general framework. Despite many benefits, Mobile Agents have a number of issues like fault tolerance, security , routing etc. Among these issues this paper emphasizes on routing of MAs. This paper defines types of itineraries based on their knowledge and based on number of Mobile Agents used to perform optimum itinerary. It describes disadvantages of single mobile agent itinerary planning(SIPs) and different challenges faced by multi mobile Agent itinerary planning(MIPs). The objective of this paper is to bring out a comparative analysis of the existing Itinerary planning algorithms.

Keywords—Itinerary planning, Mobile Agent, Mobile Agent routing

I. Introduction To Mobile Agent

Mobile Agents are the autonomous programs which are designed to perform any task or to gather desired information on behalf of any general user's requirements. Mobile Agents are comprised of both code and data, having the capability to migrate autonomously from one system to another when they are connected together through network to perform its assigned task on behalf of any remote user. Mobile agents are so intelligent that they know what to do, when to do and where to migrate. Using Mobile Agents every work can be performed efficiently, robustly and easily within a single and general framework. Any Mobile Agent System can perform better than conventional paradigms when queries are more complex and network conditions are poor but preform worse when queries are simple and network conditions are good.

They are capable of doing work in heterogeneous environment. They are also capable of reducing network load, as mobile agents can execute their programs even after the disconnection of network. Despite its many practical benefits Mobile Agents have number of design issues like fault tolerance, security and routing etc. Out of these issues, this paper focuses on routing problem. Mobile Agents are used to discover and maintain routes in network. For this an itinerary can be defined which may decide the order of movement of a Mobile Agent to gain the information or to do a task. Routing is a process used to find the optimum path to carry out the data to the destination.

II. Itinerary Planning and their Design Issues

In Mobile Agent's routing, route has to be defined for Mobile Agents. Set of nodes where Mobile Agents have to move to perform the task is called itinerary. Itinerary can be defined for single Mobile Agent as well as for multiple Mobile Agents.

- Single Mobile Agent Itinerary Planning (SIP), wherein only single Mobile Agent is dispatched in data aggregation process.
- Multiple Mobile Agent Itinerary Planning (MIP), wherein more than one Mobile Agents are dispatched in parallel, each mobile agent is assigned some number of hops in network.

SIP algorithms are satisfactory to small networks but not scalable to large networks, because traversing large networks, a single mobile Agent accumulates a large data with itself and behaves like conventional system. SIP algorithms incur following drawbacks:

- Long Delay
- Mobile Agent size increases
- Low reliability

In order to overcome these weaknesses of SIP, MIP can be used. Even MIP can overcome drawbacks of SIP but having its own challenges:

A. Finding the optimal number of Mobile Agents

Most important question arises how many number of Mobile Agents should be dispatched? If less number of mobile agents are dispatched, then network load increases and there can be delays in task duration. While, when large number of Mobile Agents are dispatched, then its obvious that the complexity will increase. If itinerary requires less MAs and processing element is dispatching more MAs means needlessly extra code is being transmitted through the network. This may cause large delay and increase in network load. Thus, when a Mobile Agent has the capability of generating its clone as per their requirement, there is no need of dispatching more number of Mobile Agents.

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B. Partitioning whole network into subsets of groups and for every group single Mobile Agent is deployed

These clustering (grouping) can be done using k-means clustering or by x-means clustering. Sometimes dense area in network become the cluster in circular or elliptical shape and randomly cluster head is defined. [6] Concentric circles are used to make them in grouping. Inner circle is used with radios ARmax where A is adjustment factor which lies in the interval (0,1], Rmax is maximum transmission range of any node in the network. Rest of the circles are of radios Rmax/2 which remains constant for all. It is not necessary that always grouping should be done in circular or elliptical shapes and this source grouping may be direction oriented [12]. They used angle gap method in which sink node is connected by other source nodes using lines and the angle gap between these lines is considered. In MST-MIP (Minimum Spanning Tree- Multi Mobile Agent Itinerary Planning) whole network behave like a minimum spanning tree and each branch can be treated as individual cluster. But each clustering method described above are geographically based. The load balancing among MAs is not considered. Because practically it is not possible that always load is distributed geographically.

C. Finding optimal itinerary for each Mobile Agent

Finding optimum path for Mobile Agent while migrating from one system to another becomes an important issue to be carried out for research. Itineraries of Mobile Agents can be classified into three categories static, dynamic and hybrid. This classification is based on knowledge of Mobile Agents. If Mobile Agents already have sufficient knowledge to decide which node is to traversed next, then itinerary is static. If route of Mobile Agents is pre decided then it is of static itinerary. But if the route of Mobile Agent is computed on the fly then it is of dynamic nature. Hence dynamic itinerary is more flexible than static. Hybrid is combination of dynamic and static itineraries, in which number of nodes to be visited are known by MA in advance but in which order to be visited is decided on fly. Some approaches (for single agent and for multiple agent) for defining itinerary are discussed.

III. RELATED WORK

In this section we review existing Single Mobile Agent (SIP) and Multi Mobile Agent (MIP) itinerary planning algorithm.

*A. **Single Mobile Agent Itinerary Planning***

- **LCF(Local Closest First):** [2] This is the example of static planning in which Mobile Agent traverses for the next node by calculating least geographical distance from the present node Fig. 1. It starts from node 1 and checks the distance from 1 then moved to 2. Now distance is checked from node to 2 and not from node 1. As in LCF MA traverses according to the least distance from its current location instead of viewing whole network which gives local optimum solution. Cost of the paths concerned to the nodes to be visited last, increases.

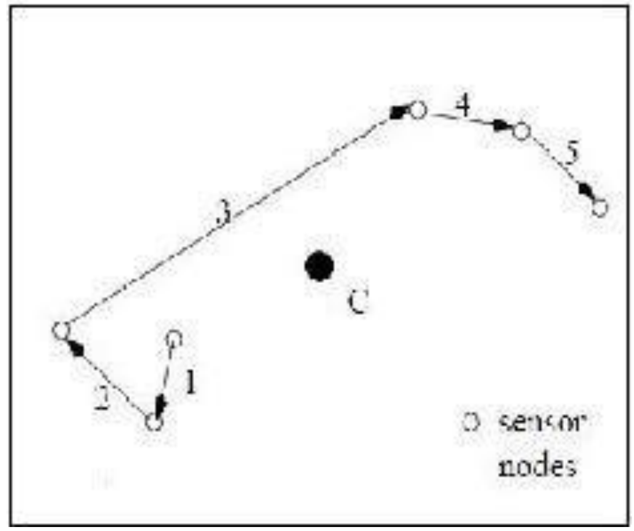

Fig. 1 Local Closest First [18]

- **GCF(Global Closest First):** [18] Mobile Agent looks for the next node to be visited by calculating the least distance from the source node. As whole network is traversed by considering distance from source node, it gives a global optimum solution. It overcomes LCF. When source nodes intend to form multiple clusters with similar distance to the sink, GCF causes zigzag routing due to the itinerary fluctuations among those clusters. This essentially utilizes sorting the distances (between the sink and other sources) to compute the MA path in fig 2. It is simple and fast but poor in terms of path loss.

Fig. 2 Global Closest First [18]

Drawback of the above algorithms is that both are based on spatial parameter and rest of the parameters which should be considered, are ignored. Information gathered can be considered to check the efficiency.

- **Mobile Agent Based Directed Diffusion (MADD):** [7] MADD have two phases to make energy efficient itinerary planning algorithm. In the first phase, subset of network to be traversed is determined. In second phase, Mobile Agent is dispatched to perform a task or to aggregate the data.

- **Energy Minimum for First-source-selection (IEMF): [7]** IEMF concentrates on designing energy-efficient itinerary planning algorithm. Number of iterations(LCF) are performed by taking different initial nodes. After comparing all the results, the node associated with least 'energy cost' is considered as first node. It is very similar to LCF, only difference is in the selection of the first/initial node.

*B. **Multiple Mobile Agent Itinerary Planning***

Multiple Mobile Agents are dispatched to gather information from number of remote locations. Network is partitioned into number of clusters. A single Mobile Agent can be deployed for individual cluster. Each cluster have its own cluster head. Each Mobile Agent unload itself to their cluster head. Then, another Mobile Agent can be deployed to gather the result from each cluster head to the sink node.

Genetic Algorithm Based Itinerary Planning : Genetic Algorithm (GA) is adaptive heuristic search algorithm based on the evolutionary theory of genetic and natural selection. Result of GA algorithm is always fittest survival because fittest will survive in every worse situation. In a GA system, firstly initialization is carried out. Then a selection operator is applied on to the initialized population which takes the fittest element for further reproduction. Then crossover operation is performed on selected population and number of more fit children are generated. Then mutation and replacement (if needed) operations are performed. A genetic algorithm based multiple MAs itinerary planning (GAMIP) scheme is proposed in [15], which mainly concentrates on finding the optimal number of MAs to be dispatched and an efficient itinerary planning for an individual MA is carried out. In GAMIP algorithm, two encoding techniques are used. First, all source nodes (contained in a single cluster) are encoded and then source nodes grouping are encoded. Which become the genes for genetic evolution. Genes can be selected randomly to form the search space called mating pool. Then, selection, crossover and mutation operations are performed iteratively to get efficient multi agent planning algorithm. In each iteration, steps of genetic algorithm such as crossover and mutations are performed so that better candidate of solution can participate in further reproduction. Exploration is done so that large number of genes(of different capability) can participate for further reproduction. Mutation and Replacement operations are optional. After these procedures, the selection operator selects the better genes to survive for the next generation.

[17]As per some convergence criteria , the algorithm converges to efficient multi agent itinerary planning algorithm. GAMIP can not be used in time critical applications and it is very complex to implement.

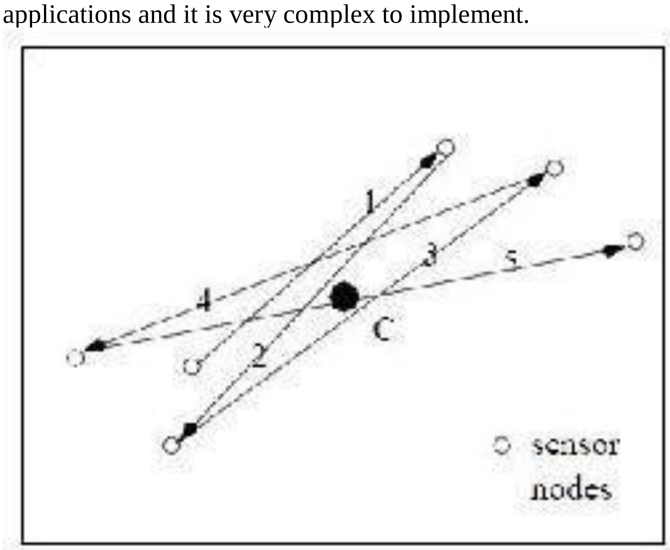

Fig.2

- **Ant Colony Optimization Technique (ACO): [4]**ACO algorithms can be applied in the multi agent itinerary planning to find the shortest path. An ACO algorithm is a meta heuristic approach that imitates the natural behavior of ants, including their mechanisms of cooperation and adaptation. The ACO algorithms use number of ideas.

- Number of ants will follow different paths, each will become the candidate of solution.
- Ants have the capability to differentiate, density of pheromone deposited by other ants.
- Pheromone deposited by the ants is of approximately constant rate, during their journey.
- The path with largest density of pheromone, is chosen by the ant when it have to select one out of many(paths)
- After some time pheromone will evaporate, this will tend to exploration otherwise some path are not identified by the ants(as they follow always more dense pheromone path)

After some iteration, it will converge to the path, which is expected to be the optimum or a near-optimum solution for the target problem.

- **NOID(Near Optimal Itinerary Design)**, [10] Originally, NOID takes total number of itineraries equal to number of sensor nodes present in the network. At every step of algorithm two itineraries are merged by combining their sensor nodes. By this procedure, cost associated with the node to be visited last , can be reduced. This algorithm concentrate on minimizing the overall cost of migration. The factors affecting the overall cost of migration are, i) amount of data aggregated at each node. ii) MAs initial size. iii) cost of link utilization. Algorithm tries to make itinerary fast to reduce task duration. NOID uses dynamic itinerary planning to adapt dynamic changes in the network topology.

- **CBID(Clone Based Itinerary Design)** [11] Author depicts network into minimum spanning tree. To make minimum spanning tree nodes are connected in such a way that chosen path should be associated with minimum cost. Mobile Agent traverse the network in depth first search manner to aggregate data. Algorithm is designed to dispatch optimum number of Mobile agents by using cloning capability of Mobile Agents. As MAs have the capability to generate their clone according to their requirement (when dispatched MAs feel overloaded).

- **TBID(Tree Based Itinerary Design)** [13] Sink is supposed to be at center of the network and then network is distributed into concentric circles to make them as itinerary. Itineraries are defined from inner circle to the outer circle. In order to construct a binary tree it chooses the nearest node hence it follows greedy approach. But farther node may be better solution for performing task.

- **FNFNNN(Farthest Node First Nearest Node Next)** [19] In this algorithm two types of Mobile Agents are used, named link agent and data agent. Link agents are responsible for connectivity issues, like which node is to be connected or disconnected and when. Data agents are deployed for actual data transmission. Network is distributed into clusters. Each cluster head have to deploy individual agent to some sensor nodes, based on their data size.

IV. COMPARATIVE ANALYSIS

Ten multiple itinerary planning for Mobile Agents are discussed in this paper to deal with the issues related to Mobile Agents routing. Table 1 brings out a comparative working of the discussed techniques with the objective of identification of the issues that may require consideration while carrying out improvements in designing routing strategies for Mobile Agents.

	Algorithm	Cardinality of MA	Routing strategy	Technique used	Cardinality of Itinerary
[2]	LCF	SIP	Static	Closest from current node	Single
[2]	GCF	SIP	Static	Closest from sink node	Single
[7]	MADD	SIP	Static	Works like LCF, but chooses farthest node as initial node	Dependent on Clusturs
[7]	IEMF	SIP	Static	Based on LCF, difference in selection of initial node	Single
[15]	GA-MIP	MIP	Hybrid	Genetic Algorithm	Dependent on groups
[10]	NOID	MIP	Static	Tree based	Dependent on subtrees
[11]	CBID	MIP	Static	Tree based	Dependent on Concentric zone
[13]	TBID	MIP	Static	Tree based	Dependent on Concentric zone
[19]	FNFNNN	MIP	Dynamic	Farthest node first, nearest node next	Dependent on Clusturs

Table.1

Following inferences are derived from the cognition of the described techniques.

- Optimum numbers of MAs should have participation in the itinerary which depends upon the grouping of source nodes in the network. This partitioning of network should not be dependent only upon geographical information.
- Contributing key factors of the itinerary planning are to minimize cost factor, maximizing information gain and minimizing task duration.
- Further, cost factor have constraints like cost of link utilization, size of Mobile Agent and increment rate of Mobile Agent size.
- GA-MIP can not be used for time critical situations.
- In tree based itinerary algorithms, Mobile Agents move back to the same path to unload itself, it may increase network load.
- Also, to reduce the network overhead there should be unloading of Mobile Agent after visiting some hops.

V. CONCLUSION and Future Scope

This paper aimed to provide comparative analysis of itinerary planning algorithms of single mobile agent and multi mobile agent. Nine Itinerary planning algorithms of Mobile Agents were discussed and a comparative analysis was carried out to identify the issues that may affect the itinerary planning of Mobile Agents.

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