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Ant-based contention resolution in slotted WDM optical packet switched networks

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Abstract: This paper proposed an Ant-based contention resolution scheme for the slotted optical packets switched (OPS) networks. The proposed contention resolution schemes are shown to be effective to resolve packet contention and to achieve good performance by using minimum number of fiber delay lines (FDL). Moreover, the cell loss rate is improved by 10% to 40% under various traffic loads using the proposed scheme.

Keywords: Ant Colony Optimization (ACO), FDL, OPS, contention resolution

Classification: Photonics devices, circuits, and systems

References

[1] L. Xu, H. G. Perros, and G. Rouskas, "Techniques for Optical Packet Switching and Optical Burst Switching," *IEEE Commun. Mag.*, 39910:136–142, Jan. 2001.

[2] M. J. O'Mahony, D. Simeonidou, D. K. Hunter, and A. Tzanakaki, "The Application of Optical Packet Switching in Future Communication Network," *IEEE Commun. Mag.*, 39930:128–135, March 2001.

[3] S. Yao, B. Mukherjee, and S. Dixit, "Advances in Photonic Packet Switching: An Overview," *IEEE Commun. Mag.*, vol. 38, no. 2, pp. 84–94, Feb. 2000.

[4] L. Berger, et. al. (2003, Jan.), RFC 3471-Generalized multi-protocol label switching (GMPLS) signaling functional description. Internet Engineering Task Force (IETF) Proposed Standard. ftp://rfceditor.org/innotes/rfc3471.txt.

[5] K. Nichols, et. al. (2001, April), RFC 3086-Defination of differentiated services per domain behaviors and rules for their specification. Internet Engineering Task Force (IETF) Proposed Standard. http://www.ietf.org/rfc/frc3086.txt.

[6] Tan Saw Chin, "An Ant Algorithm for Single-Hop Wavelength Assignment in WDM Mesh Network," *17th IEEE Int. Conf. Tools with Artificial Intelligence* (ICTAI'05), pp. 111–117, Nov. 2005.

[7] H. Mellah and F. M. Abbou, "Contention resolution in slotted WDM optical packet switching networks using cascaded auxiliary switch," *IEE*

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1 Introduction

Wavelength division multiplexing (WDM) has gained popular acceptance, as it is able to handle the forecast dramatic increase of bandwidth demand. Besides the huge amounts of bandwidth, all-optical WDM networks allow high-speed data transmission without needs of electronic converters at intermediate nodes and support transparency with respect to data format. Recently, several different technologies have been developed for the transfer of data over WDM, such as broadcast and select, wavelength routing, optical packet switching and optical burst switching. Broadcast and select networks have been extensively studied and several prototypes have been developed. Wavelength routing networks have already been deployed and currently represent the most promising technology for optical networks. Optical packet switching and optical burst switching are still in the research phase [1, 2]. A reason leading to optical packet switching is its intrinsic flexibility to cheaply support incremental increases of the transmission bit rate [3]. One of the key problems of packet switching technology is contention, which takes place when two or more incoming packets are directed to the same output line. Contention can be solved in the following three ways: 1) by dropping the contending packet; 2) by deflecting the contending packet to another port; 3) by buffering the contending packet (using delay lines or using electronic memory). Deflection of contending packets is undesirable as it is in general not compatible with end-to end requirements [4]; 2) dropping the contending packet is obviously the poorest strategy, as it relies on the higher level protocols, causing round-trip delays and reordering issues. Buffering does not have any of the above-mentioned drawbacks and moreover it enables the prioritization of traffic based on, e.g., the differentiated services (DiffServ) specification [5]. The drawback of buffering is the introduction of additional delay and jitter in the network. Thus the selection criteria in the proposed Ant-based algorithm for choosing the desired output port take into account the total delay and the number of delay imposed. The rest of the paper is organized as follows. Section 2 describes the problem statement for the packet contention resolution in the related works. In Section 3, we present our Ant-based design for packet contention resolution. In Section 4, we show simulation results for our proposed ant-based. Finally, Section 5 concluded this paper.

2 Related works

In [7], an optical switch is proposed using auxiliary output ports connected to an auxiliary switch through fiber delay lines as shown in Fig. 1. The contention resolution technique used is to randomly assign the contended packet to an FDL based on the availability of the FDL for the current time

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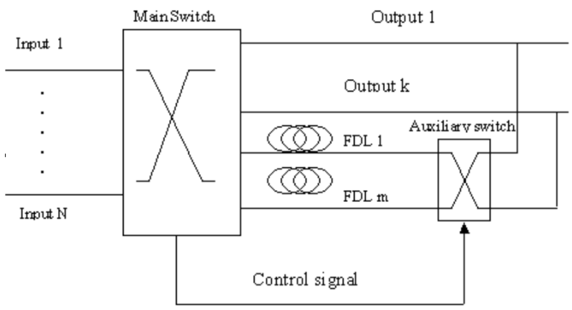

Fig. 1. Optical switch using cascaded auxiliary switch.

slot to match the output port. This contention resolution technique has two limitations. First, there is no guarantee that they can get access to the desired output ports after coming out from an FDL as they are not allowed to recirculate many times to search for free output port and it doesn't efficiently support different packet priorities because once a packet has been sent to a delay line, it cannot be stored longer than the fiber delay to eventually transmit a new packet with higher priority. Second, since all FDLs have the same delay duration, the packet contention rate is dramatically obvious at high traffic load as packets may come out from FDLs at the same time, which is undesirable, as the cell loss rate will be increased.

In order to solve these problems, we proposed to use various sizes of FDL length in the switch for solving the second limitation and to use an Ant-based contention resolution for solving the first limitation.

3 Ant-based packet contention resolution design

Upon the arrival of a contended packet request, an m-number of ant is released to search for the list of free FDL. The probability that the p$^{\text{th}}$ ant from input i selects the FDL j is given by:

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

where $\delta(i,j) = s(j)/d(j)$, with d(j) is the delay value for FDL j and s(j) is the status of the FDL where "1" indicates that the FDL (j) is free and "0" otherwise. They act as heuristic information based to guide the initial steps of the computation process when the information on the problem structure given by the pheromone has not yet accumulated (in our case it is the switch status due to the contention of packet and availability of output port). We defined $\eta(\mathrm{i,j})$ as the trace intensity (pheromone in the case of real ants) associated to the link ij coupling. Ants use heuristic factor 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 trail are updated after all the m ants have selected the FDL where m is the number of contended packet for that cycle. The update

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is made according to the following.

$$\eta_{ij}(t+1) = \sigma n_{ij}(t) + \Delta\eta_{ij}(t) \tag{2}$$

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

$$\Delta\eta_{ij}(t) = \sum_{k=1}^{m} \Delta\eta_{ij}^{k}(t) \tag{3}$$

$\Delta\eta_{\mathrm{ij}}{}^{\mathrm{k}}(\mathrm{t})$ being the quantity of trace left on the coupling (i,j) by the kth ant $(\mathrm{k} = 1, 2, \ldots \mathrm{m})$ at the end of exploring the status of output port and FDL of the switch given by

$$\Delta\eta_{ij}{}^{k} = \begin{cases} Q/f_k & \text{if the kth ant has chosen coupling (i, j)} \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

where Q is a constant. Further, since Ants collect two kinds of data along their trips: the status of FDL (how long it has been occupied) and the availability of output port, the trace's initial intensity, $\eta_{\mathrm{ij}}{}^{\mathrm{k}}(0)$ can be set to a small and positive arbitrary value and the coefficient σ must be fixed to a value less than 1 to avoid accumulation of trace and fast convergence. Concerning the quantity of trace left by ants, different choices for calculation of $\Delta\eta_{\mathrm{ij}}{}^{\mathrm{k}}$ determine the realization of slightly different algorithms. In this paper, $\Delta\eta_{\mathrm{ij}}{}^{\mathrm{k}}$ is given by the value of $\mathrm{Q}/\mathrm{f_k}$ if kth ant has chosen the coupling (i,j) and by value o otherwise. The longer the contended packet been located inside the FDL (depends on d(j)), the shorter FDL will be chosen for next cycle and the shorter time duration it inside the FDL, the longer FDL will be chosen. Thus, conflict at the same output port at the same time for any contended packets could be avoided with the usage of maximum output ports.

The basic Ant algorithm when packets are contending for an output port is as follows:

1. *Initialize the trace matrix.*
2. *Put m ants on the input port that has the contended packet.*

   For $k = 1$: m

   Repeat (for each FDL)

   Choose, with probability given by Eq. (1), the FDL to assign from those not yet assigned.

   Put the chosen FDL in the tabu list of the k-th ant.

   Until the tabu list is full. (tabu list size equal to m)

   End for.
3. *For $k = 1$: m*

   Carry the solution to it local optimum and compute f_k.

   Update the best permutation found.

   End for.

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4. *For each coupling* (i, j)*, calculate* $\Delta\eta_{ij}$ *according to Eq. (3).*

   Update the trace matrix according to Eq. (2).

5. *If not (End_TEST)*

   Empty the tabu lists of all the ants.

   Goto 2

   Else

   Print the best permutation and Stop.

   End

The "End" test is the total simulation time usually made either on a maximum number of iterations or on a maximum CPU allowed time.

4 Simulation results

An extensive simulation study of our Ant-based contention resolution schemes in 32 x 32 optical switches has been performed for comparison. The traffic model used in the simulation is Bernoulli arrival process and extensive tests are carried out to ensure that a steady state is reached. The ACO parameters used in the simulation are similar to [6]. From Fig. 2, it can be seen that the performance of switches with FDLs with various combination lengths (L $= 1, 2, 4, 8, 16$) is much better than those FDLs with the same lengths (L $= 1, 3$) in terms of cell loss rate at heavy traffic loads. The reason is twofold; first, when the traffic load is low, shorter length FDLs are able to handle packets in efficient way, as more free FDLs are available for next coming packets either from fiber delay lines or from the new generated packets, and second, most of the FDLs are holding packets longer than the arrival of next incoming packet. Thus, when less number of the FDLs is available for

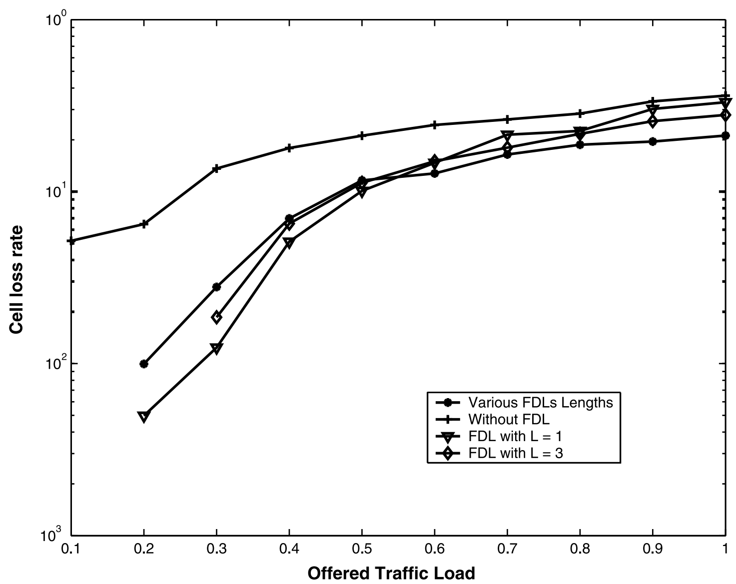

Fig. 2. Cell loss rate versus offered traffic load under different FDL lengths.

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the contended packets, higher cell loss rate will occur for FDLs with various combination lengths compared to FDLs with the same lengths at high traffic loads. We further test our ant-based algorithm with various combination lengths of FDLs as shown in Fig. 3. The result indicates clearly that the proposed ant-based contention resolution schemes performs better in term of cell loss rate compared to FDLs with the same lengths and even better than FDLs with various combination lengths [7], since in [7] the technique is based on the availability and the delay value of FDLs at current time slot and it does not take into consideration the availability of an output port at the next time slot, whereas Ant-based contention resolution scheme takes into consideration the availability of an output port in updating its pheromone for choosing an FDL for next time slot. Thus the chance for an incoming packet to be contended for the same output port is small.

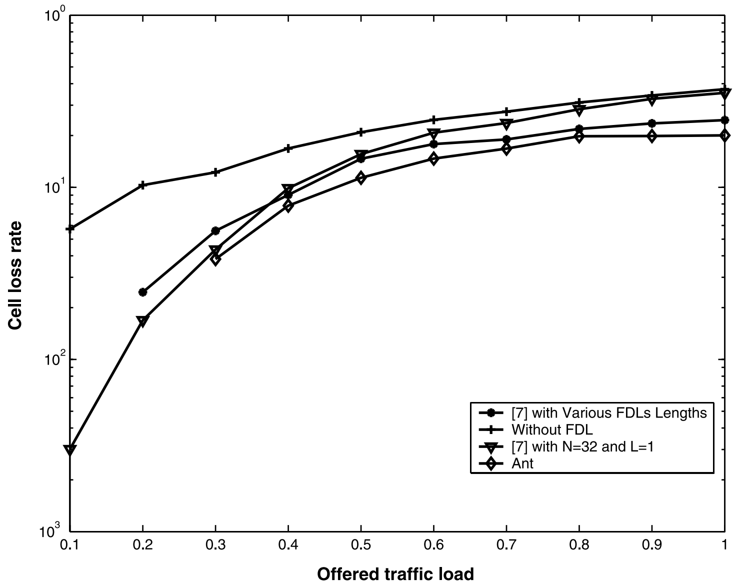

Fig. 3. Cell loss rate Comparisons.

5 Conclusion

This paper proposed an ant-based algorithm for resolving packet contention in optical switches with different combination sizes length of fiber delay lines. The proposed contention resolution scheme is shown to be effective to resolve packet contention and to achieve good performance by using minimum number of fiber delay lines (FDL). Moreover, the cell loss rate is improved by 10% to 40% under various traffic loads using the proposed scheme.

Moreover, the proposed algorithm is reliable in the sense that it requires less number of ants to achieve steady performance under various traffic loads as the number of ants needed depends on the number of contended packet. Second, due to the heuristic information (length of fiber delay (L) and status of fiber delay lines) used in the selection of fiber delay lines small number of ants is needed in simulation.

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