Proposal to Enhance AntNet Routing Algorithm by Exploiting Association Rules as Analysis Tool

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Abstract

This research introduces a proposal to enhance routing in internetworking depending on Ant Colony Optimization (ACO). The proposal concentrate on truth said: ACO itself is a metaheuristic, so when combined with an actual problem area, it can lead to several heuristics. This research presented AntNet, based on mobile agents, whose use is currently oriented towards packet switching networks, such as Internet, which inspired from ACO, implemented then obtained results are analyzed.

Analysis done by applying Association Rules (AR) on proposed database which it is transactions are the tracked routes from AntNet network routing algorithms and it is attributes are the most critical attributes for network routing algorithms. The extracted rules will be analyzed, to build the proposed Modified AntNet (M- AntNet). M- AntNet improve an existing network routing technique in terms of speed of convergence when considering delay as the most important parameter for network convergence. In general the proposed modification demonstrates a method by which delay and network overhead can be significantly reduced without a higher loss rate or jitter. Experiments also indicate that the performance of the modified AntNet, M- AntNet, is significantly improved when paths are long or alternative paths are few. Furthermore, under normal state of network operation, i.e. when all nodes are actively engaged in sending/receiving information, the modified AntNet significantly reduces the overall end-to-end delay. With M- AntNet route optimization will not get stranded into local optima and always new and better paths are explored even if the network topologies get changed very frequently. Hence problem of stagnation is solved. Also include proposed mathematical equations, which guide to the optimal shortest path with efficient deal for congestion.

Keywords: *ACO, ACS, Routing, AntNet, Delay, AR, congestion.*

1. Introduction

This section will introduces theoretical background for networking routing algorithms and data mining.

1.1. Network Routing and Ant Colony optimization

Routing algorithms, at the core of network control systems, play an important role in the exponentially growing communication systems worldwide. If appropriately configured, they can provide faster, smoother and more reliable data packet routing, and in particular greatly influence several measures of network performance such as end-to-end delay and throughput. Conventional routing algorithms depend on global exchange of information among nodes and hence become impractical as network size increases. These algorithms are based on finding shortest path such as in distance-vector algorithms, Router Information Protocol (RIP) and Link-State algorithms, Open Shortest First Protocol (OSPF) [1, 2].

A wide variety of routing protocols and algorithms exist for communication networks. In the traditional approach to routing, the routing tables are updated by exchanging routing information between the routers. Various routing protocols differ in their approaches to exchange the routing information. For example, in OSPF the routers exchange link-state information by flooding [3]. A relatively new approach to routing is the use of mobile agents for updating and maintaining the routing tables. Recently, a number of routing algorithms inspired by the ant colony metaphor and using mobile agents have been proposed for both wired and wireless networks. Traditional routing algorithms are not intelligent and do not have enough flexibility to satisfy new routing demands and they need human assistance in order to adapt themselves to failure and changes [1].

Ant Colony Optimization (ACO) is the general name of the algorithm which is inspired by a behavior of feeding of ant [4, 5]. In ACO based routing algorithm, solution construction handles formation of routing table, Pheromone update used to choose the single optimal path based on density of pheromone, in case of single path routing; and the pheromone update desires the probability of load sharing along multiple path, in case of multi path routing [4].

AntNet is an Ant Colony Optimization (ACO) meta heuristic for data network routing proposed by Gianni Di Caro and Marco Dorigo. In this network routing algorithm, a group of mobile agents (or artificial ants) build paths between pair of nodes, exploring the network concurrently and exchanging obtained information to update the routing tables. This information is also used to direct the data packets towards their destination relation of routing and ant colony [5, 6].

A number of routing algorithms based on the ant-colony metaphor have been proposed for communication networks, there has no information on the routing technique used in analysis of ant-routing algorithms. Antnet is an agent based routing algorithm based on real ants behavior technique is discovered so many algorithms have been proposed: Cauvery N K , Dr. K V Viswanatha., proposed in 2009, "Routing in Dynamic Network using Ants and Genetic Algorithm", using ant algorithm to explore the network using intelligent packets. The paths generated by ants are given as input to genetic algorithm. The genetic algorithm finds the set of optimal routes. The importance of using ant algorithm is to reduce the size of routing table. The significance of genetic algorithm is based on the principle evolution of routes rather than storing the precomputed routes [6]. M. Nofal, S.F. El-Zoghdy and M. Hadi, proposed in 2011, "An Intelligent AntNet-Based Algorithm for Efficient Secure Data Routing over Peer to Peer Networks", evaluate the performance of the AntNet routing algorithm in terms of efficiency and security in peer-to-peer networks. Using the network simulator NS2, a simulator is implemented for a network of 8-nodes which simulates the ant colony intelligence in deciding the most efficient and secured path from source to destination nodes. [7]. Ms. Meenakshi R Patel , Ms. Babita Kubde, proposed in 2012, "A survey paper on Ant Colony Optimization Routing algorithm for selecting Multiple Feasible Paths for Packet Switched Networks", perform a survey on modified AntNet routing algorithm using Multiple Ant-Colony Optimization. Multiple ant colonies with different pheromone updating mechanism have different searching traits. Design a set of adaptive rules to facilitate the collaboration between these colonies. This approach can balance the diversity and convergence of solutions generated by different ant colonies and also overcome the problem of Stagnation [8].

1.2. Data mining

Data Mining is an analytic process designed to explore data (usually large amounts of data - typically business or market related) in search of consistent patterns and/or systematic relationships between variables, and then to validate the findings by applying the detected patterns to new subsets of data. The ultimate goal of data mining is prediction - and predictive data mining is the most common type of data mining and one that has the most direct business applications. The process of data mining consists of three stages: The initial exploration, Model building or pattern identification with validation/verification, and Deployment (i.e., the application of the model to new data in order to generate predictions). ***Association Rules Algorithm*****,** The efficient discovery of such rules has been a major focus in the data mining research community. Many algorithms and approaches have been proposed to deal with the discovery of different types of association rules discovered from a variety of databases. However, typically, the databases relied upon are alphanumerical and often transaction-based. The problem of discovering association rules is to find relationships between the existence of an object (or characteristic) and the existence of other objects (or characteristics) in a large repetitive collection [9-13].

2. Proposal

The proposal concentrates on using ACO algorithms, by apply the ACO AntNet routing algorithm and from obtained results (routes resulted from AntNet) a proposed database constructed to include these routes identified as a collection of attributes (attributes derived from AntNet Specification). The database analyzed using AR and some modifications are suggested to modify AntNet to a proposed M- AntNet.

That through introducing algorithm satisfying specifications serves routing process such as performance of routing in consideration to delay and congestions with respect to preservation of routing process standard which implemented in classical routing algorithms to accommodate real world technologies. In AntNet artificial ants (agents) collectively solve the routing problem by a cooperative effort in which stigmergy, mediated by the network nodes, plays a prominent role. By using a stochastic routing policy based on local (public) and private information ants concurrently and asynchronously explore the network and collect useful information. While exploring, the ants adaptively build probabilistic routing tables and local models of the network status using indirect and non-coordinated communication of the information they collect.

2.1 AntNet Routing Algorithm

AntNet Input, In considering dynamic network so the input to the algorithm will be topology of the characteristic for network as number of nodes and cost for each edge while in using static network, topology determined within initialization phase.

AntNet Output, List of ants' path through network with cost needed to pass all nodes without duplicate which stored in data file to represent routing table for each node in network that reflect the probabilities for each possible final destination.

AntNet Initialization, As static network needs initialization for its topology characteristic so that requires to define number of nodes with identifying the neighbors of each node then two data structures resides at each network node k (the network is considered to have N nodes and each node k has N_k neighbors), as follows:

- Let *k* be any network node; its routing table will have N entries, one for each possible destination.
- Let *j* be one entry of *k* routing table (a possible destination).
- Let N_k be set of neighboring nodes of node *k*.
- Let P_{ij} be the probability with which an ant or data packet in *k*, jumps to a node *i*, $i \in N_k$ when the destination is *j* (*j*,*k*). Then, for each of the N entries in the node *k* routing table, it will be n_k values of P_{ij} subject to the condition:

$$\sum_{i \in N_k} p_{ij} = 1 , \quad j \in [1 \dots N]$$

AntNet Process, Process:

1- Forward Ant, denoted $F_{s\to d}$, which will travel from the source node *s* to a destination *d*.

2- Backward Ant, denoted $B_{d\to s}$, that will be generated by a forward ant $F_{s\to d}$ in the destination *d*, and it will come back to *s* following the same path traversed by $F_{s\to d}$ with the purpose of using the information already picked up by $F_{s\to d}$ in order to update routing tables of the visited nodes. Every ant transports a stack $S_{s\to d}$ (*k*) of data, where the *k* index refers to the *k*-est visited node, in a journey, where $S_{s\to d}$ (0)= *s* and $S_{s\to d}$ (*m*)= *d*, being *m* the amount of jumps performed by $F_{s\to d}$ for arriving to *d*.

3- End

Implementation of AntNet Algorithm

Suppose a data network, with 8 nodes, being *s* a generic source node if it generates an agent (or ant) toward a destination *d*, at each interval an agent will start from each node towards a specified destination with consideration to compute the delay that occur when moving from node to node. And now will introduce the details of AntNet implementation by the following descriptions, interfaces as shown below, figure (1) and figure (2) :

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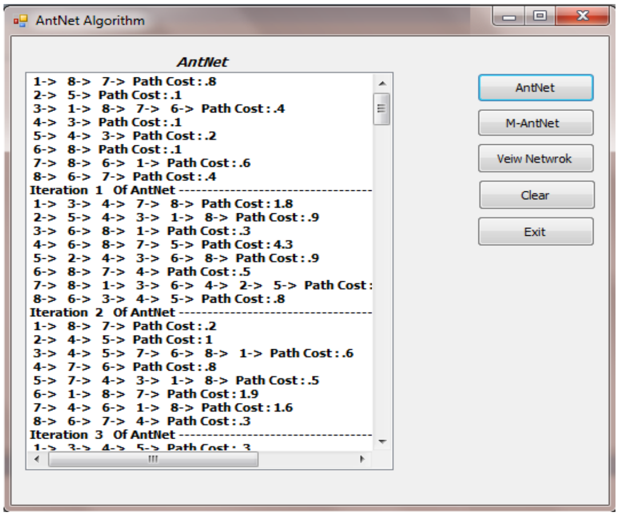


Fig. 1 AntNet of 8 nodes with 8 ants; declares path of each ant and cost requires.

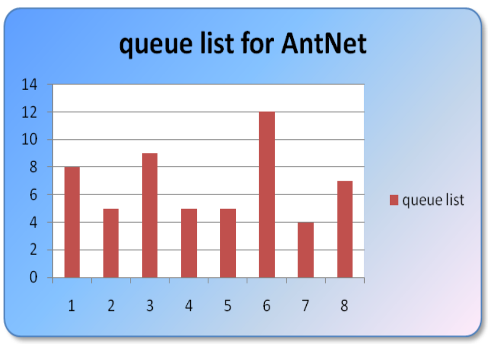


Fig. 2 shows nodes congestion during AntNet processing

2.2. AntNet Analysis

This stage presents the analysis of AntNet according the following consequence steps:

A. Build Proposed Database and Preprocessing Algorithm

Input: Get Results of AntNet routing algorithms.

Output: Proposed AntNet routing algorithm database.

Step 1: take the AntNet routing algorithm routes extracted by the implementation.

Step2: extract it is parameters (nodes, ants, and many others) as attributes.

Step3: store these attributes in attribute's file.

Step4: each attributes presented by the consequence alphabet.

Step5: construct the structure of the proposed database where,

- No. of transaction is the no. of given routes tracked by AntNet routing algorithm, since each transaction present a route result from AntNet.
- No. of columns is the no. of given attributes in attribute's file, since each column present an attribute.

Step6: For each transaction (route tracked by AntNet algorithm) insert the attributes values, that by write attribute alphabet if the attribute value is satisfy some condition. Else attribute alphabet is not written in the transaction.

Step7: end.

B. Attributes Encodings

This research takes the routes tracked by AntNet routing algorithm as transactions, the attributes will be considered are:

- Attribute (A): if the route tracked by the reasonable no. of nodes will appear, else will not appear.
- Attribute (B): if the route tracked by reasonable no. of ants will appear, else will not appear.
- Attribute (C): if the route tracked by reasonable value of the probability P_{ij} will appear, else will not appear.
- Attribute (D): if the route tracked by reasonable no. of iterations will appear, else will not appear.
- Attribute (E): if the route tracked by reasonable average time of path will appear, else if will not appear.
- Attribute (F): if the route tracked by reasonable delay will appear, else will not appear.
- Attribute (G): if the route tracked by reasonable congestion will appear, else will not appear.
- Attribute (H): if the route tracked by reasonable cost will appear, else will not appear.
- Attribute (I): if the route tracked by reasonable stagnation will appear, else will not appear.
- Attribute (J): if the route tracked by reasonable throughput will appear, else will not appear.
- Attribute (K): if the route tracked by reasonable reliability will appear, else will not appear.
- Attribute (L): if the route tracked by reasonable load will appear, else will not appear.

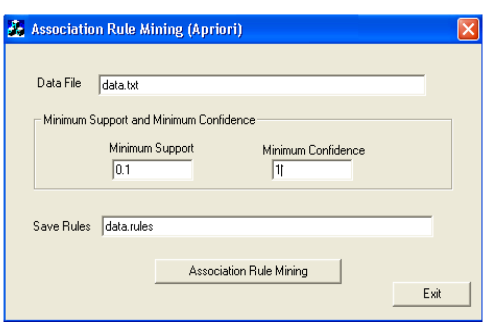
C. Association Rules Mining Stage

The problem is stated as follows, Let $I = \{i1, i2, ...im\}$ be a set of literals, represent the most important attributes of routing algorithms, called items. *Proposed database D* be a set of transactions, where each transaction *T* is a set of items such that $T \subseteq I$, *these transactions are routes tracked by AntNet routing algorithms*. A unique identifier *TID* is given to each transaction. A transaction *T* is said to contain *X*, a set of items in *I*, if $X \subseteq T$. where these items present the presence of routing algorithm attributes in tracked routes. An *association rule* is an implication of the form "$X \Rightarrow Y$", where $X \subseteq I$, $Y \subseteq I$, and $X \cap Y = \emptyset$. The rule $X \Rightarrow Y$ has a *support s* in the transaction set *D* is *s*% of the transactions in *D* contain $X \cup Y$. In other words, the support of the rule is the probability that *X* and *Y* hold together among all the possible presented cases. It is said that the rule $X \Rightarrow Y$ holds in the transaction set *D* with *confidence c* if *c*% of transactions in *D* that contain *X* also contain *Y* . In other words, the confidence of the rule is the conditional probability that the consequent *Y* is true under the condition of the antecedent *X*. The problem of discovering all association rules from a set of transactions *D* consists of generating the rules that have a *support* and *confidence* greater than the given thresholds. These rules are called *strong rules*, see figures (3 and 4).

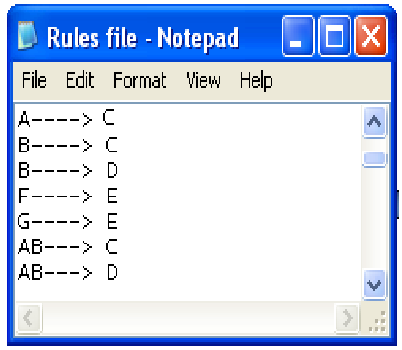
Table1

ID	attrributes
2	ABCFGHI
3	ABCDEFGHIJK
4	CDEFGHIJKL
5	ABCEDEFGH
6	ABCDEFGHIJK
7	ABCFGHI
8	ABCFGHI

Fig. 3 Proposed Encoded Routing Algorithm Database



(a)



(b)

Fig. 4 a- Association Rule Mining Program, b- File of Association Rules Extracted

D. Analysis and M- AntNet Design Stage

From analyzing the extracted rules in section above, there is many of correlations in attributes of tracked routes with AntNet algorithm. Will introduce these correlation and how will exploiting in proposing the M- AntNet. The AntNet focuses on ACO algorithms, so the relation among nodes, ants and iteration very correlated. The AntnNet concentrate on correlation between the solution quality and the distance from very good or optimal solutions. Probability in AntNet correlated with average time of path also correlated with path and packet delay. Congestion related with stagnation, and many others correlations.

To go in trend of implement M- AntNet routing algorithm, and from analyzed results some of modifications done on it for improve the performance of network, the modified algorithm focuses on the following points:

1- Well initialization of the goodness probabilities for each destination node in routing table belongs for network nodes which have the great effect on selecting jumping node that should represent the optimal path route.
2- Intelligent routing done when selection destination as a neighbor to overcome network congestion happened by network crowding with close requests rather than worth one and consequently delay in response time due to congestion.
3- In order to avoid infinite loops, self-destruction of a forward ant $F_{s\text{->}d}$ occurs when the amount of jumps

in a cycle is higher than ant age (TTL) of jumps performed by itself during its travel.

4- Decreasing overhead on network nodes by lowering the level of queue size and consequently plays big role in routing process, queue size as illustrated in chapter four, it is obvious that decreasing the level of ants waiting at each node due to intelligent strategy followed in the modified algorithm.

5- Achieve objective of reaching shortest path agree with routing principles by decreasing delay that may occur in reaching destination , although natural occurrence of delay but in modified algorithm trying to shorten it.

2.3. Proposal of modified AntNet Alogirthm (M- AntNet)

M-AntNet basically uses the same pseudocode as AntNet. However, several modifications were done, in order to improve the performance of AntNet, these modifications are briefly explained here.

1-*Intelligent Initialization of Routing Tables*

- An array $M_k = [(\mu_j , \sigma_j^2 , T_{best})]$, j=1…N, where μ_j is the mean, σ_j^2 is the variance and T_{best} is the best trip time to destination j, from node k.
- A routing table T_k which has N rows and N_k columns. It stores for each pair (d,n) the probability p_{dn} , which is the goodness of choosing node n as the nest hop for the destination d. These probabilities are normalized such that,

$$P_{ij} = \frac{1}{N_k}, \qquad \forall i \in N_k$$

2- *Intelligent Selection of destination node*

At regular intervals, from every network node s, a forward ant $F_{s\rightarrow d}$ is launched with a randomly selected destination $d;$ here checking for destination not to be a neighbor because that action can lower the algorithm performance without getting good results such that making destination far-way at least two hops distance as minimum from source in order to increase the level of performance.

3- *Increase performance of ant travel*

By determining age for each ant, delimits ant tour through network that may causes results which are may be not accepted while ever in network there is always a limitation for any packet travel assigned by Internet Protocol represents in TTL (Time To Live) which is decremented while passing nodes.

4- *Intelligent Selection of Jumping Node*

In case of using random strategy for selecting jumping node, a problem of stigmergy and great delay of time will occur even between adjacent nodes meanwhile if it depends on goodness probability for reaching destination, problems can be recovered.

5- *Intelligent routing with less overhead*

In case of selection a neighbor as a destination, agent's task will be shorten as a one jump without entering in routing process, this modification can reduce overhead consumed through Boolean flag placed at each agent have a neighbor as destination, this modification gives a opportunity to an gent have a randomly destination as a neighbor rather than excluding randomly selected destination because it is a neighbor and may consume overhead although close distance.

6- *Intelligent congestion control*

Proposed congestion state measure, which aim to examine the congestion state for all neighbors nodes to select the best one which present a minimum congestion. That done by a proposed modest mathematical equation to measure the congestion, and as in the follow:

CSRi = TPPA – TPPS, Where

CSRi, Congestion State nodes (no. i)

TPPAi, Time Ping Packet Acknowledgement (no. i)

TPPSi, Time Ping Packet Send (no. i)

Which mean, the measure of congestion depend on counting all the times between sending ping packets from current source to all neighbors represent the current destinations and receiving ping packets acknowledgements from all current destinations to the source. The minimum time will be depended and the related current destination will be taken as the best congestion state node to represent the new current source.

Process:

Step one: The forward ant $F_{s \to d}$ chooses a route based on the current routing table. Each neighbor is selected as the next node with the probability of $P_{n,d}$ is calculated as follow:

$$P_{n,d} = \frac{p_{n,d} + \propto I_n}{1 + \propto (N_k - 1)}$$

Where I_n (neighbors readiness parameter) is a normalized range between [0,1] which depends on q_n

$$I_n = 1 - \frac{q_n}{\sum_{n=1}^{N_n} q_n}$$

here q_n is the length of the queue of the packages that are sent from node k to its neighbor n and $\alpha \in [0.2 , 0.5]$ is the weight of I_n in calculation of $P_{n,d}$ that has been obtained experimentally.

Step two: The forward ants create a stack and place the travel time and congestion states for each node inside it.

- If cycle is detected, that is, if the ant is forced to return to an already visited node, the cycle's nodes are popped from the ant's stack and all memory about the cycle is destroyed.

Step three: When the forward ant reach destination, they give their stack to backward ants and they die.

Step four: The backward ants take out the data items from the stack and take the route back toward the starting node.

Step five: Arriving at a node k coming from a neighbor node h, the backward ant updates the two main data structure of the node, the local model of the traffic M_k and the routing table T_k

Step six: After getting to the destination, the backward ant also dies.

Step seven: Save Resulting data.

Step eight: End.

Implementation of Proposed M- AntNet Algorithm

Suppose a data network, with 8 nodes, being s a generic source node if it generates an agent (or ant) toward a destination d, now will introduce the details of M- AntNet implementation by the following descriptions, interfaces, as shown below, figure (5) and figure (6):

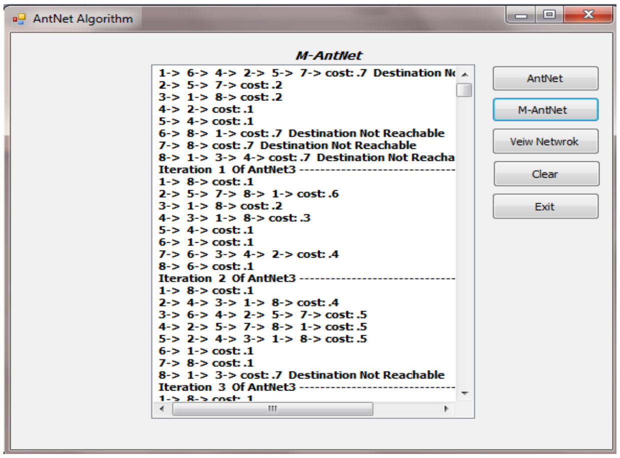


Fig. 5 M- AntNet with 8 ants; declares path of each ant and cost requires.

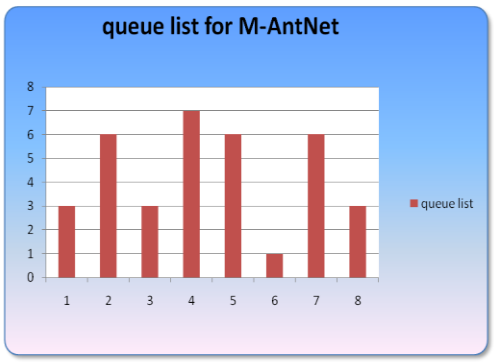


Fig. 6 shows nodes congestion during M- AntNet processing

Now, can compare between results in implementation the two algorithms by fixing path cost and can clearly recognize the optimization performed by modification done through introducing M- AntNet algorithm as shown below, figure (7), figure (8) and table (1):

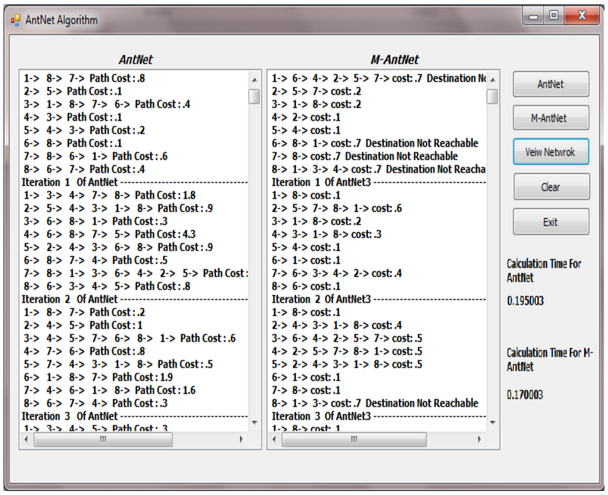
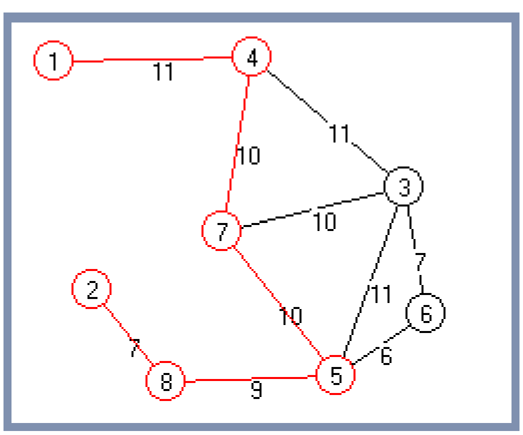
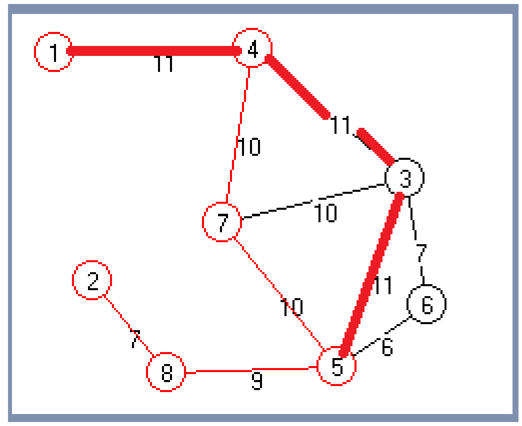


Fig. 7 shows comparison results during implementing AntNet and M-AntNet.

Now before display how the proposed enhanced routing algorithm first will display the implementation of Antnet algorithm, the resulted shortest path is (1-4-7-5-8-2), see figure (8-a). In AntNet the basic criteria is the shortest and low cost of distances between source and destination, without consideration of congestions, delay and stagnation. In the proposed M- AntNet all of them shortest path, minimum cost, minimum delay, minimum stagnation and minimum congestion state will be taken as a basic considerations, see figure (8-b), which explain the implementation of M- AntNet shortest path which display how the selection of shortest path will affected by congestion state, delay, stagnation. So the shortest path with congestion consideration was (1-4-3-5-8-2).



(a)



(b)

Fig. 8 a- Traditional Algorithm, b-Proposed Algorithm.

Table 1: comparison results of implementing Traditional Bell-manford, Traditional Dijkstra, AntNet and M-AntNet.

Parameter	Bell-man ford	Dijkstra	AntNet	M-AntNet
Routing table structure	1.Route type 2.Destination address 3.Adminstrative distance 4.Next hop 5.Exit interface	1.Route type 2.Destination address 3.Adminstrative distance 4.Next hop 5.Exit interface	1.Destination address 2.Next neighbor 3.probablity goodness	1.Destination address 2.Next neighbor 3.probablity goodness
Packet structure	1.Source IP 2.Destination IP 3.Protocol field	1.Source IP 2.Destination IP 3.Protocol field	1.Ant id 2.Source node 3.Destination node 4.Node list 5.Ant age 6.Pointer to node list	1.Ant id 2.Source node 3.Destination node 4.Node list 5.Ant age 6.Pointer to node list 7.forward flag
Hop count metric	√			
Link cost metric		√	√	√
Congestion				√
Load balance		√	√	√
Convergence	Slow	Fast	Slow	Fast
Multiple path			√	√

3. Conclusion and future works

Many point concluded from the proposal, these are:

1. AntNet algorithms is better than regular routing algorithm in adaptation and load balancing with purpose to quicken the speed of convergence by updating routing table with values reflects some of

parameters of network stat such as load on each node represented by queue size.

2. Experiments shows that AntNet algorithm take longer path cost than M- AntNet algorithm even with adjacent destination and that caused by congestion happened while ants move randomly without deliberate jumps.
3. The performance of AntNet algorithm is lower than M- AntNet algorithm because ants can continue moving among nodes without respect to ant's age factor which must be taking in consideration specially with network packets routing in order to avoiding ants looping forever.
4. Based on the performed experiments, it is also expected an efficient M- AntNet behavior with: flow control, congestion and admission schemes. Therefore, it can be inferred that a commercial implementation of this algorithm may be feasible and its use can be considered for large networks, such as Internet, as a future option.
5. After some trails of moving artificial ants passing network nodes and updating to routing table upon the decisions in selecting jumping nodes, algorithm reach to stat of convergence noted by stable movement of ants with fixed route which mean that a stat of stability occur.
6. The proposed congestion measure by broadcasting ping packets and calculates the times of arrival the acknowledgment for these ping packets. Then select the fast response node as the best and make the shortest path algorithm depend on two critical criteria the cost and congestion.
7. Although Experiments of AntNet have shown very promising results, AntNet has outperformed under different experimental conditions with respect to other dynamic routing algorithms e.g. RIP, OSPF. Still there are some problems with this adaptive algorithm like stagnation.
8. The current algorithm uses symmetric delay between nodes as metric for optimization further, it can be extended to be other metrics like load and multimedia data.
9. For solving problem of stagnation, suggested to use limiting and smoothing pheromone, privileged pheromone laying and pheromone-heuristic control.

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