Journal of Advances in Computer Research
Quarterly pISSN: 2345-606x eISSN: 2345-6078
Sari Branch, Islamic Azad University, Sari, I.R.Iran
(Vol. 8, No. 4, November 2017), Pages: 107-119
www.jacr.iausari.ac.ir

Improvement of Routing Operation Based on Learning with Using Smart Local and Global Agents and with the Help of the Ant Colony Algorithm

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Received: 2015/10/19; Accepted: 2017/02/01

Abstract

Routing in computer networks has played a special role in recent years. The main reason is the role of routing in a performance of the networks. The quality of service and security is one of the most important challenges in routing due to lack of reliable methods. Routers use routing algorithms to find the best route to a particular destination. When talking about the best path, we consider parameters like the number of hops, change times, and communication cost of sending data packet. In this study we will try to improve the routing operations using local and global smart factors. The Ants Colony Algorithm is a multi-factor solution for optimization issues. This solution has models based on the ants' collective intelligence and has attracted some users in computer networks through converting to an efficient technology. Although the Ant is a simple insect, but a colony of them are able to perform useful tasks such as finding the shortest path to the food source and to share this information with other ants through leaving back a chemical material called pheromone. This algorithm consists of three stages. The first phase is clustering nodes of the network to smaller colonies. This phase is conducted by using learning automata network in accordance with the need of the network; For example, putting nodes in one cluster which will have more close relations in near future. The second phase is finding the routes of the network by ants, and the third phase is sending network traffic to the destination through routs found by ants.

Keywords: *Routing, Computer Networks, Ant Colony Algorithms, Learning*

1. Introduction

Nowadays, many of the world data warehouse centers are to follow procedures to increase the number of inquiry responding and also providing effective services, in a way that in many of these datacenters they perform procedures like caching the information, physical resources management such as the routers, load dividing, additional load control, and utilization of quality control services. One of the issues that causes reduce the efficiency level of router since a while after started to work, is reduction the buffer size and deletion of packets caused by routers that leads to so many solicitations remain unanswered or at least, their response time increase [1].

Routing in computer networks has played a special role in recent years. The cause of this is the role of routing in a performance of the networks. The quality of service and security is one of the most important challenges in routing due to lack of reliable methods.

2. Definition the Issue

Routers use routing algorithms to find the best route to a particular destination. When talking about the best path, we consider parameters like the number of hops, change times, and communication cost of sending data packet. There are many variations in routing protocols and algorithms for networks communication. In traditional routing, the routing tables are updated through exchange of information between routers. The existence of complex network problems such as proper routing, load balance and its adjustment, and controlling the density and congestion needs intelligent and advanced technology. Working on development of intelligent systems now inspired by the nature is a very popular context of collective intelligence. For example, there are some algorithms presented inspired by the ants' routing, which uses mobile factors for routing data networks.

In general, when there is a change in a large network, it is necessary to notify all nodes of the network, whilst these changes are more important for the groups dealing with these nodes. Thus, dividing the network to smaller groups make the nodes of each set have only the routing information of that set and get rid of conserving information of the all changes within the whole network. Therefore, routing is done so distributed. Even if there is a variation in the network, because of the mentioned clustering, just a small part of the network is influenced by it and the others are far from being affected. Therefore, on one hand, routing operation can be conducted there the without regards to the network changes outside the group, and on the other hand, due to lower volume of overhead data exchange with outside of the sets and operating routing inside them, routing speed grows.

So far, many clustering algorithms have been designed for computer networks. The main objective of protocols based on clustering is making an approach for efficient use of network resources and thus, increasing the longevity of the network [2]. Also, a cluster method has the ability of the network to be scaled which is one of the most important design parameters in the censoring wireless networks also has [3,4]. A nodes is considered as head-bunches in each cluster and the other nodes are as the members of the cluster and each node can only be a member of a network cluster [2]. Since collecting and sending the environmental information the base station is of responsibility of the head-bunches, as a result, the energy consumption in head-bunches will be more than other nodes. Therefore, remaining energy can be a good criterion to select the head-bunches [5]. Clustering algorithms are divided into two distributed and centered. Centered clustering algorithms need the general knowledge of network and computing overhead and they are not suitable for sensor nodes with limited resources. On the other hand, in a distributed clustering algorithm the decisions are usually made based on local information. Generally, distributed clustering methods have fewer communication cost compared to centralized methods [6]. Hence, the components that we have to evaluate to find an optimal routing pattern are as follows:

- Increase the speed of sending and receiving information on the network
- Dynamic routing on the network
- Relieve congestion on routers
- More secure packets
- limiting instability of network in one region and prevent its dissemination to other areas.
- Getting a new method in optimizing the routing algorithms

• Comparing routing algorithms with analytical methods of this study
• Hypothetical and theoretical methods for direct addressing of packets
• Reducing the overhead on a router
• Increasing the convergence speed

3. Concepts

Routing: this process involves choosing the best path in the network and plays an effective role in sending the data in a network. Routing is practical for multiple networks, like telephone, internet, and transfer network. This routing can send logic packets from the origin to the destination.

Ant Colony Algorithm: Ant Colony Algorithm is inspired by studying and observations of ant colonies. These studies have shown that ants are social insects that live in colonies and their behavior is more in the direction of survival of the colony rather than the survival of one component of it. One of the most exciting behaviors of ant is their behavior in finding food and how to find the shortest path between the nest and food sources.

The process of finding the shortest path by ants has very interesting features. First of all, is its ability to extension and it's being auto-organizer. In the meantime, there is no central control mechanism. The second feature is its great strength. The system includes a large number of factors that are unimportant alone, so even the casualties of an important factor do not impact on the effectiveness of system. The third feature is that, it is of an adaptive process. Since the behavior of the ants is not specified by any and many of ants choose longer path, the system can comply with the environmental changes. And the final feature is that this process is developing and can get bigger as much is it likes. The same features have inspired the designing of algorithms which are used when these features are necessary.

Learning Automata: Learning Automata is one of the models of strengthening and exercising learning, in which an Automaton learns an optimum deed according to an action done and the feedback taken back from the environment. The final goal of automata is to learn the best action between the actions of its own. The best action is the one which makes maximum possibility of bonus receiving from the environment.

4. Related Work

Genetic algorithm was presented in 1975 by John Holland [7]. This is an algorithm of random search technique based on the theory of human development course. Different purposes have caused the growth of genetic algorithms during the past 30 years. Genetic algorithms are, in fact, random search technique based on the natural mechanism and genetic rules of composition and mutation.

In [8] Dorigo, Maniezzo and Coloriniy have provided very initiative Ant Algorithms for solving issues with resolution capability. This algorithm has some features such as simple versatility in implementation in such a way that it is used in combined optimization as the problem of quadratic allocation and work scheduling in the workshop with least changes [8].

In 1997 Dorigo and Gambardella made some amendments in Ant Algorithm made Ant Colony Algorithm [9]. This algorithm is different from the previous one in three factors. These factors are:

The rule of position transmission which controls the influence of old and new nodes on the algorithm directly.

The rule of general updating which is used only in nodes that is in the path of the ant (best nodes).

When the ants create an answer, the rule of local updating is used.

In the 1971, Tsypkin introduced a method for simplification of learning to diagnose optimum parameters and using hill-climbing techniques to solve them [10]. Tsetlin and his colleagues started working on the learning automata at the same time. He introduced the concept of learning Automata for the first time. Tsetlin was interested in modeling behaviors of biological systems and he chose certain automaton which was working in a random environmental as a model for learning.

In the next researched the use of learning in engineering systems were considered as well.

In [11], the authors proposed two adaptive routing algorithms based on ant colony algorithm, the Adaptive Routing (AR (algorithm and the Improved Adaptive Routing (IAR (algorithm. To check the appropriateness of ADR algorithm in the case) of WSN, the author modified the ADR algorithm removing the queue parameters) by involving reinforcement-learning concept and named it as AR algorithm. The AR algorithm did not result in optimum solution. In IAR algorithm by adding a coefficient, the cost between the neighbor node and the destination node, they further improve the AR algorithm. Both AR and IAR algorithms are consuming energy in the initialization phase by broadcasting through every node.

An Improved Modified Tabu Search Algorithm to Solve the Vehicle Routing Problem with Simultaneous Pickup and Delivery presented (VRSPD) in [12]. The VRPSPD is an NP-hard combinatorial optimization problem. Therefore, practical large-scale instances of VRPSPD cannot be solved by exact solution methodologies within acceptable computational time. Our interest was therefore focused on meta-heuristic solution approaches. For this reason, a modified tabu search (PA) is proposed for solving the VRPSPD [12].

A Routing Algorithm based on Fuzzy Clustering and Minimum Cost Tree (FCMCT) in Wireless Sensor Network in [13]. In this reference [13] tried to decrease hard and complex computing with using soft computing such as fuzzy logic and used it in cluster head selection part. Hard and complex computing can waste energy, so some techniques were used to solve this problem. Minimum cost tree (MCT) helps to find minimum path, so used this technique for intra cluster routing and again more over used distributed source coding (DSC) technique for aggregating data. Finally, all of methods could reduce energy consumption and increased network lifetime.

A new approach in position-based routing protocol using learning automata for VANETs is city scenario presented in [14]. In this method a main characteristic of learning is increasing performance over time and exploit this characteristic to decreasing use of traffic information.

One of the most efficient ACO based implementations has been Ant Colony System (ACS) [15], that introduced a particular pheromone trail updating procedure useful to intensify the search in the neighborhood of the best computed solution.

5. Proposed Algorithm

We will try to improve routing operation in this article by utilization of intelligent factors locally and globally. Ant Colony Algorithm is a multi-factor solution for optimization having some models based on ants' collective intelligence and is applied in computer networks through converting to an efficient technology.

This algorithm consists of three phases. The first phase is clustering the network nodes into smaller colonies. This phase is done using the learning automata in accordance with the needs of the network; for example, putting nodes together which they will have more relations in a cluster in future. The second phase is finding the routes by ants, and the third phase is sending network traffic to the destination through the routes found by the ants.

We have used learning automata for clustering in this study. Any action selected is evaluated by a potential environment and the results are sent to the automata in the form of a positive or negative signal. Automata will use the response in choosing its next action. The final purpose is the automata learn to choose the best action from all of its actions. The best action is that maximize the potentiality of receiving reward from the environment. In fact, we can use the learning automata to perform clustering due to the behavioral model of data transferring between members of the network. Also the traffic swarm can be forecasted and the traffic load can be transferred to other directions.

In addition, we use direct addressing technology which omits processing in routers. In this way, the packets go through the routers directly without wasting time and only its report in router is send to sender system. This issue causes acceleration of sending and receiving data and more secure information. As mentioned previously, we considered the leading issue of adaptive routing for communication networks in this study. We have focused on routing for datagram networks of a wide area with irregular topology and best-effort service, for example, the most suitable network with above mentioned features is the Internet. Adaptive routing algorithms that we recommend here are called AntNet, that its flexibility of distribution and being a multi-factor algorithm matches it well with routing issue. The design of this algorithm is inspired by the previous studies in Ant Colony and in general, is based on signaling, which is routing by indirect relations between members through local changes, permanent (or changing gradually), and influenced by its environment. In optimization of Ant Colony, each ant uses a group of combined, random, and local, search strategies simultaneously in order to create a solution to their problem. By this way, we can put Ant Colony Algorithm in a parallel process to accelerate and increased run speed as much as possible. A collection of ants try to search a high quality solutions together through an indirect cooperation, gather information about the structure if the problem from each other, and use collected data to achieve their solution.

Ants start detecting the network and gathering useful information about it simultaneously and non-synchronous through a random routing policy and local and private positioning data. Ants, during the detection, start creating possible routing tables and local models of the network adaptively. This information can be collected using indirect and disharmonious communications by Ant's collaborators.

We examined two different versions of actions of AntNet in this study and compared it with the following algorithm: open shortest path first (OSPF), shortest path first (SPF), the comparative distribution of Bellman ford (BF), Q-routing, and PQ-routing. We examined the algorithm in an actual experimental condition, which was a NTT base private network that made from 100 and 150 random nodes. AntNet algorithms proved that has the best performance and its behavior creates most stable status. This algorithm has the best performance among opponents of SPF and BF.

Two versions of AntNET were implemented, which were AntNet-CL and AntNet-CO respectively. AntNet-CL (the same algorithm which is simply called AntNet) was the first performance of AntNET which we developed it for routing management in best-effort networks, while AntNet-CO is a version of more reactive AntNet-CL, which provides the routing requirements of high speed connection-oriented networks - that are in best-effort form - best.

First, we describe AntNet-CL algorithm unofficially, then we will discuss its differences with AntNet-CO algorithm. In AntNet-CO the general behavior is like the last one with the difference that:

Forwarding ants use the high priority queue as reversing Ant.

They have no stack memory along with them in order to the information about the time of their departure from starting point to destination be saved.

Reversing ants change the routing tables on the each node that they visit estimating departure time.

This estimation can be calculated in each node of K using a statistical model of L_k^l, which is taken from a local link of dynamics dump. The simplest type of model L is used in this study, in which according to the number of q_1 bits amongst data packets waiting in the line L, the virtual travel time to the target neighbors is calculated through formula:

$$d_1 + \frac{(q_1 + s_a)}{B_l} \qquad (1)$$

Where B_l is the link bandwidth, s_a is the size of Ant's packet, and d_1 is the delay of the link.

In both algorithms of AntNet-CL and AntNet-CO of forwarding ant a random policy is applied that leads to detect an applied good path. In AntNet-CL the forwarding ants are behaved exactly as the data packets and their delay experience will be used by reversing ants; thus, the quality of the routes passed can be calculated. While, in AntNet-CO forwarding ants are used to immediately discover a rout which is achieved by reversing ants estimating travel time to reach the destination using L model.

In order to develop the AntNET-CO method more, we have added few bits of experience to each Ant that are initially zero. We can consider these bits as the life of an Ant. On every hop, some of its life is used according to how close the ant is to its target.

The data that the Ant should go to which neighbor node be saved in path data, the data that the ant how quickly calculate these calculations and its kind of operational function will be stored in control data, the data that how long its effects remain in the network will be saved in time data, and the data how long it should live will be stored in experience. This issue will generates some sort of random algorithm in which there is no longer need to manually delete the network data offline. It is because in algorithms provided, as mentioned before, it should always be monitored and checked whether the Ant is in a circle or not and it causes strain on internal resources of the network.

In our algorithm we consider the ant's lifetime equal to the number of nodes in the network, i.e. If the number of hops the ant has seen is more than the number of network nodes, then we can certainly determine that it has fallen in a circle. Therefore, its calculation overhead will be more than its benefits. Thus, while we wait N times for that ant to reply, it its reversal ant didn't come back, so we can send another forwarding ant ahead. The parameter T_c is considered in this study as an 8-bit unit, that according to each node they have created in and according to the values already are learnt, were initialized separately for each ant. For the case that the system has not learnt anything yet, it learns $T_c = 00000000$. At first, when the node turns on, it sends a signal to its neighbor nodes to announce its existence. The neighbors as examining the receiving link, send a welcome signal to newborn node with their T_c to help this node to have a primary estimate of T_c. Then the newborn node can have an estimation of incoming signals by calculating the mean value of T_c. So we have:

$$T_c^{New} = \frac{1}{N_{New}} \sum_{i=1}^{N_{New}} T_c^i \quad (2)$$

$$\log(110) = 7$$

In where N_{New} displays the number of neighbors of newborn node. Now, the ants play the role of messenger in addition to data collector in the way that they replace their original T_c. This means that if a node reaches to a node with smaller T_c than the ant's T_c, then the T_c of the node changes to the larger value.

6. Experimental Settings

We use MATLAB software for this purpose and considered a network with 110 nodes of with Cisco RV0xx router and we connected them together at random and then examined our routing using algorithm using different protocols. We use a Poisson distribution to create a virtual traffic; in fact the interval between requests will have an exponential distribution.

6.1. Simulation platform and system evaluation

We used the throughput rate (bit delivery/s), data packet delay (s), and routing overhead (routing bandwidth/bandwidth available) as the criteria for comparing the algorithms. In our algorithm an ant is send out every 0.3 seconds initially from each node to collect information that its value is displayed as $28+8N$ in which N_h is the number of hops surveyed on the network, in which, its value will increase by increasing of an ant's path.

We considered a 7-bit unit for the life parameter because the average number of hops an ant should pass forward is $\log(110) = 7$ in which it should at least have the life of a tree. The forwarding and reversing ants both have the same structure in their 28-bit time and control data related to pheromones and times recorded that is mentioned before.

In OSPF, SPF, and BF algorithms, it is assumed that the interval time between any two equal communication signals is in the range 0.8 to 3 seconds. We have considered 24 MB data for each session which can be sent and received from any random source or destination.

These tests were conducted on a 16 core of core i7 server with 128 GB of RAM which needed 43 hours for every run. We have repeated the run 300 times for every result of the table to minimize the accidental impact of events. Results are achieved in total of six implemented algorithms in the form of a chart that we will discuss below.

6.2. The first test

In this test we randomly sent 1000 of 2 MB-volume-files from two random points in the network, to random destinations, and calculated the value of throughput rate as 5 for each of the 6 algorithms, then we repeated the entire test for another 1000 files until we have had repeated the whole experiment 300 times. Then we calculated mean throughput in a period of time till achieved below diagram.

By doing a test once, the test results had many fluctuations; therefore, we repeated the test 300 times to catch to correlation in our observations.

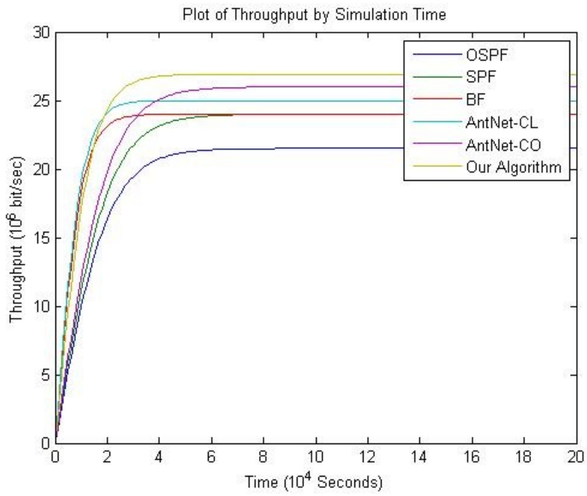

Figure 1. The changes of throughput rate of different algorithms over time period

As it can be observed in Figure 1, the algorithm proposed in this study have had higher throughput rate in the ranking than other algorithms, while the first shortest path (OSPF) had minimum throughput rate among all the algorithms.

Since packet-based network has naturally burst properties, the algorithm which matches more with this feature is better for us. All algorithms have gotten to steady state over time as shown in Figure 1; however, the first few seconds of their performance are more important for us. Three algorithms of AntNet-CL, BF, and the one presented in this study cover network burst features better. To express more precisely, we consider the algorithms that have more slope of changes at the beginning of the requests.

We cannot logically consider OSPF entirely inefficient because routers needed for this algorithm have simple equipment, for instance the processor needed for such an algorithm does not require a high cache.

6.3. The second test

As the terms of the previous test, the total test repeated 50 times. Finally we achieved Figure 2 calculating mean value for throughput in each size of the network.

In this experiment as well, we could come along with many swings in test results, so we repeated it for 50 times to get to the coherence in the observations. The distance between each test is 500 nodes; it means after every time we get the results of 50 experiments, we add randomly 500 nodes to the network and calculated the throughput rate test results for the new network. We also changed randomly the network edges (communication links between the routers) each time testing the network to prevent the results calculated just for a particular network.

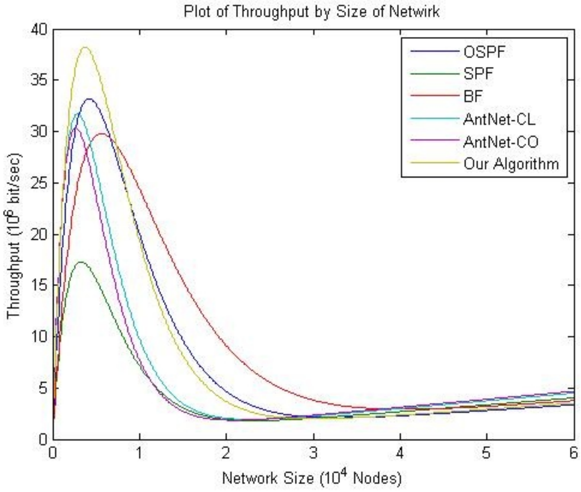

Figure 2. Changes of throughput rate by changing the size of the network

As seen in figure 2, all algorithms have a high rate of throughput for a range of network size. This is because the algorithms need to change their routing tables faster for smaller sizes of network and also Ant-based algorithms have less freedom of action in small sizes to transfer the a packet of data to their destination. But in larger networks, more number of nodes is, longer the path between the source and target can be.

However, as shown in Figure 2, the larger size of the network is from a threshold on, the throughput rate grows a little. The cause of this phenomenon is the existence of shorter routes that their number increases as the number of nodes increases from a threshold on.

The presented algorithm shows the most throughput rate in the period all algorithms arrive at their maximum coefficient of throughput rate. But BF algorithm is more sustainable and changes its throughput rate later as the network grows in size that is due to the structure of the algorithm which starts the local changes in its routing tables only when there are some packets lost. Also in the algorithm presented, to some extent, by increasing the size of the network, the elements of Ant experience loose its influence and acts like AntNet-CO and AntNet-CL algorithms. Therefore, this can be done with a compromise between the size of the packets of presented algorithm and the value of throughput rate to achieve a correct adjustment that will be specific to the very same network.

In other words, we could use a space of 16 or 32 bits for the storage of ants' experience instead of 8-bit, but it would have additional overhead on the system due to the length of the whole packets. On the other hand, according to the description mentioned in preceding paragraph, if this dedicated space for memory would be very small, it could not have a positive impact in a large network.

SPF algorithm have had weak results related to the changes of the network length due to its need to find the shortest route and the time of this algorithm will increase by power 3 by increasing the length of the network.

The last thing that should be added is that we have a basic noise in this network. Therefore, increasing the length of the routs, the possibility of error grows up and as a result, the throughput rate will be reduced significantly. This issue is displayed well in Figure 2.

6.4. The third test

In this experiment we send a thousand 10KB-file from two random points in the network to the random destination. We calculated the average number of hops found in the rout randomly for each of the two algorithms. Just like in previous tests, the whole test conducted for 20 times, and then we calculated the mean value of the number of the hops for each size of the network and achieved the results of Figure 3.

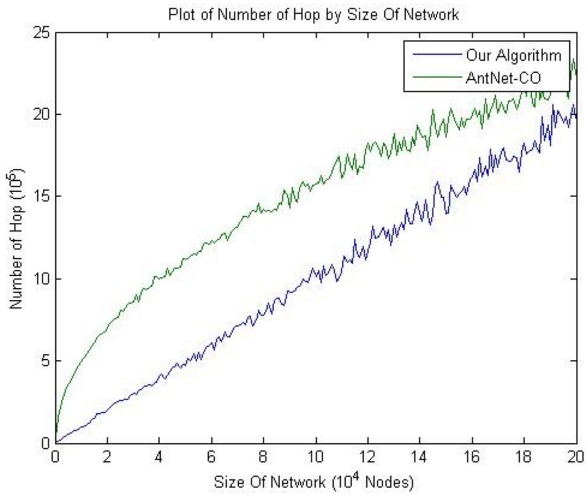

Figure 3. The average number of hops that the presented algorithm and AntNeT-CO provided in their path

The noise created in Figure 3 is because of low number of repetitions of the algorithm that was refused to repeat too many times due to the results being very obvious and to prevent from wasting time. AntNet-CL algorithm generally creates longer paths of AntNet-CO algorithm. Thus, it has not brought in Figure 3. The creation period of random routs are omitted from the results in this algorithm to prevent from wrong conclusions.

6.5. The fourth test

The other criteria that can be used to identify a desirable algorithm are the length of paths it finds for routing between points. As a result, besides the algorithms such as OSPF, BF, and SPF that exactly spend their time on finding the shortest path and finally, return on the shortest route -or the approximately shortest path-, we have compared the algorithms related to the Ant Colony algorithm. This experiment totally were conducted 30 times, and then calculating the average delay time of receiving packets in each file size, we may have the following results.

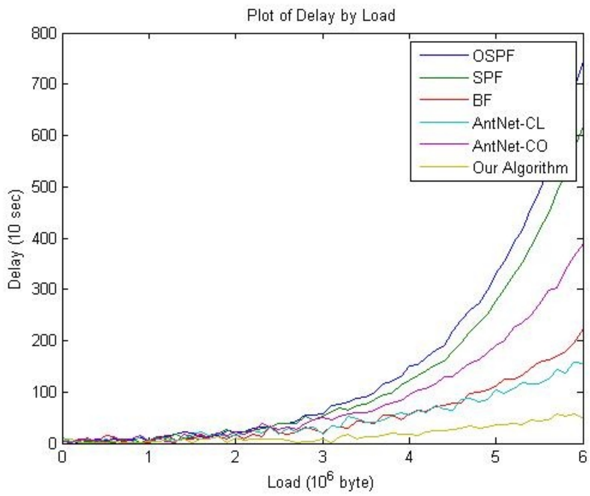

Figure 4. The mean delay time in relation to network load

As shown in Figure 4, the delay value of our presented algorithm is lowest in between the all the algorithms. This is because after getting the first packet, the experience of the bits passes to the next packets and they will be used as their experience until a certain change such as network congestion, transfer rates, or any structural changes happens.

Considering more, it can be recognized that AntNet-CO and AntNet-CL algorithms are in the next rank relating to delay time. In general, the algorithm working based on finding the shortest path, have higher delay time than genetic algorithms.

Another reason that can be considered for low delay time of presented algorithm is that learning automata which is defined to learn the experience parameter of every ant can be learned after a while so that there is no longer need to learn in the other ants. Therefore, after a while the parameter is learnt, it can be implied for any other packet that cause the delay time be reduced.

7. Conclusion

In this research we will attempt to improve direct routing process in communication network using Ant Colony Algorithm and learning automata system. We have focused on routing of a wide area datagram networks with irregular topology and best-effort service.

In this study, the routing tables for a specific destination is maintained in structural data based on a priority queue related to T_c which as a result of using this data structure, there is no longer need to search for the best path with lower T_c. If there is a destination with the lowest T_c then the router sends the data to the specified router. However, if no paths could be found to specified destination, then the system will post a detector forwarding packet ad that will wait for the reversing packet. As a result, there will be a learning delay time. The learning time might be a little delay, but because we have a homogeneity assumption, the results will be sent to the rest with the first learning, so that the learning process will be quicker and the algorithm gives better results at the end.

AntNet-CO algorithm is more suitable for large files, static relations, and networks with little changes because it has the most throughput rate in static status after the presented algorithm. This algorithm first of all, implemented in MATLAB, then in C++ programming languages.

When the size of the network gets large, in every time the network is created the different paths created will have different lengths. Therefore, another results we could obtain is that larger network size will lead to more unpredictable behavior networks will create. So if we would uniform all along the charts we obtained, more repetition is required for larger networks. Another point is that the preference of presented algorithm is during a specific interval because in larger sizes these two graphs are leant together.

Also, if the path length increases, ants rarely can alert the other Ant of their passing routes history. As a result, each of the ants will remember the last section of the previous ant's path.

In presented algorithm the slope changes of lengths of passed routes is in the linear form based on the size of the network, but AntNet-CO algorithm draws a logarithm.

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