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SOLVING RWA PROBLEM IN ALL-OPTICAL NETWORKS BASED ON OPTIMIZED ANT COLONY ALGORITHM

MAYSAA ALI ABDULLAH[1,*], and FIRAS MAHMOOD MUSTAFA[**]

[*]The Graduate School of Natural And Applied Sciences, University of Çankaya-Turkey

[**]College of Engineering, Nawroz University and (Duhok Polytechnic University), Kurdistan Region-Iraq

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ABSTRACT

The information bandwidth growth can be achieved using optical networking technology. Optical fiber has been used as a physical means through many network technologies. Wavelength Division Multiplexing (WDM) has emerged as a promising technology to conquer the use of large-bandwidth in optical networks. In WDM network, the essential problem is to serve the load traffic represented by the requests that arrive at the network and need to be served. For serve the request, the network will determine a path paired with a specific wavelength used to send the request's data from source to the destination node. This problem is called the routing and wavelength assignment (RWA). In this work, Multi-Node Optimized Ant Colony Algorithm (M-NOACA) proposed and implemented to solve the RWA problem in all-optical networks by simulating traffic with the RWA algorithms. A performance measurements applied to study the optimization problem of the RWA, and apply a comparison with the classic algorithms. Determining the best collection of parameters for an ant-based algorithm to obtain the best performance remains an open issue, in this work, a study is done to introduce a new contribution to obtain the optimal setting of Ant Colony parameters used to solve the RWA problem.

KEYWORDS: Ant Colony; All-optical networks; Network performance optimization; Routing and Wavelength Assignment (RWA); sorted shortest path algorithm.

1. INTRODUCTION

All-Optical Networks (AON) have become an efficient means to fulfill the tremendous demand for bandwidth due to a huge increase in internet traffic. WDM is used in optical fiber networks to achieve the client's ever-increasing bandwidth loads (Reinhold N. 2016). WDM is the most dominant technique to achieve the dramatic increase in the massive loads in an optical network which overshoots the congestion of electronics without deploying new links. The concept of a wavelength-routed WDM network depends on connecting end-users via all-optical WDM channels, which are often referred to as lightpaths (Mohamed K. 2010). A lightpath can span multiple fiber links; also it is used to support a connection in a wavelength-routed WDM network. To convert from wavelength to another through traverse the lightpath, the wavelength converter should have existed. The absence of wavelength converters leads to the inability to change the wavelength and the lightpath will use the concept of wavelength-continuity constraint which reserves the same wavelength on all the fiber connections. In the RWA, the establishing of lightpath is performed by picking the rout of a physical link

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd

[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

between the origin and target end nodes, then packing an appropriate wavelength on each of these links for the lightpath. So in WDM networks, there are two subproblems to deal with. The first is the selection of the path (Routing) and the second is the allocating the available wavelengths for the connections (Wavelength Assignment). The two subproblems provide one composite case that is well known as the RWA problem (Mustafa F. 2017). To decrease the processing complexity, the RWA problem is solved in two processes: first is to solve the routing part by select a route between the source and the target node, this can be done by using a routing algorithm, while the second part is determining a free wavelength on the chosen path by using a wavelength-assignment algorithm. The RWA case is subject to the following couple constraints (Ali N. 2011, Ramamurthy 2002):

Wavelength continuity-constraint: the identical wavelength is utilized on every connection along the full path from the origin to the target.

Distinct wavelength-constraint: separate wavelengths are selected for complete lightpaths using the same fiber link. These constraints provide additional complexity in analysis and model.

If there remain no free wavelengths available at any link, the connection cannot be established and as a result the arrived request will be rejected. The blocking probability is calculated as in the following equation:

$$B.P = \frac{\text{the number of call requests rejected}}{\text{the number of call connections requested}} \quad (1)$$

The performance of the all-optical network is evaluated by metrics of blocking probability. The blocking probability is taken as performance metrics in comparing different routing algorithms as well as various wavelength assignments. The blocking probability occurs when there are no available resources for the connections request. Therefore algorithm which has the minimum blocking is the best one regarding the performance (Rajneesh Randhawa 2013).

The basis of the ACO-based RWA algorithm depends on launching ants as discoverers, then it forwarded through the network to establish the connection request. Finally, through their journeys, ants put trails on the selected path to help the follower ants to optimally find paths of the network. Using these trails become less attractive over time due to pheromone evaporation property which makes the trails disappear. Pheromone evaporation has a great role in avoiding the convergence and also helps to dynamic network exploration. Besides, evaporation helps to avoid stagnation which happens if all ants follow the same paths chosen by the first ants.

The algorithms have been implemented by using the co-operation within MATLAB and OPNET to enable MATLAB to utilize its powerful analytical functionality and OPNET to utilize its ability to manage simulations. In this work, the Optimized Ant Colony Algorithm (OACA) has been introduced, which depends on the ACO in addition to improving its parameters. The improvement has been implemented by applying Multi-Node Optimized Ant Colony Algorithm (M-NOACA) with proposing an optimum collection of parameters to solve the RWA issue in all-optical WDM systems. Eventually, to measure the performance, and to measure the efficiency of applying for the proposed work, a comparison operation has been implemented with the traditional routing methods.

2. RELATED WORK

(Matlotia S., and Kaur B.2014), introduced the performance analysis of optical mesh network using first fit, random and proposed algorithms were based on OPNET simulation

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

technique. After comparing the results of various algorithms having load variations concerning processing time it is concluded that blocking probability of the proposed algorithm is better than first fit and random algorithms

(Mustafa F. 2017) tested the RWA algorithms by a simulator built with Matlab software. Dynamic traffic is used to perform the load for all-optical network topology. The work shown that the wavelength continuity constraint introduces load correlation between links and that the type of wavelength assignment and routing scheme used affects the blocking in the network. While in (Zakouni A. et al, 2017) they have implemented and compared two metaheuristics to solve the static many cast RWA problem, with a special focus on maximizing the number of many cast requests established for a given number of wavelengths. The problem was studied for the static case only. A relevant comparison, including the performance and the time involved, was made between the two algorithms, making a total of 144 experiments.

In (Li JZ, 2018) the algorithm applied to the traveling salesman problem (TSP) solving, to construct the model of an artificial ant colony system, was designed to solve the model algorithm. The results show that the application of an artificial ant colony algorithm in solving TSP is feasible, in the operation time and optimal solution quality, an artificial ant colony algorithm than the other algorithms perform a certain superiority.

In the study of Katona, G., (2019), the parallelization of the Ant Colony algorithm was introduced. Different parameters and thread counts were investigated. They emphasize that it is worth using more threads because the probability of finding valid routes is increasing. Besides, time usage and resource utilization are also better. While (Qiao D., 2020), provided a review of the ant colony algorithm and shown that it has been continuously researched and developed, and its theory and application have made great progress. The initial stage of the ant colony algorithm has certain blindness, which reduces the global search ability of the algorithm.

3. ROUTING AND WAVELENGTH ASSIGNMENT

The RWA problem can be admitted as one of the most crucial problems in wavelength routing systems. It may be explained by certain network topology, using the minimum possible number of wavelengths, how we could establish a set of lightpaths on best routes over the network, and assigning their wavelength. The traffic can be divided into either static or dynamic in a wavelength routing network. Sometimes it is called offline or online lightpath requests instead of static or dynamic traffic. In the offline lightpath requests (in this case, The RWA problem is known as (offline RWA), the setting of lightpath is all in-advance then remains inside the network for a long period and may consider permeating sense. In an online light path requests (The RWA problem here is known as online RWA), setting the lightpath for each connection as it comes, also the lightpath is cleared after a certain period.

3.1 Wavelength Routing:

The algorithm's performance is affected by many factors such as routing algorithms and wavelength assignment. In this part, the wavelength routing will be illustrated as one of the critical factors that play a significant purpose in the system achievement and overall blocking probability, besides its impact on the plan of all-optical networks. The router that assigns wavelength to the rout is called wavelength router (WR). The wavelength router will run a pre-allocated algorithm whenever a request arrives, it will then select the exit port and a wavelength. So a WR has to function; the first is finding a route for the light path request and the second is assigning a wavelength which

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

minimizes the probability of blocking. Recalling the classification of RWA schemes into two fixed or adaptive (dynamic) (Mustafa F. 2017). In a fixed RWA scheme, the RWA scheme assigns the reallocated wavelength and route for this demand, and all the routes and wavelengths for the lightpaths are fixed initially. Subsequently the routing scheme doesn't vary among time. "XY routing in 2D topology is an illustration of dimension order routing. This technique aims to increase the total throughput in the network, i.e., the total number of lightpaths that can be authorized concurrently in the system. Different scout techniques have been suggested to solve the fixed RWA problem in a network without wavelength conversion. In a wavelength-routed all-optical network, lightpath requests present following an appropriate accession method and the waiting period for these requests also follows a specific method. An adaptive RWA algorithm utilizes the present case concerning the network to choose a route for an assigned lightpath demand." (Matlotia S., and kaur B.2014). Developing efficient algorithms and protocols with the condition of minimizing the blocking rate in the network is the main goal in proposing wavelength-routed networks with dynamic traffic requests. For solving the RWA problem, there are two objectives; the first is rout selection with shortest path length. The second is the wavelength assignment to reduce the blocking probability.

3.2 Strategies of Wavelength Assignment

Wavelength assignment is the basic parameter which impacts the probability of blocking and whereby the performance of the network. The appropriate assignment of wavelengths can minimize the number of wavelength converters which can decrease the overall network cost to a great extent. Connection requests can be separated into a couple of cases static and dynamic. The static case involves that the connections are provided and the problem is to set lightpaths for all demands in the condition that minimizing the No. of wavelengths required. On the other hand, in the dynamic case, requests of connection arriving randomly, therefore the dynamic RWA became extra challenging. At each node, each algorithm controls a set of reserved and available wavelengths for any assignment scheme. This free wavelength is selected from the set of wavelengths and then assigned to demand. There are several wavelength assignment algorithms (Demeyer S., 2008).

4. ANT COLONY OPTIMIZATION (ACO)

An ant colony algorithm is a random search method. It is formed for the search according to the nature of the ant society collective. When the ants went out seeking food attitude and simulate the whole process of real ant colonies which work together to find food. Also, the search operation is for finding the shortest foraging operation. The information elements play a significant role. The path to be selected must be with the more pheromone, which means that many ants have been used and passed from this path (Li JZ, 2018). The goal of the stand (colony) is to find sufficient resources existing in an obtainable range (Katona G., 2019). Simulated ants are mobile workers who use mathematical data (pheromone data) to share their knowledge in finding a solution for other ants' problems (Dorigo M. 2004). The essential purpose of an ant colony algorithm utilization is that the possible resolution of the problem to be optimized is described by the route of ants. All routes of the entire ant colony create the resolution range of the problem to be optimized (Li Z. 2020). Hence, algorithms which adopted from the ACO heuristic methods are named ACO algorithms. In ACO algorithms, a particular ant builds up solutions to a conjunctional optimization problem with the beginning of an initial state and then adding incremental components in a repetitive fashion

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

until a complete solution is achieved. The ants employ data that gives back the knowledge gathered by the previous ants, named pheromone data to determine which solution element will be accumulated to its existing incomplete solution in the form of a stochastic building process. Pheromone infinite accumulation can be avoided by the way of implementing an evaporation factor. Before updating the pheromone data, all deposited amounts are reduced by a factor that represents the evaporation process. In this way, the amount of pheromone associated with a particular solution is reduced if there are no newer trails. Over time the evaporation process is responsible for neglecting bad selections (Christine Solnon 2010).

4.1 ACO Algorithms for Network Routing

Research shows that classic routing algorithms are not suitable to deal with modern networks which has a large amount of computational complexity (Mohamed K. 2010). In distributed algorithms, there are oscillations and instability problems. Network routing uses movable ants as a promising technique to build distributed algorithms. In a cooperative manner, they can accomplish complicated tasks in a distributed fashion (Ngo S. 2006). These agents discover and work together in a network. They accumulate routing data and routing tables are updated in each node, for example, a routing route can be estimated for data transfer. Several routing algorithms that are based on ant-agents has been proposed (Caro G. D. 1998, Garlick 2002, Ngo S. 2006).

AntNet is the most clarified one, a routing algorithm that is an ant-based has a group of superior routing methods on numerous packet-switched data networks (Matlotia S., and kaur B.2014). In the same context, it introduces a swarm dynamic routing technique according to Bellman's precept. Furthermore, a group of ant-based routing algorithms is proposed for MANET networks e.g., in (Marwaha S. 2002). In the AntNet algorithm, investigation agents (ants) are used to make interactions by moving them forwarding and back warding to form the routing. The idea of moving ants in the two opposite ways is the data collected by the forward ants used by the backward ants over the route from the source to the target. Ant-based algorithm mentioned before discuss the routing problem not the problem of the load. The routing table which contains the probabilities is sustained in each node. The allocation where the target is to use per link the minimum no of wavelengths by making fair wavelength distribution with keeping the routing length short (Sim K. M. 2002).

4.2 Multi Objectives ANT Colony Optimization

Multi-objective ant colony algorithms (MOACO) are a special type of ant colony implementation that stand up the idea of using several colonies, pheromone data managing, and the heuristic techniques (Schaerer 2003). Based on the features of ant colony foraging, different pheromone updating processes have different effects on the eventual results of ant colony algorithm (Qiao D. 2020). First of all is to have numerous colonies, where the colony size is divided into separate smaller size colonies, while each one is handled as a dedicated colony. Using a supportive soul, results that are generated from each colony are exchanged to be taken into account in the pheromone updating process (Schaerer 2003). Two models exist. The first one is to use a single pheromone matrix regarding all information associated with all objectives. The second model is, to use a dedicated pheromones matrix to each objective in this problem. There are several types of MOACO algorithms, and all of such algorithms are optimization methods of independent general purpose. To specify them to the RWA, each ant constructs the lightpaths set that generates a solution. Each Ant-RWA constructs a solution traveling called Wavelength Graph (Marwaha S. 2002, Sim K. M. 2002, Lopez-Ibañez 2004). An Ant-RWA construct if a

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

possible, route for each request in Wavelength Graph. Once a solution to the problem is found, then the light paths are found. Finally, mapping the solution to have the favorite solution in the original topology.

5. SYSTEM MODEL

The routing and wavelength assignment plays an essential position in improving the efficiency of all-optical networks. So providing an optimum path and suitable wavelength from all available picks for all connections in the condition that no many paths sharing a link are provided the same wavelength is the more important challenge in this problem. This problem is varying according to the provided topology and network connection. Assuming that the system has nodes connected through a group of fiber links as illustrated in figure 2, where each link has its cost and wavelengths and each node has two tables (P-route table, pheromone table). Traffic requests of users are modeled as static (offline) and dynamic (online). Table 1 lists all system parameters.

Table (1): System Model Parameters.

n	**node index, with** $n = 1, \ldots, N$
s	source node index with $s = 1, .., N$
d	destination node index with $d = 1, .., N$
k	neighbor (next hop) index per node with $k = 1, .., K$
w	wavelength index per link with $w = 1, .., W$
m	wavelength index per link with $m = 1, .., M$
r_{n,d_k}	Probability of node n to reach destination d using next hop k
$S_w = \{1, 2, \ldots, W\}$	The wavelength set where W *is* the total number of wavelengths per link.

As it is mentioned before that RWA is an NP-complete problem, so it is separated into two sub-problems (routing and wavelength assignment). In this work, the ACO-based algorithm is proposed to solve the routing problem and at the same time, it can handle the wavelength assignment problem with one of the traditional.

5.1 OPNET/MATLAB Co-simulations

In the proposed model, we use OPNET and Matlab. OPNET Modeler produces complete improvement circumstances maintaining an accurate model for telecommunication networks and distributed systems. The performance and behavior of created systems are dissolved by producing discrete event simulations. In addition, the modeler environment consolidates means for all stages of a study, starting from model design, simulation, data gathering, and data analysis. Co-simulation permits users to leverage other specific simulators with OPNET Modeler and get the "most useful of both worlds". Co-simulate OPNET with other simulators using: High-Level Architecture (HLA), Co-simulation API, and Extensible Transceiver Pipeline (e.g., co-simulation with MATLAB). As we Know MATLAB is a software simulator that is fit for simulating mathematical modeling and feedback control. A co-operation between MATLAB and OPNET has been planned to allow MATLAB to use its powerful mathematical functionality and OPNET to use its capabilities to handle simulations.

5.2 ACO Routing Algorithm

In this section, the basic mechanisms in the ACO-based algorithm will be described. This includes the structure of the routing table, the mechanisms of ants' generation and how they

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

collect data, and how we update the routing tables by the collection so as to reflect a more realistic figure for network status.

5.2.1 The structure of routing table

In Ant based algorithm, the double routing table structure implies adopted at any point. This structure comprises of a pheromone table 1 for ants' foraging and a P-route table 1 for connection establishment. Suppose we have network of N nodes, which has k neighbors, has a probabilistic pheromone table:

$$r_s = \left[r_{n,d}^{s}\ \right]_{N-1,k} \qquad (2)$$

The row represents possible destinations which are equal to $N - 1$ and column represents the neighbors which is equal to K . The selection probability of neighbor node k, traveling from node n , and going to a destination node d is represented by the value $r_{n,d}^{s}$ in the pheromone table. Furthermore, the P-route table has a structure of two columns and $N - 1$ rows, and describes all possible routes from the origin node to each target weighted by a corresponding preferable value. The value dr, reflects the weight of that route and it depends on two parameters the first is the length of that rout towards the destination. The second is the number of free wavelength which available for this rout. There are several related works to compute these two parameters each other. One of these, is to use the following equations (Demeyer 2008).

$$dr= \emptyset \frac{1}{(dl+1)} + (1-\emptyset)dw\ , \qquad (3)$$

Where

$$1 > \emptyset > \frac{[(W-1)(N-1)N]}{[W+(W-1)(N-1)N]}\ , \qquad (4)$$

$\emptyset$ is a scalar parameter used to accuracy the affirmation between two parameters; the first one is dl which performs the scope of the path, and dw which represents the percentage of free wavelengths on that route. In the proposed model dl is equal to the distinction between the length of the existing route and the length of the total shortest route to the destination. To give more emphasis on shorter routes, a greater value of $\emptyset$ should be taken. On the other hand to give emphasis on free wavelength number, a smaller value of $\emptyset$ should be taken.

5.2.2 Data Collection by Ants

At the data collection phase in ant colony algorithms, the ants are generated from random sources, s, and traversed to a random destination. Through this trip, it passes through each available neighbor and tries all probable routes till reach to the destination. In this trip, the ants collect data of all routes and the available wavelength as well. Besides the generated ants measure the length of each route and availability of wavelength at each rout it gathers. Through this collected data, the best neighbor node to carry the traffic to the destination can be obtained. The neighbor with higher selection probability is more probable to be the next hop. Another important parameter should be considered which the launching probability of ants is. To collect data about wavelength availability information, the ant colony algorithm uses a binary mask while crossing nodes in a network (Matlotia S., and kaur B.2014). This binary mask consists of W bits that are corresponding to the number of wavelengths in the network. When the value of ith bit $\boldsymbol{w}$ = 1 means the wavelength λ_i is free, and 0 otherwise. M_{ant} is updated according to the following equation:

$$M_{ant} = M_{ant} AND\ M_{link} \qquad (5)$$

At the source node, the M_{ant} actual mask is initially set with all bits of 1, implying that all the wavelengths are free. M_{link} is the available wavelengths mask on the next selected link along the path. By apply AND operation between M_{ant} and M_{link} the remaining available wavelength can be obtained.

5.2.3 Ant Movement in the Network

In order to calculate the pheromone trail amount whose should be added to routing table. Let an

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

ant move from a random source s to a random destination node d. Let the ants use the following path $(s, \ldots \ldots, i-1, i, \ldots \ldots, d)$. By traversing from an intermediate node $(i-1)$ at time t, to intermediate node i, at time $t+1$ the selection probability for destination node d from source node s through certain intermediate node is updated using equation 6:

$$r^{i}_{i-1,s}(t+1) = r^{i}_{i-1,s}(t)\frac{\delta r}{(1+\delta r)} \qquad (6)$$

While the selection probability of node i is increased by this value, the selection probability of all i neighbor node (which considered non-chosen next hop for node $(i-1)$ in ant moving) are decreased with same value according to equation 7.

$$r^{i}_{n,s}(t+1) = r^{i}_{n,s}(t)\frac{1}{(1+\delta r)}, \quad n \neq i-1 \qquad (7)$$

In equations 6 and 7, δr is the pheromone trail amount of on a selected network path and it is calculated as shown in equation 8 below (Matlotia S., and kaur B.2014):

$$dr = \alpha \delta l + (1-\alpha) dw, \qquad (8)$$

Where, α is a scalar parameter which can be used for tuning the emphasis of two parameters δl and δw. The first one is δl which corresponds to the length of the path traversed by the ant until now and the second is δw which corresponds to the percentage of free wavelengths on the corresponding path. The values of δl and δw are calculated as illustrated in equation 9:

$$dl = e^{-\beta dl} \quad dl = l - l_{min} \text{ and } \delta w = e^{\gamma w} - 1, \qquad (9)$$

Where w corresponds to the percentage of free wavelengths on the path. The design parameters of the pheromone trail, α, β, and γ which controls the conversion of length and the number free wavelength to probabilistic form, can be adjusted to improve the performance of the algorithm.

5.3 Routing and Wavelength Assignment in ACO

The ants generation and foraging from random source and traverse through the network until reach to the random destination according to the algorithm of the ACO. At this phase, the P-route table is filled with enough candidate paths. After that, the traffic is dynamically generated according to connection requests. When traffic is generated from a random (origin) source s to a random (target) destination d, then the algorithm searches in the P-route table of the source s into the list of all the routes. Given several possible destinations, the chosen path is based on the highest probability cost for the next hop for each destination. The wavelength is randomly assigned among every available wavelength if the chosen route has more than one wavelength free. Then this procedure will be supported by each node in the target list for the request's origin node to estimate a set of lengths for each nominee target. After the best route is selected for each connection demand in the first phase, the wavelength is selected in the second phase and finally, the selected path is reserved for the new arriving request. To study the proposed algorithm routing based and wavelength assignment, an extensive simulation environment has been built for system verification and analysis. The network environment is built using MATLAB/OPNET Co-operation. For comparison and verification of the results, then the performance metrics are compared with OSPF routing. The OSPF network is built using OPNET and its routing table is used in MATLAB to provide OSPF routes. Figure 1 illustrates the block diagram of the proposed ACO used in this work.

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

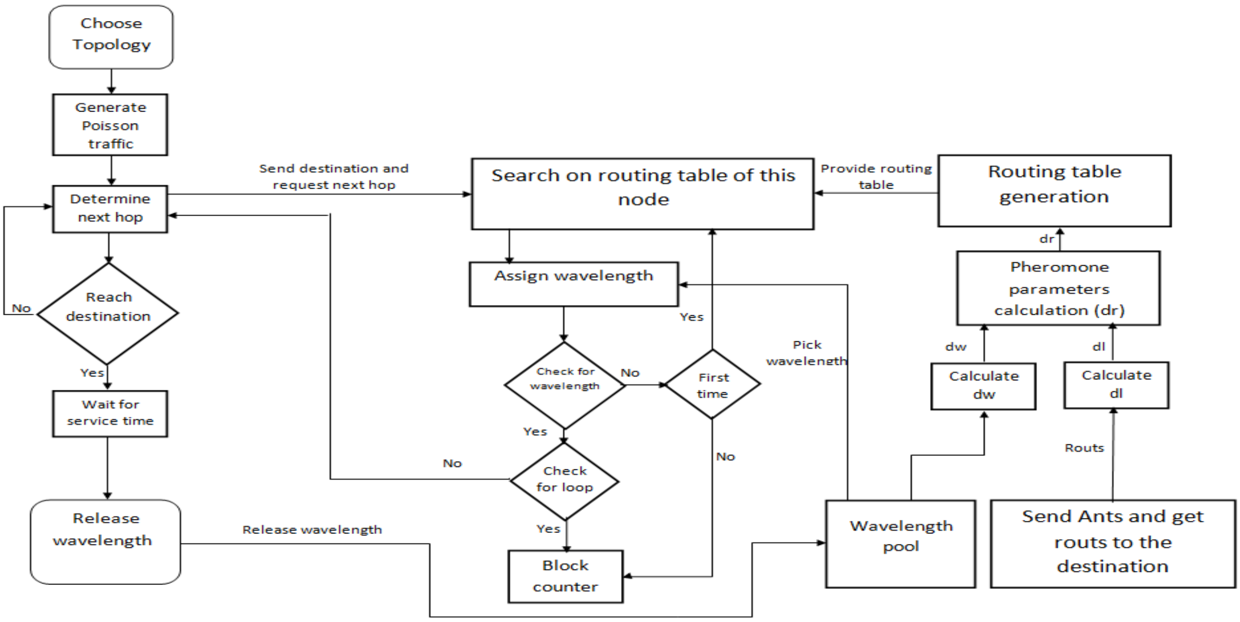


Fig. (1): Block diagram of the proposed ACO algorithm.

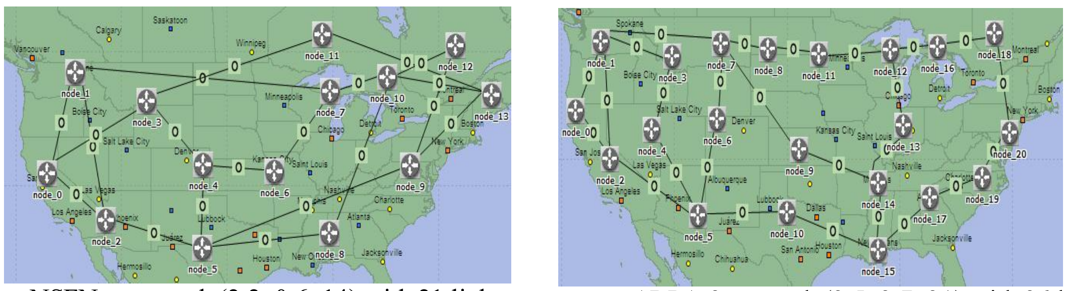
5.3.1 Simulation Settings

In the following, the network topologies that have been used in simulation and the main characteristic of generated traffic for system verification and analysis will be presented.

5.3.1.1 The Selected Network Topology

The typical network topologies that have been adopted in our simulation are two and as shown in figure 2. The essential features of every network topology are described by three parameters, the average shortest path (*H*), the variance of the average shortest path (*D*), and the number of nodes (*N*). These parameters have a direct impact on the routing problem difficulty (Matlotia S., and kaur B.2014). In the simulation, the following network topologies are selected:

1. NSFNet backbone (2.2, 0.6, 14) which has 21 links.
2. ARPA-2 backbone (3.5, 2.7, 21) which has 26 links



a. NSFNet network (2.2, 0.6, 14) with 21 links. b. ARPA-2 network (3.5, 2.7, 21) with 26 links.

Fig. (2): The topologies utilized in the simulation.

5.3.1.2 Traffic Generation Scenario

To generate traffic in the simulation scenario, the overall dynamic traffic type extensively accepted in the achievement evaluation of data transmission systems is adopted. In order to adopt a more realistic simulation, suppose we have connection requests with arrival rate λ (call/s) and follows a Poisson process. These arriving connection requests are randomly distributed between nodes. The holding time of

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

active sessions is exponentially disseminated among mean μ (the average holding time of the active session is T seconds). The network load is computed by $T\lambda\mu$ (Erlangs) where T is the entire number of sessions over the entire network, λ is the arrival rate and μ is the service rate. In scenarios of this work, the parameters T and μ are kept as constants and varying the arrival rate to study the network performance under different traffic loads. These are repeated at μ = 10 sec and μ =20 sec.

5.3.2 OSPF algorithms Used for Comparison

The routing methods utilized for comparison are the OSPF method. In the OSPF routing algorithm, every node has a routing table that includes a set of fixed routes to each target node with the different cost for each rout and next hop for each of these routes according to Dijkstra algorithms. When a connection call comes, the source node sends a call into the next hop based on the routing table which in turn forwards the call to the next hop specified in its routing table for the destination node. In each node, when the next hop is determined the wavelength is picked in sequence for lightpath establishment. In case there is no free wavelength is available the request is blocked. In this work the First-Fit algorithm is used as a wavelength assignment method with any routing method. The routing table of the OSPF algorithms in our simulation is picked out from OPNET simulation (for the selected two topologies) and is used in the MATLAB environment.

5.3.3 Parameters Setting and Tuning

In this part, the main parameters used in the simulations are presented. The time step for the ant generation is set as t=1s. In comparing with OSPF, the numbers of wavelengths W per link, 8 and 16, are used in the simulation. For every case, the proposed number of sessions is 10 T sessions with the time of session holding pointing set to 5s. By varying the arrival rate λ different load values can be got. The range of arrival rate is chosen accordance with that OSPF method can perform a practical blocking prospect (around 5%). To achieve stationary results, every attempt is completed in 150s and it is reproduced twenty times. These twenty times are equalized to achieve blocking probability.

5.3.4 Optimization of Pheromone parameters

One very important object is the design of pheromone parameters which rarely considered in most previous research despite its great impact in the path selection at each node and consequently the obtained blocking rate. Obtains the optimum setting of qualities (α, β, γ) for the ACO algorithm which provides the best system achievement remains an open field, which merits further research works (Ramaswami 1998). This part will try to get the most suitable pheromone parameters that optimized system performance. In order to trace the effect of each parameter individually, two of the three parameters should be constant while varying the third one. According to equations 7 and 8, there are three parameters: β which refers to the link length, γ which refers to the free wavelength at each link, and finally α which used for adjusting the emphasis in link length or free wavelength available. In order to more accurate parameters, the system performance will be extended at different load rates. Figure 3 depicts the blocking rate when varying β while α & γ are constant as 0.2, and 0.2 respectively. The regions of lowest blocking probability at each load are indicated. The optimized value of β depends on the selection probability for each β which illustrated in figure 3. Also, from figure 4, we can notice that region with low β value has a smaller selection probability that one in the region with high β values. According to equation 8, the selected value of α will depend on the region at which β will work. In short, if we take β in low region value (for example β=0.5), small values of α should be taken as well (this is because of the linear relation of equation 8) and vice versa.

Figure 5 depicts the relation between γ and blocking probability at different load values. It

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

can be shown that the region with γ less than 0.2 provides less blocking rate at different loads. In order to select α which suited to chosen γ, the selection probability of γ is provided in figure 6. It can be noticed from figure 6, that the selection probability of γ=0.2 (in the selected region) varies from 0.02 to 0.21. This requires choosing low values of α for adjusting the emphasis in available free wavelength. In addition, it suited for the ranges of γ values.

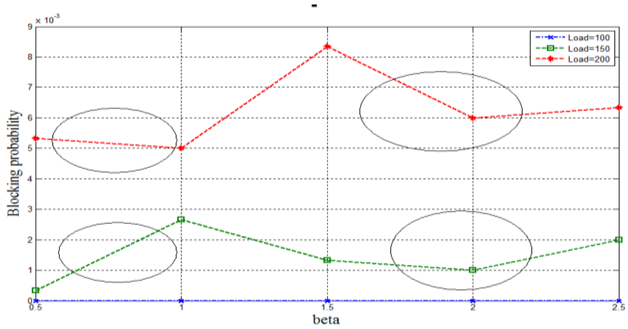


Fig. (3): Blocking probability at different values β with 14

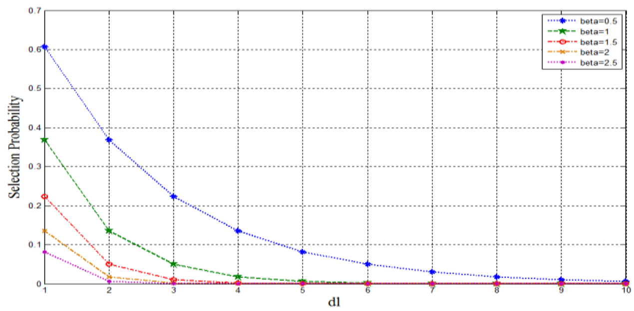


Fig. (4): The Selection probability at different

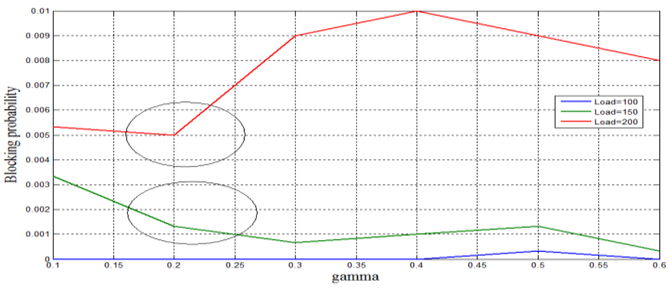


Fig. (5): Blocking probability at different values γ with 14

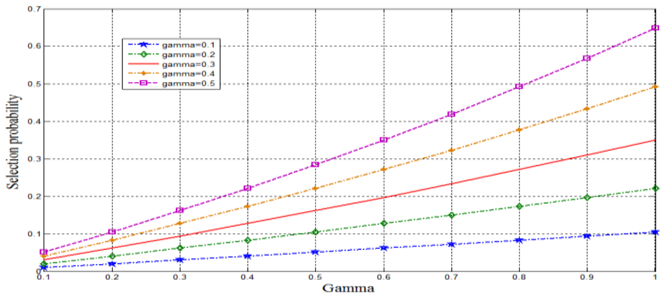
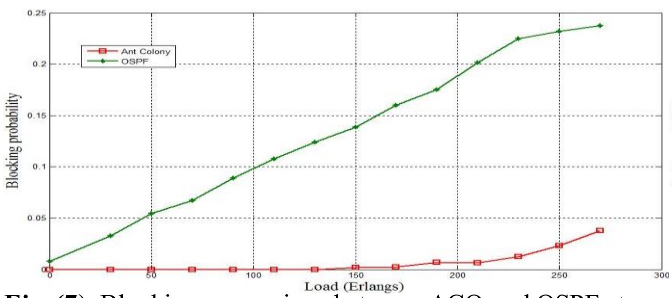


Fig. (6): Selection probability at different free wavelength

Figures 7 to 8, explain the blocking probability of the system in the two network topologies and compared them with the blocking at the OSPF algorithm. The number of wavelengths in the obtained results is W =8 and the service rate μ = 10 sec while the number of sessions is set to T =10 sessions. The pheromone control parameters (α, β, γ) are equal to 0.2, 1.75, and 0.2 respectively. For convince and reasonability, the values of arrival rate were chosen such that the obtained blocking probability to be not to exceed its practical values.



Fig, (7): Blocking comparison between ACO and OSPF at NSFNet.

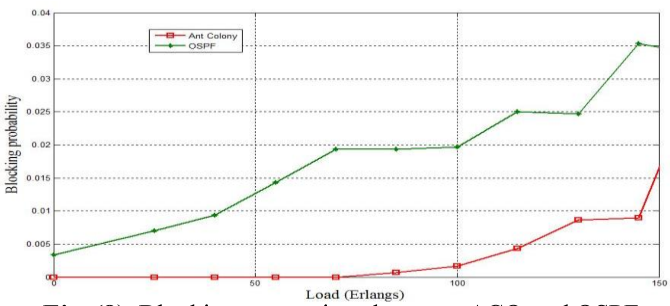


Fig. (8): Blocking comparison between ACO and OSPF at ARPA-2.

In ACO, the routing policy is modified at each node by deposing a pheromone way on its routing table; so, the routing tables are adapted to the traffic variations at run time. So any change in

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

both of wavelengths and links are tracked and reported at each node routing table, so it is considered in each call next hop. These wavelength and link updates are not considered in the OSPF case. So ACO behaves better than OSPF. Also the blocking increases when the number of nodes increments and the network to be more complicated. In the following, the impact of varying the number of wavelengths in the blocking probability is introduced. Figures 9 and 10 shows the blocking probability at different values of *W* as a function of call arrival rate at first network topology (14 nodes). It is observed that as *W* decreases, the blocking probability increases rapidly, this because the routs will not find sufficient wavelength for the lightpath to go through and so more calls will be blocked. The service rate in figures 9 and 10 is set to be 10 sec and 20 sec respectively. The effect of changing the service rate can be noticed when comparing the results of figures 9 and 10. It can be shown that when the service rate increases the blocking rate increases because the channels will release faster and so more routes will be available for a new call request. Similar results can be obtained from figures 11 and 12 for second network topology.

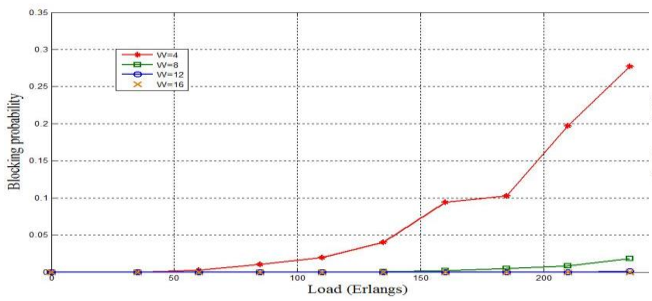


Figure 9. The blocking probability at different total number of wavelengths per link W at NSFNet at μ= 10 sec.

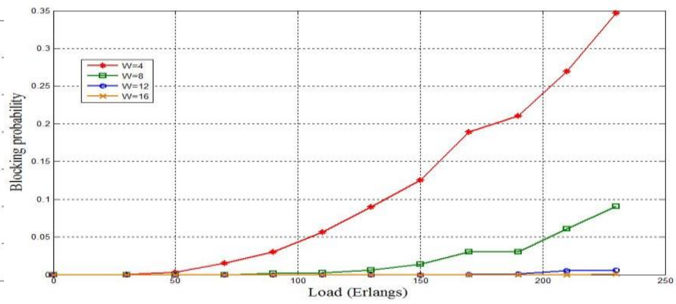


Figure 10. The blocking probability at different total number of wavelengths per link W at NSFNet at μ= 20 sec.

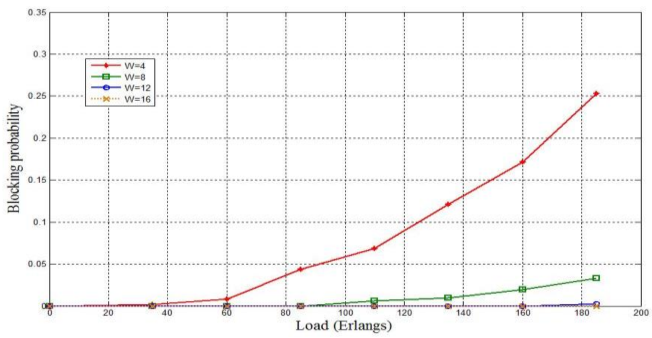


Fig. (11): The blocking probability at different total number of wavelengths per link W at ARPA-2 at μ= 10 sec.

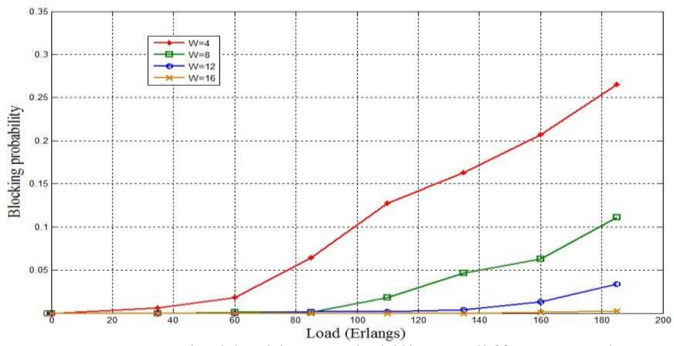


Fig. (12): The blocking probability at different total number of wavelengths per link W at ARPA-2 at μ= 20 sec.

6. CONCLUSIONS

In this work, M-NOACA algorithm is proposed to resolve the RWA problem in AON by simulating traffic with the RWA algorithms, and implement M-NOACA with the best set of parameters (which have been shown through the results as the pheromone control parameters (*α, β, γ*) were equal to 0.2, 1.75, and 0.2 respectively) for an ant-based method to solve the RWA problem. The main milestones of this work can be concluded is that the ACO procedure is an

dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

efficient method in getting optimal routs. This procedure includes the routing mechanisms, table structures used by the ACO method, and the way they make updates based on exploring the network using a proper estimate of ants.

Simulation results show that the ACO based algorithm provides significant improvements over the OSPF traditional algorithm, and also performs significantly better than other dynamic load-based routing algorithms. This improvement can be shown through figures 7 and 8 for both topologies that have been used in this work. The results of the NSFNet topology in figure 7 shows that the improvement was about 92% at the load 150 Erlang, while the results of the ARPA-2 topology in figure 8 shows that the improvement was about 51.45% at the same load 150 Erlang. Besides, this algorithm is flexible in significance to obtain better achievement. The simulation results indicate that an ant-based algorithm consistently outperforms the other dynamic load-based routing algorithms in different network topologies. These interesting characteristics make the ant-based dynamic RWA algorithm very encouraging for the next models of WDM networks.

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dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.

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dr.maysaaalrawei@yahoo.com; firas.alfaqe@nawroz.edu.krd
[1] Corresponding author: College of Engineering, Nawroz University, Kurdistan Region, Iraq.