

Adaptive Proportional Distribution Scheme in the OBS Network

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Abstract— OBS (Optical Burst Switch) network is a promising network. In our study, a new Adaptive Proportional Distribution Scheme is adopted as the route algorithm of OBS network, to improve the network performance. It splits traffic from the source node among the several candidate paths with special proportion to finish transmission. And GMPLS protocol is used herein to set up the paths. The main idea of the scheme is how to distribute proportion and how to select candidate paths. Compared with the conventional shortest path first scheme, the new one can reduce burst loss rate and balance link load of the network, which is proved by simulation on NS-2 platform.

Keywords— OBS; ROUTE; SPF; APDS; GMPLS

I. INTRODUCTION

The current development trend of network is to achieve the overall IP-based network. With the IP business increasing obviously, the demand for the transmission network bandwidth and switch system capacity is growing at an unprecedented rate. To actualize a transparent and all-optical communication network with higher survive capability is the future development trend of the broadband communications network.

The Optical Packet Switch (abbreviated OPS) is a comparatively favourable switch mechanism, allowing not only for the statistical multiplexing network channel bandwidth resources, but especially for the burst data services, which shall be a relatively optimized solution for the Internet business in the future. However, due to some unresolved key technologies, there is still a certain distance away from the practical application.

The fundamental idea of OBS [1,2] refers to the integration between the Optical Circuit Switch (abbreviated OCS) and OPS, whose switch granularity stands between the abovementioned two, called burst as the combination of packets. With respect to the OBS network, each and every edge node would integrate and assemble the data into bigger burst packets. The corresponding control packets taking the control information and administrating the resource

reservation in the middle edge nodes would carry out the output. A bias, contained in the control packet, would arrive in the middle of the node in advance to make time for processing and configuring switch matrix. At the end of the data packet transmission, the light path would be released for other connections.

The separation of the control packet and data package can reduce the complexity of intermediate switching nodes, as well as the requirements of optical devices. Burst control packet only operates in the electric field, so with the data rate decreasing, the effective load of the network processor is correspondingly reduced. Burst of data packets in the optical domain carry out the end to end transmission, thereby reducing the optical core networks - electrical - optical conversion and buffering. The intermediate nodes can be no light cache, with lower synchronization requirements, which is conducive for OBS toward practical use. The transparency of such a network can support different formats and transmission rate of data being transmitted simultaneously.

For the OBS network, one of the key issues to be resolved is the routing algorithm. In the OBS network, the source node, without waiting for confirmation of the establishment of optical path, can send the burst data, with relatively large blindness. Because the service in IP network has strong outburst and the link state changes frequently, the upstream node can not immediately understand the wavelength of the downstream link occupancy status and routing information, resulting in the sudden increases of the probability of conflict. As a result, how to select an appropriate routing algorithm becomes a key issue to reduce the burst conflict.

Following are the composition of this article as well as the main content in each section. The first section briefly discusses the shortest path first algorithm and its shortcomings. The second section elaborates the proportional distribution scheme. The fundamental idea of the algorithm is to distribute the flow to several pre-established links (hereinafter referred to as the candidate path) according to a certain percentage of the allocation. This section introduces the adaptive proportional distribution schemes, consisting of the selection rules of the candidate path and description of the algorithm. The third part of the new algorithm focuses on the performance of the new

algorithm through the simulation. We would draw our conclusions in the last part.

II. MAIN CONVENTIONAL ROUTING ALGORITHMS

In the general OBS studies, the shortest path first routing algorithm would be adopted as a basis for the OBS algorithm agreement [3]. The shortest path first routing algorithm collects the status information in the entire network by updating the link-state, based on current information to select the best path. If each source node can obtain a precise time on the overall network state information, the shortest path first algorithm is excellent. If the stream reaching the source node is mixed with a variety of business streams, the network resources in a variety of information would change accordingly. In this case, the shortest path first algorithm will require frequent exchange of network state information, causing the channel congestion and making the performance of the algorithm degrading dramatically. If you increase the status of the update interval in order to avoid congestion caused by the exchange of information, then the shortest path first algorithm can also cause performance degradation due to the use of outdated link information. This indicates that the shortest path first algorithm is not a good choice for the burst packet transmission.

In order to avoid the defects of the shortest path first algorithm, a variety of proportional distribution schemes have been proposed.

III. PROPORTIONAL DISTRIBUTION SCHEME

The proportional distribution scheme, firstly according to certain rules, establishes at least one candidate path (generally use the MPLS (Multi-Protocol Label Switching) or GMPLS (Generalized Multi-Protocol Label Switching) protocol to establish) between each source - destination node pair. The stream reaching the source node will flow along these paths to the destination node in a certain proportion. Combining the characteristics of OBS networks, the algorithm can be divided into two kinds of application manner, shown in Figure 1 and Figure 2. Note that in the figure the purpose of the entry node and edge nodes are directed at a specific node pair.

The first method refers to distributing the IP flow to each cluster units, then the burst packets converged will be sent along this path to the destination node [4]. The second method is to form the burst packets at first, and then the burst packets are assigned to different candidate paths to the destination node. The advantage of doing so is to ensure the independence of the specific technologies of the routing algorithm and the OBS network entry node, not only easy to be implemented, but having a strong future viability.

The proportional distribution can be divided into many sectors. We will briefly describe the optimal proportional distribution scheme, and then elaborate the adaptive proportional distribution scheme.

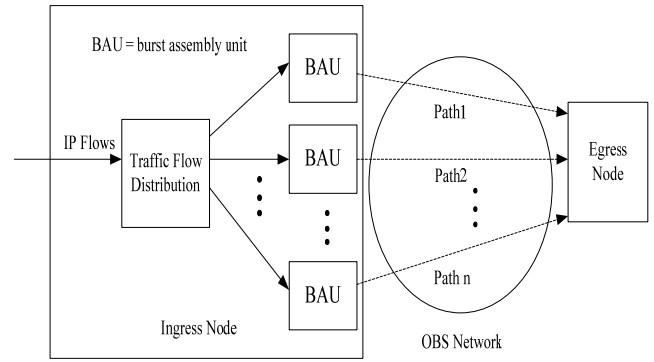


Figure 1. A method of the proportional distribution scheme

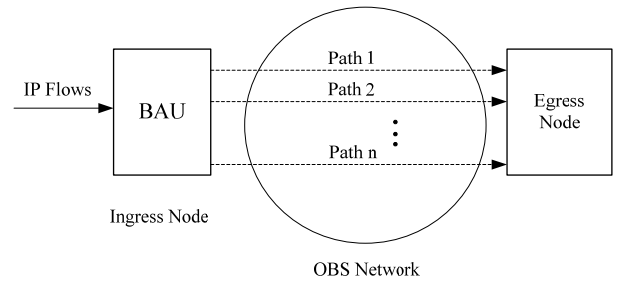


Figure 2. Another method of the proportional distribution scheme

A. The Optimal Proportional Distribution Scheme

The goal of the optimal proportional distribution scheme is to find a proportion set. According to the set, the proportional flow will be allocated to each candidate path, so that the network can minimize the overall blocking probability.

R_σ is used to indicate the candidate path set between the source node σ and the destination node V_σ . The optimal proportional algorithm can be attributed to how to find a group of proportion $\{\alpha_r^*, r \in R_\sigma\}$, minimizing the overall network blocking probability. It is equivalent to how to maximize the overall transmission success probability $(\sum_\sigma \sum_{r \in R_\sigma} \alpha_r V_\sigma (1 - b_r))$ in the network. In between, b_r refers to the blocking probability of the r path when the load on r equals $v_r = \alpha_r v_\sigma$. The optimal proportional distribution can be considered as the non-linear optimization problem, solved by quadratic equations through successive iterations step by step. We call this method as the optimal proportional distribution [5].

This algorithm is much more complex, time-consuming and difficult to specific applications, so this algorithm is generally used as a standard of comparison with other algorithms. In the following article, we will describe a simple algorithm, the adaptive proportional distribution scheme.

B. The Adaptive Proportional Distribution Scheme

First of all, we will introduce the principle of selecting the candidate path, and then a detailed description of the scheme as follows.

1) The Candidate Path

The candidate path is the basis for the Adaptive Proportional Distribution Scheme. The GMPLS protocols are adopted to establish the candidate path. In this way, each path will be to establish its own label switching path. After the candidate path is established, the source node of the burst will be sent along these paths to the destination node. Therefore, the entrance to the corresponding edge nodes need only to maintain a small stream mapping information, greatly improving the network efficiency.

What needs to be underscored is that the candidate path has not always fixed, the re-routing can be conducted after a certain time interval (denoted as ΔT).

The candidate path involves two main problems: the number of paths and principles for selection.

What needs to be explained at first is that the number of candidate paths is not the more, the better. Too many paths will bring a lot of extra overhead, resulting in the non-linear increase in complexity in management as well as the rapid decline in performance of the algorithm. In general, three well-chosen candidate paths will be able to achieve the performance of the optimal proportional distribution scheme.

When choosing the right candidate path, what we are concerned is the link share between the paths. The excellent performance of various paths when used alone does not ensure that same good performance when put together. There exists the possible links share, which may have a negative impact on the overall performance. One of the simple ideas is to disjoint paths of each candidate, that is, no any shared link among different links. In fact, this restriction is too strict. If there is a path owning the available bandwidth, the sharing of this link may reduce the packet loss rate. Such a path can be used as the candidate paths. In Figure 3 (a), $S \rightarrow 1 \rightarrow 2 \rightarrow D$ is a candidate path, if the link $S \rightarrow 1$ is still the remaining bandwidth, then the path $S \rightarrow 1 \rightarrow 3 \rightarrow D$ is also available as a candidate path. In this sense, the actual physical link Figure 3 (a) can be seen as the equivalent link shown in Figure 3 (b).

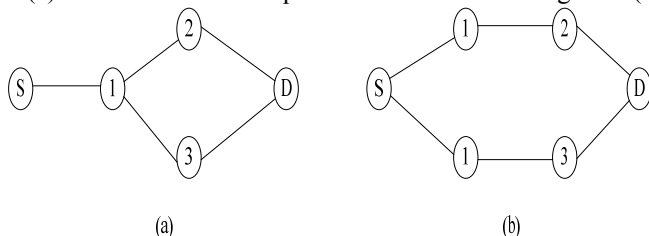


Figure3. The actual link and equivalent link

Next we study the candidate inter-path shared bottleneck link situation. When two candidate paths of the same source - destination node share a bottleneck link, it might be a full transfer of the load on the path to another path above, and then remove this path, and does not increase the packet loss rate. Therefore, to ensure the candidate path does not share the bottleneck link is to reduce the number of candidate paths, while not increasing the packet loss rate. In the Figure 4, the $3 \rightarrow D$ shall be the bottleneck link. Therefore, if the path $S \rightarrow 1 \rightarrow 3 \rightarrow D$ has emerged as a candidate path, the path $S \rightarrow 2 \rightarrow 3 \rightarrow D$ is not a candidate as an alternative path. Thus, where exists no intersection

bottleneck link between the candidate paths is the key to the problem.

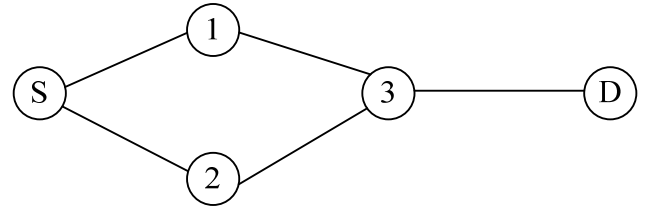


Figure 4. Bottleneck link

In the routing selection process, there is a basic principle to be explained, that is, what is exactly a "good" path. Generally speaking, if a path joining the candidate path set could reduce to a large extent the packet loss rate, it is a good path. The maximum carrying flow $max_traffic$ in the path set is hereby introduced. Each link can carry traffic, and the traffic will be determined by its average available bandwidth. Therefore, the $max_traffic$ can be calculated by the average available bandwidth for each link and other information to be consolidated. This information can be obtained through periodic link state updates. And then follow some rules, it can be converted into the corresponding link available bandwidth. After adjustment, the average link bandwidth utilization reflects the source - destination node pairs of the bandwidth utilization. Note that when two paths share a bottleneck link, the two paths separate the total bandwidth and the bandwidth of a path is the same.

Based on the above-mentioned concepts, defining the path selection process, we can put it as a candidate path only when the path's entry would increase the $max_traffic$. When the removal of a candidate can not decrease the $max_traffic$, then this candidate path shall be deleted. If the replacement of a candidate path by using a non-candidate candidate path can be able to increase the $max_traffic$, then this replacement is effective. In other words, the adjustments of the candidate path set either increase the $max_traffic$ or reduce the number of candidate paths. Essentially speaking, the Adaptive Proportional Distribution Scheme selects the largest $max_traffic$ path with the bottleneck link disjointing.

The following specific example is to illustrate with an APDS how to select a candidate path. The network topology structure is shown as in Figure 5.

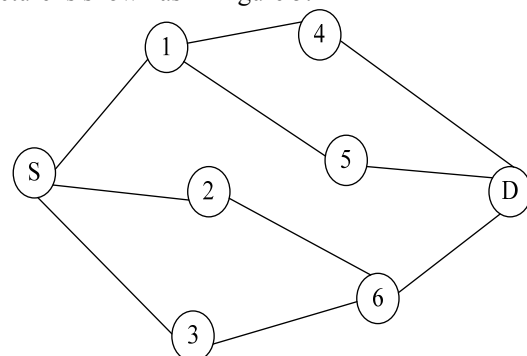


Figure 5. Topology Loop

Suppose the source node S needs to recalculate the candidate paths to the destination node D, and there exist four

available paths between S, D. Suppose the path 1 (S → 1 → 5 → D) and the path 2 (S → 2 → 6 → D) are used currently, and the proportion is allocated to the same stream. Suppose further that between S, D the average load transferred successfully is 40. Before re-calculating a candidate path, S must be converted to the available bandwidth of these two paths. Therefore, the average available bandwidth of these two paths will increase by 20 after the adjustment. If the currently allowed maximum number of candidate paths is 2, you need to compare the two existing paths with the remaining two paths 3 (S → 1 → 4 → D) and path 4 (S → 3 → 6 → D). If the max_traffic of path 3 or 4 is more than 1 or 2, then its place will become a new candidate path. Otherwise, it shall be remained unchanged. If the number of paths can be more than 2, the path 3 will be added to the candidate path set whose accession would increase the overall width. Note that although the path with the existing candidate has shared a link S → 1, but the S → 1 is not a bottleneck link, it does not affect the routing result. However, the path 4 can not be the candidate path. the reason is that it will share the bottleneck link 6 → D with the existing path 2.

2) Description of the Algorithm

With regard to an algorithm, one of the most crucial questions is that which indicators will be the ultimate goal to achieve better beneficent. In the OBS network, the packet loss rate is a key indicator. Meanwhile, taking into account simple and easy to implement, we make the same packet loss rate of each candidate path as the goal of APDS. This strategy only requires the path-level information: the current load of each path and the corresponding packet loss rate. Each source node can acquire the information by tracking the total number of burst packet and the lost burst packet. We will overview the algorithm first, and then describe it in detail.

The proportion set of goal of APDS can be obtained by simple iterative process, which is not different from the optimal ratio algorithm. The goal of APDS is to find a special proportion set so that all candidate paths have the same packet loss rate. We suppose in t time, the proportion set is $\{P_1^{(t)}, P_2^{(t)}, \dots, P_n^{(t)}\}$, $P_i^{(t)}$ represents the proportion value of i^{th} path in t time, and $\sum_{i=1}^n P_i^{(t)} = 1$. The

corresponding packet loss rate is $\{loss_1^{(t)}, loss_2^{(t)}, \dots, loss_n^{(t)}\}$. The rate can be calculated as follows: in a period of time from t_0 to t (i.e. the time interval Δt), the source node counter records the burst packet number $total_burst_i^{(t)}$ that is distributed to i^{th} candidate path, the destination node counter records the received burst packet number $receipt_burst_i^{(t)}$, so that we can count the lost packets $dropped_burst_i^{(t)}$. The packet loss rate in i^{th} path can be acquired from the following formula:

$$loss_i^{(t)} = \frac{dropped_burst_i^{(t)}}{total_burst_i^{(t)}}$$

If all of $loss_i^{(t)}$ is equal, then the proportion set is the expected result. Otherwise, we make the overall average packet

loss rate $\overline{loss}^{(t)} = \sum_{i=1}^n loss_i^{(t)} / n$ as the goal packet loss ration

of each candidate path. On a certain path, if the current packet loss rate is bigger than the average packet loss rate, then the path will be assigned to less burst packets; and vice versa. The same iteration process repeats till the packet loss rate of each path is equal. The difference between $loss_i^{(t)}$ and $\overline{loss}^{(t)}$ determines the magnitude of change in each iteration. In addition, the iteration process uses special control parameters to ensure that the change is gradual.

IV. SIMULATION AND ANALYSIS

In this section, we study the performance of the new algorithms APDS with the network in Figure 7. The simulation network comprises 10 nodes and 20 bi-directional links. Each link consists of two unidirectional fibers in the opposite direction. Each fiber has 4 data channel by 1Gb/s transmission capacity. That channel scheduling scheme used here is the latest available unscheduled channel with void filling (LAUC-VF). All of node has a wavelength converter. Data source has the same statistical characteristics. Traffic that arrives at each node pair in the network is the aggregation of multiple IP flows that obey the poison distribution with λ . The packet length is set to be 100 byte. The transmission rate per flow is fixed to 20kb/s.

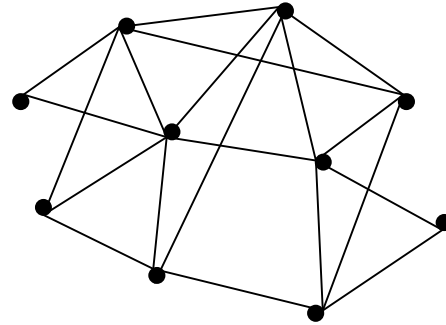


Figure 6. The simulation network

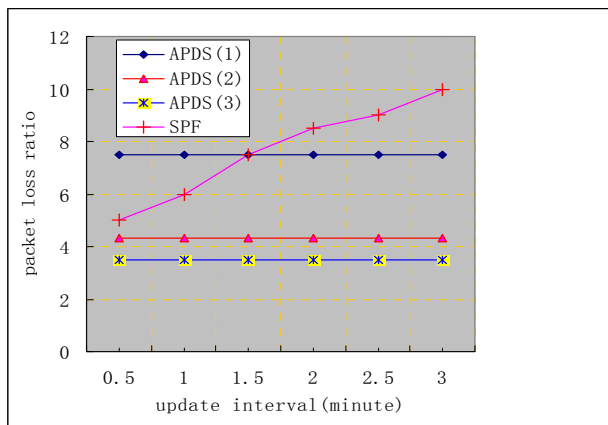


Figure 7. Simulation of update interval and packet loss ratio

Figure 7 shows the different performance between APDS and shortest path first routing (abbreviated SPF) on the packet loss rate. The update interval of APDS is fixed at 10 minutes; the values in parentheses indicate the number of candidate paths (the simulation assumes that the number of candidate paths fixed). We can find that the more paths are employed, the better performance of packet loss rate we will acquire. When the number of candidate paths adds from 1 to 2, the packet loss rate will get very significant improvement. The change of path from 2 to 3 also brings about much improvement. The performance of SPF decreases dramatically when the update time increases. The performance of SPF with 1.5 minute update is even worse than APDS with only 1 path. As mentioned before, the main disadvantage of SPF is that it uses outdated information that results in lower performance. In APDS, traffic is assigned to several better paths, rather than using of inaccurate information to allocate traffic. Moreover, the exchange of information of APDS is the average information rather than real-time information, so the frequent update is not necessary. In essence, APDS scheme makes the system more stable, and therefore it has better performance.



Figure 8. Simulation of traffic intensity and average link load

Figure 8 displays the different performance between APDS and SPF on link load. Generally speaking, SPF adopts the Dijkstra algorithm to acquire the only shortest path. In this way, the load of some paths used frequently is very heavy while that of others is very light, resulting in the uneven load at link. From the above figure we can find that the average load of APDS with 1 path almost is the same as the SPF. At the moment APDS is equivalent to GMPLS. The average load of APDS with 2 paths is great improvement. The reason is that more than one candidate paths can distribute the traffic evenly, so it can naturally improve the average load. In turn, it can reduce the packet loss rate to some extent.

V. CONCLUSIONS

In this article we discuss the application of OSP and APDS in OBS network. By simulation, we have reached conclusions as follows: The latter is superior to the former in packet loss rate and network equilibrium which are two key indicators in the OBS network. The material [5] has proved that a similar algorithm has a good performance in the traditional IP network. Moreover, the new APDS has a very strong portability. The fundamental ideas can not only be used in the traditional IP network and OBS network, but also in the future all-optical network, OCS. So it is a promising algorithm.

REFERENCES

- [1] Nuno M. Garcia¹, Paulo P. Monteiro¹, Mário M. Freire, José R. Santos¹, *A New Architecture for Optical Burst Switched Networks Based on a Common Control Channel*[J], IEEE, 2006.
- [2] J. Y. Wei and R. I. McFarland, *Just-in-Time signaling for WDM optical burst switching networks*[J], Journal of light wave Technology, vol. 18, pp. 2019-2037, 2000.
- [3] Ji Yuefeng, Wang Hongxiang, *OPTICAL BURST SWITCHING*[M]. Beijing University of Posts and Telecommunications Press, 2005.
- [4] Jia Lu, Gurusamy Mohan, Kee Chaing Chua, *Adaptive Proportional Flow Routing in Optical Burst Switching Networks*, IEEE, 2006.
- [5] S. Nelakuditi, Z.-L. Zhang, and R.P. Tsang, *Adaptive Proportional Routing: A Localized QoS Routing Approach*, IEEE INFOCOM 2001, Mar. 2001.
- [6] Xu Leiming, *NS AND NETWORK SUMULATION* [M]. The People's Posts and Telecom Press, 2007.