

Simulation Study of a Heuristic Near-Maximum Ant-Based Dynamic Routing

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Abstract: A new ant-based routing is proposed for solving dynamic routing and wavelength assignment in mesh WDM network under the wavelength continuity constraint. The ant algorithm favors paths with maximum number of available wavelengths between two nodes, resulting in improved load balancing and less congested shortest path. The simulation results showed that the proposed ant-based routing algorithm is highly reliable in the sense that the number of ants used is predictable to achieve a steady performance in terms of blocking probability.

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1. Introduction

Routing and Wavelength Assignment (RWA) policies have a great impact on the entire network performance by affecting such factor as blocking probability. In most previous research, routing and wavelength assignment were addressed separately through heuristic algorithms, because it is NP-complete to find the optimal solution for the two problems at the same time [1]. RWA algorithms are closely related to the routing protocol. For optical networks, various types of Open Shortest Path First (OSPF) extensions have been suggested. Several papers assume that each optical node exchanges full link state information including the state of each wavelength in every fiber [1, 2, 3, 4]. Other papers [5, 6] assume that link state messages contain only simple bandwidth usage information like the Number of Wavelengths (NWs) and the Number of Unreserved Wavelength (NUW) on each link, since sharing individual wavelength information can incur a larger overhead.

Generally, routing strategies can be classified into two groups: static routing and dynamic routing. In this paper, we consider the dynamic routing with wavelength continuity constraint in WDM where the route selection is based on the current network status (e.g., the current traffic load distribution) which is a good candidate for traffic engineering and generally it can improve the performance significantly [7, 8]. An adaptive algorithm which performs routing and wavelength assignment using a global wavelength utilization matrix has been suggested in [9]. This algorithm searches for the shortest path along which a specific wavelength can be used. If one wavelength is infeasible, it tries another wavelength sequentially until it finds a feasible route. However, this algorithm

become computationally expensive when they are applied to a large network as the size of the auxiliary graphs and the global wavelength utilization matrices grow proportionally with the multiplication of the number of wavelengths and the number of links in a network. Our proposed ant-based algorithm does not suffer from this problem as we utilize a heuristics near-maximum value instead of the optimal value.

The rest of the paper is organized as follows. In section 2, we present our ant-based design for dynamic routing. In section 3, we show simulation results for our proposed new ant-based compared with the others routing algorithm in term of blocking probability. Finally, section 4 summarizes this paper.

2. New Ant-Based Dynamic Routing Design

The proposed ant-based algorithm has been developed to match an accuracy level of the OSPF protocol, where the algorithm performs hop-by-hop routing using local wavelength state information and link connectivity, but not the global state information of each wavelength. In this paper, we consider the NUW information during its hop-by hop routing process where the connection request chooses the node with the highest preference value among the available nodes that are ahead of the current node. The preference acts as measurement indicating how many wavelengths are available on both the current and the next candidate link. When a connection request arrives at node i , the preference of node as the next hop j is calculated as follows [10]:

$$pref(i, j) = \log_AND(wave_i, w_{ij}) \times \sum_{dist_k < dist_j} NUW_{jk} \quad (1)$$

where w_{ij} is the wavelength usage stage of link e_{ij} , and

$wave_i$ is available wavelengths from the source node to the current node i , considering wavelength continuity. NUW_{jk} is the number of unreserved wavelength at e_{ij} ($NUW_{jk}=0$, if e_{jk} does not exist) and $dist_i$ is the shortest distance between node j and the destination node. However, all these parameters are information collected by ants when the ants travel around. This preference policy will be addressed later in equation 6.

Upon the arrival of a connection request, the source node releases m ants which travel towards the destination node. As the ants arrive at each intermediate node, it collects wavelength usage information indicating the wavelengths that can be used from the source node to the current node, considering the wavelength continuity. Each ant updates at every intermediate node by a logical AND operation between the wavelength usage state of the current link and the usage information up to the preceding link. The probability that the p^{th} ant from node i select the next hop j with the destination s when it moves toward its destination node s is given as following:

$$P(i, j, s) = \frac{\delta(i, j)^\alpha \cdot \eta(i, j)^\beta}{\sum_{j=1}^N \delta(i, j)^\alpha \cdot \eta(i, j)^\beta} \quad (2)$$

where $\delta(i, j)$ is defined as follows:

$$\delta(i, j) = Link(i, j) \quad (3)$$

where $Link(i, j)$ is the link connectivity between node i and j . $Link(i, j)=1$ if node j is the adjacent node for node i , 0 otherwise. We define $\eta(i, j)$ as the trace intensity (pheromone in the case of real ants) associated to the link ij coupling. Ants use heuristic factor (network status) as well as pheromone factor. The heuristic value is generated by some problem dependent heuristic whereas the pheromone factor stems from former ants that have found good solutions.

Pheromone trails are updated after all the m ants have reached the adjacent node of destination where m is the number of adjacent node that is connected to the current node. The update is made according to the following.

$$\eta_{ij}(t+1) = \sigma \eta_{ij}(t) + \Delta \eta_{ij}(t) \quad (4)$$

where σ is a coefficient that represents the trace's persistence and

$$\Delta \eta_{ij}(t) = \sum_{k=1}^m \Delta \eta_{ij}^k(t) \quad (5)$$

where $\Delta \eta_{ij}^k(t)$ is the quantity of trace left on the coupling (i, j) by the k^{th} ant ($k=1, 2, \dots, m$) at the end of exploring the network status. The trace's initial intensity, $\eta_{ij}(0)$ can be set to a small and positive arbitrary value. The coefficient of σ must be fixed to a value less than 1 to avoid accumulation of trace and fast convergence. The pheromone is deposited on per

link basis. The pheromone matrix is reset once the final selection of next hop from current node is made for each time. Concerning the quantity of trace left by ants, different choices for calculation of $\Delta \eta_{ij}$ determine the realization of slightly different algorithms. In this paper, $\Delta \eta_{ij}^k$ is given by the value of Q if k^{th} ant's produces the highest value of $pref(i, j)$ based on the network status it collects along its path and the value of 0 otherwise. Q is constant value obtained by the k^{th} ant as follows.

$$\Delta \eta_{ij}^k = \begin{cases} Q & \text{if the } pref^k(i, j) = \max(pref^k(i, j)) \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

where $\max(pref^k(i, j))$ is the largest value among all the m ants obtained for the $pref(i, j)$. Upon the arrival of a connection request at node i , the current node launches m number of ants toward next hop. When each ant reaches the next hop, it duplicates itself to m number of new ants toward next hops. m depends on the number of node connected to current node. This process repeats until it reaches the adjacent node of destination.

For each ant to travel through the node, it collects the information such as $wave_j$, W_{ij} , and NUW_{jk} and compute the $pref(i, j)$ to update the trace matrix according to equations 4, 5, and 6. Then reset the trace matrix once the next hop has been determined. The next hop becomes the new current node now and the whole process repeats again until the next hop is the destination node. The basic algorithm which is as the follows:

- A. Initialize the trace matrix.
- B. While current node is not the adjacent node of destination node.
 - For $k=1$ to m (m is the number of adjacent node for current node)
 - Repeat (for each adjacent node)
 - Choose, with probability given by equation (2), as the next hop from those not yet chosen.
 - Put the chosen node in the tabu list
 - End for
 - End while
- C. For $k=1$ to m
 - Carry the solution and compute $pref^k(i, j)$.
 - Update the best node (next hop) found.
 - End for
 - Current node=best node.
- D. If (best node \neq adjacent node of destination)
 - Empty the tabu lists of all the ants and goto 1.
 - Else
 - Current node=best node
 - End
- E. For each coupling (i, j) calculate $\Delta \eta_{ij}$ the according to equation (5)
 - Update the trace matrix according to equation (4)
- F. If not (END_TEST)
 - Empty the tabu lists of all ants
 - Goto B

Else

Print the best permutation and stop

End

The End_Test is usually made either for a maximum number of iterations or a maximum amount of CPU allowed time.

3. Simulation Results

An extensive experimental study of our RWA algorithm has been performed for three types of topologies (small, medium and large) of network for comparison. The networks are shown in Figure 1. The traffic model used in the simulation is an independent poisson process with arrival rate β . An arriving session is equally likely to be delivered to any node. The session holding time is exponentially distributed with mean $1/\mu$. A node may engage in multiple session and several sessions may simultaneously be conducted between an s-d node pair. In our simulation, extensive tests are carried out to ensure a steady state is reached. Six wavelengths are used in all simulations. We utilize a first-fit wavelength assignment scheme in all simulations. ACO parameters used in the experiment are the same as used in [11]. The simulation result shown in Figure 1 for three different sizes of network.

In all of the simulations, every single data is obtained by conducting 20 independent replications of the same simulation and then calculates the average results. The routing algorithms used for comparison are the fixed routing algorithm [3], fixed-alternate routing [12] and exhaustive algorithm [9]. As expected, the performance of our new ant-based algorithm is always much better than the fixed and the fixed alternate algorithms in terms of blocking probability in all cases in Figure 2. The proposed ant-based algorithm performs better than the fixed alternate and fixed routing but approaching exhaustive method. The fixed and alternate fixed methods cannot find a route after all channels in candidate paths are consumed as it is a static routing scheme. It is interesting to note that the proposed Ant-based algorithm does not perform well under high resource utilization in large network as shown in Figure 2(c), since it cares about load balancing rather than path hop counts from the beginning. This results in wasted network resources, which in turn has a negative impact on admission for future connection requests.

4. Conclusion

By referring to the simulation results, we can see that the new ant-based algorithm can outperform the comparison schemes and approaches the exhaustive search method. Moreover, this algorithm is efficient in the sense that the number of ants used is always equal to the number of links in the network to achieve steady performance.

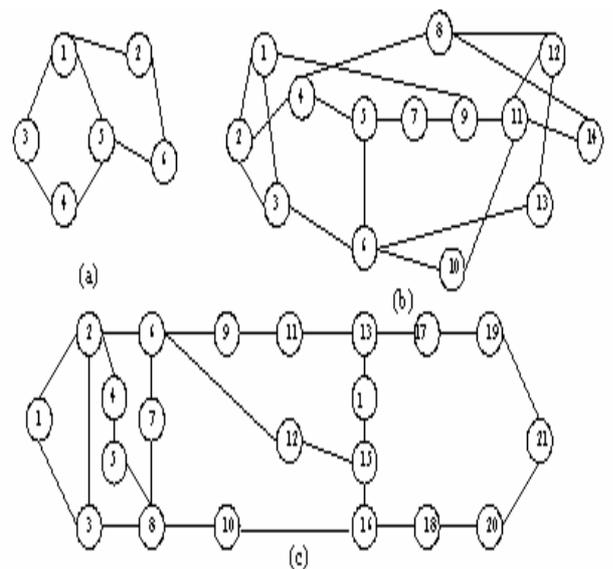


Figure 1. Network topologies used in imulation.

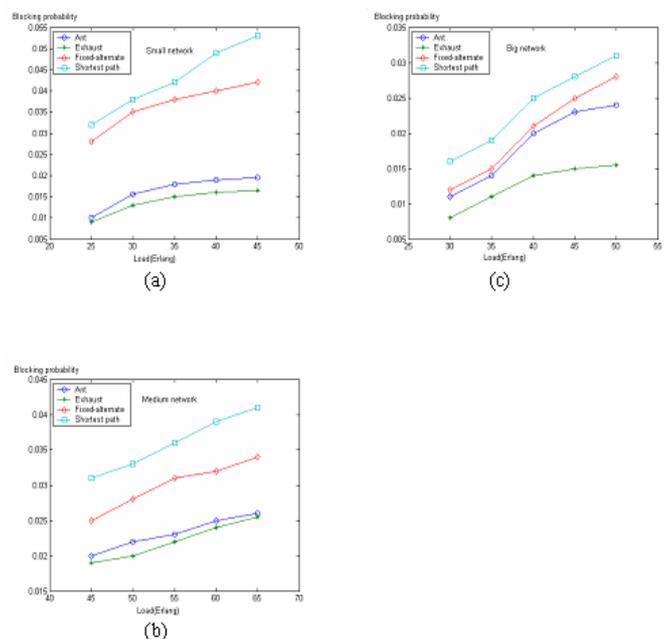


Figure 2. Comparisons between new ant_based algorithm and other routing algorithms. (a) small network (b) NSFNet. (c) ARPA-2.

Extensive simulation results upon different network topologies indicate clearly that our new ant-based algorithm is highly adaptive and robust and it always outperforms the fixed and the fixed alternate algorithms in terms of blocking probability.

References

- [1] Chin T., "An Ant Algorithm for Single-Hop Wavelength Assignment in WDM Mesh Network," in *Proceedings of the 17th IEEE International Conference on Tools with Artificial Intelligence (ICTAI'05)*, pp. 111-117, 2005.
- [2] Hsu C., Liu T., and Huang N., "On Adaptive Routing in Wavelength-Routed Networks," *SPIE/Kluwer Optical Networks Magazine*, vol. 3,

- no. 1, pp. 15-24, 2002.
- [3] Karasan E. and Ayanoglu E., "Effects of Wavelength Routing and Selection Algorithms on Wavelength Conversion Gain in WDM Optical Networks," *IEEE/ACM Transactions Networking*, vol. 6, no. 2, pp. 186-196, April 1998.
- [4] Mokhtar A. and Azizoglu M., "Adaptive Wavelength Routing in All-Optical Networks," *IEEE/ACM Transactions Networking*, vol. 6, no. 2, pp. 197-206, April 1998.
- [5] Qiao C. and Xu D., "Distributed Partial Information Management (DPIM) Schemes for Survivable Networks: Part I," in *Proceedings of the 21st IEEE INFOCOM*, New York, USA, vol. 1, pp. 302-311, June 2002.
- [6] Ramamurthy R., Mukherjee B. "Fixed-Alternate Routing and Wavelength Conversion in Wavelength-Routed Optical Networks," *IEEE/ACM Transactions Networks*, vol. 10, no. 3, pp. 351-367, 2002.
- [7] Yamanaka N., Katayama M., Shiimoto K., Oki E., and Matsuura N., "Multi-Layer Traffic Engineering in Photonic-GMPLS-Router Networks," in *Proceedings of the IEEE GLOBECOM'2002*, pp. 2731-2735, 2002.
- [8] Ye Y., Dixit S., and Ali M., "On Jint Protection/Restoration in IP-Centric DWDM-Based Optical Transport Networks," *IEEE Communications Magazine*, vol. 38, no. 6, pp. 174-183, June 2000.
- [9] Yoo Y., Ann S., and Kim C., "Adaptive Routing Considering the Number of Available Wavelengths in WDM Networks," *IEEE Journal on Selected Areas in Communications*, vol. 21, no. 8, pp.1263-1273, 2003.
- [10] Zang H., Jue J., and Mukherjee B., "Review of Routing and Wavelength Assignment Approaches for Wavelength-Routed Optical WDM Networks," *Society of Photo-Optical Instrumentation Engineers (SPIE) Optiocal Networks Magazine*, vol. 1, no. 1, pp. 47-60, 2000.
- [11] Zang H., Jue J., Sahasrabudde L., Ramamurthy R., and Mukherjee B., "Dynamic Lightpaht Establishment in Wavelength-Routed WDM Networks," *IEEE Communications Magazine*, vol. 39, no. 9, pp. 100-108, 2001.



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