

Routing Algorithm using mobile agents and Genetic Algorithm

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Abstract— This paper presents a routing algorithm for computer network using mobile agents (Ant algorithm) and genetic algorithm. Ant algorithm is a class of Swarm Intelligence (SI) algorithms. SI is the local interaction of many simple agents to achieve a global goal. SI is based on social insect metaphor for solving different types of problems. Ant algorithm uses mobile agents called ants to explore network. Ants help in finding paths between two nodes in the network. Paths generated by ants act as input to Genetic Algorithm (GA). GA finds the set of suboptimal paths between nodes with the objective of minimum cost. This hybrid algorithm exhibits better performance when compared to basic ant algorithm.

Index Terms— Mobile agents, Routing, Genetic algorithm.

I. INTRODUCTION

Routing is a process of finding path between two nodes. The objective of routing algorithm is to find paths with minimum cost. Cost can be a function of sum of delay between intermediate nodes, hop count or bandwidth utilization. Routing in conjunction with congestion control and flow control defines the performance of the network [1]. This paper presents a routing algorithm that not only generates minimum cost paths but also achieves load balancing (if the optimal path is congested).

Ant algorithm uses collective intelligence of groups of simple agents called mobile agents for path finding. Ant algorithm offers an alternative way of designing intelligent system, in which autonomy, emergence and distributed functioning replace control, preprogramming and centralization. This approach emphasizes on distributed ness, flexibility, robustness and direct or indirect communication among relatively simple agents [2]. This concept of mobile agents is used in this paper for routing in network. In ant algorithm, mobile agents (ants) are allowed to explore the network (collect information of different nodes in the network) and report to the specified node. This information can be used to transfer data between nodes. Many

researchers have investigated and adopted mobile agents for routing in networks. Ali Selamat and Md Hafiz Selamat [3], have proposed a routing algorithm of mobile agents for query retrieval using genetic algorithm, Tony White, Bernard

Pagurek, Franz Oppacher [4], in their paper describe how

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ant system can be improved if it is integrated with genetic algorithm for the purpose of routing in network. ARA [5] describes the modified ant algorithm for mobile ad hoc network.

Genetic Algorithms are search algorithms which are based on the concept of natural selection. GA uses adaptive heuristic search technique which finds the set of best solution from the population. New offsprings are generated /evolved from the chromosomes using operators like selection, crossover and mutation [6]. Most fit chromosomes are moved to next generation. The weaker candidates get less chance for moving to next generation. This is because GA is based on the principle of Darwin theory of evolution, which states that the “survival is the best” [7]. This process repeats until the chromosomes have best fit solution to the given problem. GA exhibits robustness, hence they do not converge to local optima.

II. ANT SYSTEM

Ant system arises from intelligent behavior of thousands of autonomous swarm members through complex interaction in food searching or nest building process. The individual ants make their decisions on which direction to go just on chance during food searching process or nest building process. As ants move they leave behind a chemical substance called pheromone, which other ants can smell and identify that an ant has been there before (indirect communication). The stronger the pheromone level, the more likely an ant is to take that route. Complex group behavior emerges from the interactions of individuals, something is created that is greater than sum of its parts [8]. Ant agents have numerous applications in the real world such as industry, design, vehicle routing, network and gaming to name a few.

The ability of ants to self organize is based on four principles.

- 12) Positive feedback – this is used to improve the good solution. When ants move from one node to another, the concentration of the pheromone along that path increases. This helps other ants to travel in this path.
- 13) Negative feedback – this is mainly used to destroy bad solution. This is done using the concept of decay of pheromone. The rate of decay is problem specific. Low decay rate encourages the bad solution not being destroyed and higher decay rate destroys good solution.
- 14) Randomness – path to be taken by ant is completely random, hence there is possibility of generation of new solutions.
- 15) Multiple interaction – the solution is found by interaction of many agents. In food searching process, one ant cannot find the food, as the pheromone would

decay. Hence more ants can find food faster [5].

- 16) Stigmergy – user agents are autonomous and communicate each other indirectly by modifying the environment [8].

III. GENETIC ALGORITHM

Genetic Algorithm (GA) is a search technique used for optimization problems. It depicts the biological evolution as the problem solving technique. GA works on the search space called population. Each element in the population is called as chromosome. GA begins with randomly selecting set of feasible solution from population. Each chromosome is a solution by itself. Each chromosome is evaluated for fitness and this fitness defines the quality of solution. GA is adaptive heuristic search technique which finds the set of best solution from the population [9]. New offsprings are generated /evolved from the chromosomes using operators like selection, crossover and mutation. Fitness value of the offspring is calculated. Most fit chromosomes are moved to next generation. The weaker candidates get less chance for moving to next generation. This process repeats until the chromosomes have best fit solution to the given problem. The summary is that the average fitness of the population increases at each iteration, so by repeating the process for many iterations, better results are discovered.

GA has been widely studied and experimented on many fields of engineering. GA provides alternative methods for solving problems which are difficult to solve using traditional methods. GA can be applied for nonlinear programming like traveling salesman problem, minimum spanning tree, scheduling problem and many others [10]. Using a GA for difficult scheduling problems enables relatively arbitrary constraints and objectives to be incorporated painlessly into a single optimization method.

IV. DESIGN

Let $G = (V, E)$ be a connected graph and N be the total number of nodes in the network. The goal is to find the path with minimum cost between source node V_s and destination V_d , where V_s and V_d belong to V . The total cost is the sum of cost of individual hops. The path length is given by the number of nodes along the path. Each link/edge $e(i,j) \in E$ of the graph connecting node V_i and V_j has a variable $\phi_{i,j}$ indicating the artificial pheromone value. The value of $\phi_{i,j}$ is incremented by $\Delta\phi_{i,j}$ by the ants which move along the path V_i to V_j . ie $\phi_{i,j} = \phi_{i,j} + \Delta\phi_{i,j}$ The concentration of $\phi_{i,j}$ indicates the usage of the link. If an ant at V_i wants to move to next neighboring node, it chooses next node based on the pheromone value. The pheromone value $P_{i,j}$ is computed as follows

$$P_{i,j} = \begin{cases} \phi_{i,j} / (\sum \phi_{i,j}) & \text{for } j \in N_i \\ 0 & \text{otherwise} \end{cases} \quad \text{Eqn 1.}$$

where N_i is the neighboring nodes of V_i .

The transition probability $p_{i,j}$ of a node V_i has the condition that

$$p_{i,j} = 1 \quad \text{if } i \in N \text{ and } j \in N_i$$

This paper presents the efficient on-demand, source initiated routing algorithm using ant algorithm and genetic algorithm. It is implemented as two modules viz., initialization of routing tables using ant algorithm and

generation route of optimal path using genetic algorithm. Finally data is sent along the generated path.

V. WORKING OF ANT SYSTEM FOR ROUTING

At regular interval of time t , the source node S generates n ants called forward ants (FA) to explore the network. These FA are sent into network to get the information of other nodes in the network to reach destination D and return the status to node S . Each FA has unique identification and travel independently to reach destination. During their journey, they deposit pheromone at the intermediate nodes. This pheromone indicates the usage of the link. Higher the concentration pheromone indicates that more ants have traveled along the path. Once the FA reaches the destination, a backward ant (BA) is generated. FA's information is loaded onto BA and FA is killed. BA travels back to source in the same path in reverse direction as that of FA, but in reverse order. BA updates the routing table at each of the intermediate nodes indicating that it is along the path between source S and destination D , it also stores the cost (distance/delay) to reach destination. Once BA reaches source node S , it updates routing table at S and BA is killed. After certain time for stabilization of network, the source node S would have received n backward ants. Each BA defines one path to the destination. Now GA is applied to these n paths to generate set of suboptimal paths to the destination.

VI. PATH GENERATION USING GA

Integrating GA with ant system is to achieve high level of adaptation in the route generation process. The objective of this work is to have minimum cost path, which also achieves load balancing. Following is the algorithm for optimal path generation.

initialize population
repeat

for ($i=1$ to population size)

- 1) Evaluate each chromosome in the population for its fitness
- 2) Select two chromosomes (selection)
- 3) Perform crossover (single point uniform crossover), validate and repair (if required)
- 4) Perform mutation (insertion), validate and repair (if required)

until (termination condition)

A. INITIALIZATION OF POPULATION

Ant algorithm will generate set of paths from a given source to the destination. For each of the path generated, it has to be coded properly such that it is easy to implement. Each path consists of 'n' elements (each chromosome is of size n). Example: Let the network consist of 10 nodes, each chromosome is represented as [1 2 3 4 5 6 7 8 9 10]. Source node is 1 and destination node is 10. If no route exists then it is indicated by 0. Say [1 2 5 7 8 9 0 0 0 0] indicates there are no outgoing links from node 9.

For each of these paths generated, the cost and fitness of the paths are computed using Eqn.2 and Eqn. 3

$$\text{Cost}(\text{path}) = \sum_{k=1}^n \text{cost of link} \quad \text{Eqn.2}$$

$$\text{Fitness}(\text{path}) = \text{cost}(\text{path}) / (\text{Total_cost} + 25) \quad \text{Eqn. 3}$$

where $\text{Total_cost} = \sum_{j=1}^n \text{Cost}(i)$

Once the fitness of the chromosomes is computed, the chromosomes for the next generation are selected based on the following methods.

B. SELECTION

This section presents different methods for selecting parents for next generation. This is mainly done to retain good solution and discard bad solutions. Some of the selection methods are- Elitist selection, Rank selection, Roulette wheel selection and tournament selection. Current work is based on selective those chromosomes to next generation whose fitness is greater than the average fitness of previous generation.

C. CROSSOVER

Crossover or recombination operator combines sub parts of two parent chromosomes and produces offspring that contains some part of both the parents. Crossover is mainly of two types namely single point crossover & multipoint crossover and fixed length & variable length crossover. This paper uses single point fixed length crossover. In single point crossover, first child consists of part before crossover site of parent 1 and part after crossover site of parent 2, second child consists of part before crossover site of parent 2 and part after crossover site of parent 1. In current work, the length of each path are same, the crossover site is decided by the equation Eqn 4.

$$\text{The crossover site} = \lfloor (n+m)/3 \rfloor \quad \text{Eqn 4}$$

where n and m are number of nodes visited by ant in parent 1 and 2 respectively.

Example: Let parent 1 = [1 2 4 5 8 0 0 0 0] and parent 2 = [1 4 6 8 0 0 0 0 0] are the two paths to source node 1 and destination node 8. The crossover site = (5+4)/3 = 3. Hence child 1 = [1 2 4 8 0 0 0 0 0] and child 2 = [1 4 6 5 8 0 0 0 0], care is taken such that the source node and the destination node remains unaltered.

D. MUTATION

Mutation is a method of introducing the loss of data (if any) by crossover operation. The different types of mutation operations are inversion, insertion and interchange etc. This paper uses the method of insertion. An element (allele) in the path (chromosome) is selected and inserted by non existing node in that path.

E. VALIDATION

Once the new path is generated using crossover and mutation, it has to be validated. The reason for this is to detect the existence of cycle and to check if there exists links between the intermediate nodes in the path. If the generated paths are invalid, they are repaired using repair function.

F. REPAIR FUNCTION

The repair function is used to correct the path under two conditions

- 1) When no link between intermediate node is present or
- 2) Cycle is formed.

The function converts the invalid path to a valid one or drops path based on the above two conditions. If the path consists of intermediate nodes for which the link is absent, then the child is discarded. If the cycle is detected, the node

causing the cycle is deleted from the path.

G. TERMINATION CONDITION

The algorithm is terminated under any one of the following conditions:

- 1) Number of iterations reached (say 100 or 200)
- 2) Reached the optimal solution
- 3) The rate of change of optimal solution is less than threshold value.

This paper uses two termination conditions. First, let sum of cost of all paths of generation i be Si and that of generation j be Sj (j>i), If Sj>Si, then continue else terminate. Secondly if ((Si/Sj) *100) >= 25% (threshold) then continue with next generation or else terminate.

VII. RESULTS

Current work is tested on following network with 7 nodes. The topology the network is as shown as cost adjacency matrix in Fig 1.

	1	2	3	4	5	6	7
1	0	3	0	999	999	6	10
2	3	0	2	5	1	999	3
3	0	2	0	1	1	2	0
4	999	5	1	0	2	8	1
5	999	1	1	2	0	5	0
6	6	999	2	8	5	0	0
7	10	3	0	1	0	0	0

Fig 1. Cost adjacency matrix.

The cost 0 indicates that there exists no path between that pair of nodes and cost 999 indicates that no direct link exists between the pair of nodes (not a neighbor node).

The population size in each generation is considered to be 30. Number of iterations/generation considered is 50,100 and 150. The crossover probability is 0.60, 0.70, 0.75 and 0.80. The mutation probability is 0.02 and 0.03. Following graph of Fig2 shows that crossover rate of 75% and mutation rate of 3% gives better result for average fitness when compared to other probabilities.

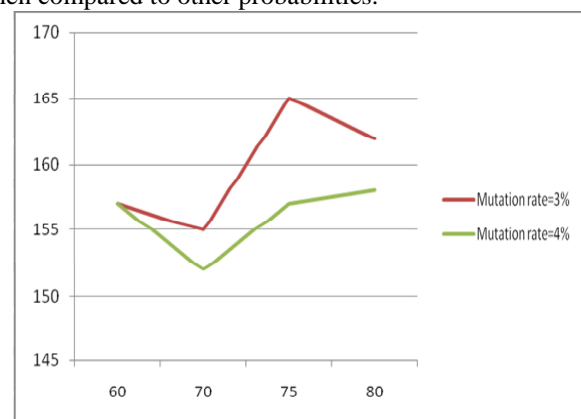


Fig 2 Crossover probability with average fitness

It is also found that average cost reduces as the number of generations increase. This is shown from the Fig 3, which shows the decrease in average cost with respect to number of generations.

Run	No of Gen	Crossover prob	Mutation prob	Average cost
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1	50	0.60	0.03	19
2	100	0.70	0.03	16
3	150	0.85	0.03	14

Fig 3. Variation of average cost with respect to number of generation.

development for about 18 years. He has been working in academics for about 15 years. He has to his credit two International and one National publication. His area of research includes Algorithms and Network Security.

VIII. CONCLUSION

In this work ant algorithm and genetic algorithm are used for routing in computer networks. Ant algorithm, is found to reduce the size of routing table. Genetic algorithm cannot use global information of the network. Hence, the combination of these two algorithms, which makes the packets to explore the network independently, helps in finding path between pair of nodes effectively. The proposed algorithm creates initial population, forwards forward ant, access fitness, generate new population using genetic operators and update routing table. The hybrid algorithm shows good results for not only generating routes between pair of nodes, but also achieves load balancing.

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