Burst Routing Planning for Optical Networks using the Association Rule Approach

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Summary
The Optical Burst Switching (OBS) is a technology positioned between optical circuit switching (OCS) and optical packet switching (OPS). It is a promising buffer-less DWDM switching technology that provides high wavelength utilization. One of the critical design issues in OBS network is effective planning in minimizing burst dropping resulted from resource contention. In this paper, we attempt to adopt the association rule approach to pre-determine a suitable routing path in the OBS network. We propose the hybrid OBS routing planning with the aid of Apriori algorithm searches for the suitable routing path to reduce the transmission collision rate. The heuristic rules discovered by Apriori algorithm are stored in the Knowledge Base (KB) as references for determining the most suitable routing path. The experiment results show that the successful rates of routing paths obtained by the proposed routing planning approach can effectively improve the successful rates of transmission.
Key words:
Optical Burst Switching, Association Rule, Knowledge Base

Introduction

Optical fibers represent the preferred network transmission medium because they support high-speed, high-capacity and high reliability transmission with a low error rate. Wavelength Division Multiplex (WDM) [1] technology, which uses wavelength division, markedly increases the bandwidth of existing optical fiber networks. The advent of Dense WDM (DWDM) [2] in optical networks has significantly increased the bandwidth available over a single optical fiber. DWDM combines the optical signals within the multiple wavelengths in a single optical fiber, so the transmission capacity of the network can be increased greatly.

The Optical Burst Switching (OBS) is a promising buffer-less DWDM switching technology that provides high wavelength utilization [3]. It is a technology positioned between optical circuit switching and optical packet switching. All-optical circuits tend to be inefficient for traffic that has not been groomed or statistically multiplexed, and optical packet switching requires the scalable implementation of optical buffering and optical header processing, which are very difficult to be realized at present. The OBS network is a hybrid switching technology that employs electronics to control routing decisions, but maintains data in an optical form as they pass through each intermediate router.

The structure of OBS includes the core router and the edge router. The core router passes data to the next node using the packet label. The edge router provides the interface to the different domain and to assemble and disassemble packets. Each burst in the OBS consists of a header and a payload. The control packet (header of a burst) is transmitted on a separate wavelength ahead of the burst payload to ensure sufficient time for header processing (Fig. 1). The control packet is smaller and is sent in advance, and has to pass through Optical-Electric-Optical (O-E-O) process in the core router. Data burst, can be sent all-optically, does not need to perform an O-E-O process in the core router. The packets are assembled into a data burst while they are routed to the ingress router of the OBS network. Finally, data burst is disassembled and then passed on to the next node at the egress router of the OBS network.

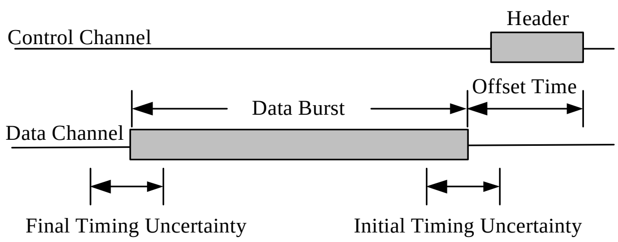

Figure 1: Graphic Representation of Burst

Data collision is one of the important issues in OBS network. The transmission of such a large number of underestimated data causes blocking or serious delays that will certainly affect network utilization. In order to avoid the data collisions, we propose a novel routing planning approach based on Apriori algorithm to find the suitable

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routing path instead of the traditional scheme to send the control packet.

The rest of this paper is organized as follows. Section 2 presents a brief overview of the Optical Burst Switching concept. The proposed routing planning approach is given in Section 3. The experiment assumptions and the simulation results are presented in Section 4. Section 5 describes the conclusion and extensive discussion with future research directions.

2. Related Works

Many contention resolutions schemes for OBS networks at a core router have been proposed. For example, the technologies of wavelength conversion and optical buffering can be used in a core router to solve such a problem. However, the all-optical wavelength conversion is still immature because of the performance and cost consideration [4, 5]. On the other hand, it is not easy to store optical bursts because the optical buffers are constrained within a few tens of ms delay [6, 7].

In order to avoid the data collisions, we propose the hybrid OBS routing planning with the aid of Apriori algorithm searches for the suitable routing path to reduce the transmission collision rate. The heuristic rules discovered by Apriori algorithm [8] are stored in the Knowledge Base (KB) as references for determining the most suitable routing path. The association rules imply the relation of item-set in database. Association rules include the support and confidence. The most important issue is how to meet the requirements from those item-sets. The Apriori algorithm decomposes the original data mining association rules into 2 steps [9].

(i) Join Step: Combines the dataset with the minimum support and minimum confidence into one large dataset that is called the frequent item-set; generate another candidate item-set from the Frequent Item-set.

(ii) Prune Step: Selects the item-set which is satisfied the requirement with minimum support and minimum confidence, otherwise, prune those item-set.

In this study, we propose the scheme that reduces the probability of burst contention by controlling the route at an edge router without the need of further resolving at a core router. Each edge router pre-discovers a suitable route to the destination by using the association rule approach. To demonstrate the effectiveness of our proposed approach, we apply the approach to elucidate the suitable routing paths in the real-life network topologies (PACNet). The successful transmission rates of the proposed routing planning approach are compared with the best case to verify the efficiency of this study.

3. Paragraphs and Itemizations

This study proposes an intelligent routing scheme using Apriori algorithm to set up optimal routing path of OBS network. The Conceptual Diagram is shown in Fig. 2.

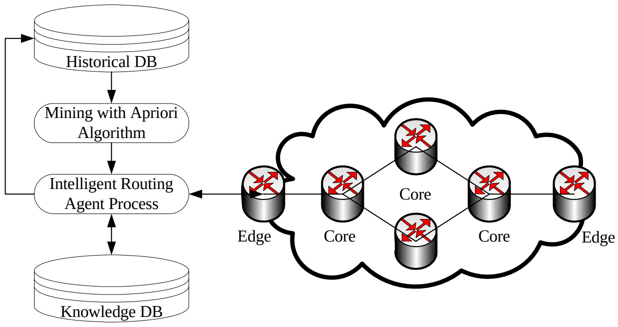


Figure 2: Conceptual Diagram of the Proposed Routing Planning Scheme

First of all, system gathers all the possible routing paths and discovers the local optimal path from all data sets that are satisfied with the minimum support and minimum confidence. After the local optimal routing is generated, we save it into the database of historical paths while one simulation is completed and we add the previous local optimal path into the original data sets as an new data set then we go on to the next simulation to mine the new optimal path from the new data sets. We will get the next local optimal path during the mining process and we repeat the simulation times up to 50 as one simulation cycle. We will save the global optimal path into the knowledge base and this global optimal path will be the optimal routing path selection with first priority. Instead of sending the control packet, we search the path from the knowledge base. The Burst Routing Algorithm is shown in Fig. 3.

The procedures of burst routing path selection using Apriori Algorithm are shown as follows:

(i) An ingress edge router prepares for routing: In the session, besides routing path selection, it has combined the burst packets with the control burst packets generation.

(ii) Search the LSPs: List the available LSPs while the sending and receiving edge router is decided.

(iii) Select the core router with the lower burst blocking and high support rate; compare the priority of the LSP using association rules.

(iv) Send the control burst, data burst after the offset time while the routing path is selected. Control burst and data burst are sent by different channels.

(v) An egress edge router will send the successful acknowledgement to the ingress edge router when the burst transfers successfully. The ingress edge router will record the log into the database of historical paths and the system will reactivate the association rule analysis for the next incoming burst. The ingress edge router will erase the failure LSP if the burst transfer fails.

(vi) Select the appropriative routing path according to the association rules and the priority of the network load.

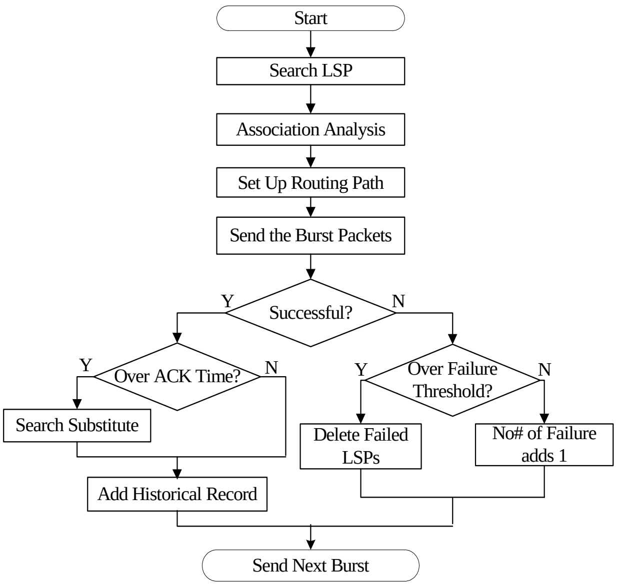


Figure 3: Burst Routing Algorithm

For ease of exposition, we make the following assumptions:

(i) The successful rate of the routing path is the product of the successful rate of each node in the routing path.

(ii) The similarity degree is defined as the ratio that is the successful rate of best case divided by the successful rate of Apriori algorithm.

(iii) The average similarity degree is the average value of similarity degree of the 50 simulations.

(iv) The optimal routing path is defined as routing path with the highest product of the successful rate of each node in the routing path.

4. Experiments and Simulation Results

4.1 The Simulation Scenario

We evaluate routing performance in terms of successful rates with different pair values of support and confidence.

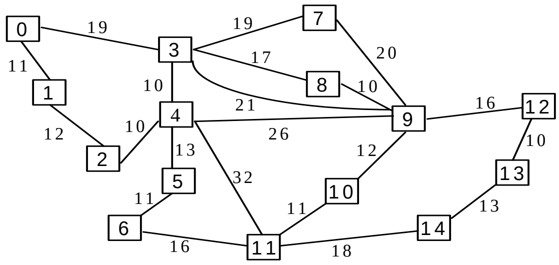


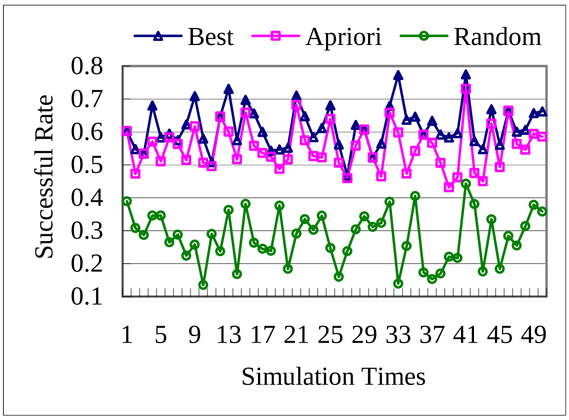
Figure 4: The Topology of Simulation Environment

The PACNet topology is shown in Fig. 4. The PACNet topology includes 15 nodes and 21 links and the digit shown in each link is the unit of the distance. The distance of link is 10km per unit. Each link is single channel and transfer speed is 10G/s. This study assumes that each path in the network is recorded and saved in the original database which is used as historical database in Apriori algorithm. Additionally, this study assumes that each node in the network is connected via one exclusive channel to the source node and provides the blocking information at present. The routing path with the lowest blocking probability is input into the database of historical paths after the data have been sent successfully.

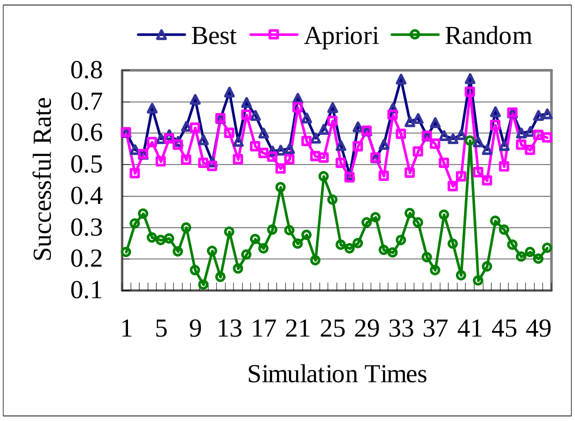
In the course of the simulation, the range of blocking probabilities of each node is assumed to be between 0.01 and 0.3 [10], yielding 50 different blocking probabilities for each node, following the Normal distribution and the Poisson distribution. The Apriori algorithm adds the path with uppermost successful rate to the database of historical paths. Two far nodes are selected to compare the simulation results concerning Network topology.

Based on these assumptions, the simulation system generates the successful rate for each node with Normal distribution and Poisson distribution. The system will store the information of the optimal routing paths into database for the policy of the decision support. This paper will search for the Local Optimal and the Global Optimal in each cycle and plot the result. The simulation environment is described as follows:

(i) Sending and receiving node with random selection (routing 4 hops at least), for example node 0 and node 14, or chose path with more hops connected (node with 4 paths pass at lease) for example node 3, 9, 11.

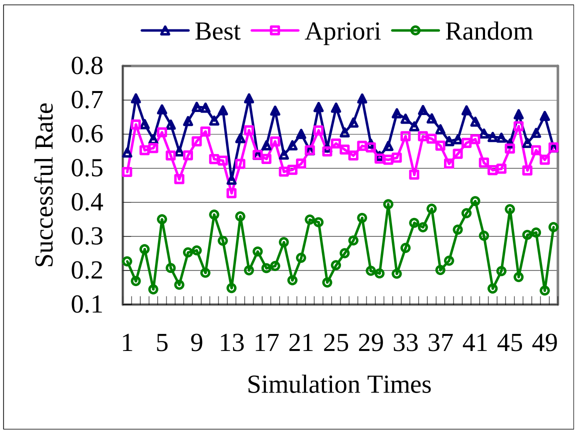


(a) Min. Support = 0.8
Min. Confidence = 0.6

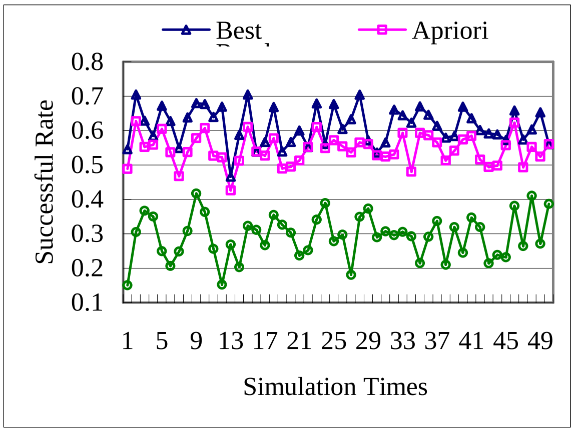


(b) Min. Support = 0.8
Min. Confidence = 0.8

Figure 5: Successful Rate of Normal Distribution



(a) Min. Support = 0.8
Min. Confidence = 0.6



(b) Min. Support = 0.8
Min. Confidence = 0.8

Figure 6: Successful Rate of Poisson Distribution

(ii) Simulations take 50 times and the burst successful probability with Normal distribution or Poisson distribution.

We evaluate routing performance in terms of three parameters (support, confidence, successful rate) in the simulation model.

4.2 Simulation Results

PACNet (Origination: 0, Destination: 14)
Routing parameters:

- Limit of hops Count: 14, Limit of max Distance: 150
- Burst block rate: 0.01～0.3, Successful rate: 0.7~0.99

We apply the different minimum supports and minimum confidences for each case on Fig. 5(a), 5(b), 6(a), 6(b). Due to the hop counts limitation and support rate requirement in Apriori algorithm, we will select the routing path as little as we can in the proposed algorithm and the routing path will get higher successful rate.

Fig. 5 shows that the successful rate of Apriori algorithm will higher than that of the random selection. There is no hop count limitation and support rate requirement in random selection. The average similarity degree of the simulation samples will increase to 90% with Normal distribution and Poisson distribution as the minimum support is increased in spite of the minimum

Table 1: Simulation Results with Sender: 0 and Receiver: 14

Min. Support	*Min. Confidence*	*Max Item-set*	*Routing Path*	*Sum of Distance*	*Number of Hops*	*Burst Block Prob.*	*Successful probability*
0.4	0.6	[3,9,11]	0-3-9-4-11-14	116	6	0.31	0.69
0.4	0.8	[9,12,13]	0-3-9-12-13-14	79	6	0.17	0.83
0.6	0.6	[3,9]	0-3-9-10-11-14 0-3-9-4-11-14	81, 116	6	0.19	0.81
0.6	0.8	[3,9,11]	0-3-9-10-11-14 0-3-9-4-11-14	116	6	0.16	0.84
0.8	0.6	[9], [4], [3]	0-3-9-4-11-14	116	6	0.22	0.78
0.8	0.8	[9], [4], [3]	0-3-9-4-11-14	116	6	0.26	0.74

Table 2: Average Similarity Degree for Apriori Algorithm with Normal Distribution

Support/Confidence	0.4/0.6	0.4/0.8	0.6/0.6	0.6/0.8	0.8/0.6	0.8/0.8
Average Similarity Degree for Apriori algorithm	0.86	0.86	0.87	0.87	0.90	0.90
Average Successful Rate for Apriori algorithm	0.51	0.52	0.54	0.54	0.55	0.55
Average Successful Rate for Best Case	0.61	0.61	0.61	0.61	0.61	0.61
Average Successful Rate for Random selection	0.23	0.24	0.24	0.25	0.28	0.26

Table 3: Average Similarity Degree for Apriori Algorithm with Poisson Distribution

Support/Confidence	0.4/0.6	0.4/0.8	0.6/0.6	0.6/0.8	0.8/0.6	0.8/0.8
Average Similarity Degree for Apriori algorithm	0.85	0.85	0.87	0.87	0.89	0.89
Average Successful Rate for Apriori algorithm	0.52	0.52	0.54	0.54	0.54	0.54
Average Successful Rate for Best Case	0.61	0.61	0.61	0.61	0.61	0.61
Average Successful Rate for Random selection	0.22	0.23	0.24	0.25	0.26	0.29

confidence. The proposed routing planning will increase 50% of the performance.

We also apply the hop counts limitation and support rate requirement in Apriori algorithm for the case in Fig. 6. Fig. 6 shows that the successful rate of Apriori algorithm is also higher than that of the random selection. Table 2 and Table 3 show the average similarity degree for both Apriori algorithm and random selection with Normal distribution and Poisson distribution. The results show that the higher the minimum supports the higher the similarity degree. Also, both tables depict that the successful rate of the Apriori algorithm is better than that of the random selection.

5. Conclusions and Discussion

Many factors, such as the data collision rate, the number of core routers and blocking probabilities, affect the quality of services of data transferring. From Fig. 5(a) and 5(b), the routing path gets higher successful rates while the routing path with a higher support ratio. From Table 3, we know that the routing path solution using Apriori algorithm will get the higher successful rate than that of the random selection and the similarity degree is over 90% while the support rate is over 60% in Normal distribution and Poison distribution. There are some conclusions summarized as follows:

(i) The experiments will get a higher successful rate when the routing path with a higher support rate over 60%.

(ii) The experiments will get a better solution when the routing path using Apriori algorithm with the weight, minimum support.

(iii) The experiments will get a better solution than random selection.

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