ORIGINAL ARTICLE

Research on Topoloty Reconstruction Mechanism Based on Traffic Identification

Qishuang Zhu, Hongxiang Guo, Cen Wang, Yong Zhu

Beijing University of Posts and Telecommunication School, Optoelectronic Information College, Beijing 100089

Abstract: Due to the growing variety of data center services, the bursty and variability of data traffic is increasing. In order to make the network better meet the needs of upper-layer services, it is necessary to design a more flexible optical internet topology reconstruction mechanisms to adapt the changing traffic demands. In the past research on optical internet, all topology reconstruction mechanisms are designed based on global data traffic. Although these mechanisms can fully utilize the flexibility of the data center optical interconnection network topology and adjust topology in real time according to the traffic demands, but when the traffic is presented at the regional level, this mechanism does not give optimal results. This paper proposes a topology reconstruction mechanism for data center optical interconnection network based on traffic identification for the previously proposed data center optical switching architecture—OpenScale. The simulation results show that it utilizes the flexibility of the network to save bandwidth resources and increase the wavelength connection bandwidth utilization with a little sacrifice of throughput.

Keywords: Optical Communication; Traffic Pattern; Area Reconstruction

Introduction

In recent years, with the rapid development of cloud computing technology, the traffic in the data center (DC: Data Center) has exploded, and the introduction of optical switching has become inevitable. Various new data center optical interconnection network architectures, such as Helios[1] OSA[2] and C-through[3], etc., usually adopt optical circuit switching (OCS: Optical Circuit Switching) to transport large amounts of traffic. Therefore, in order to enable the network to better match the various communication modes of the data center, a fast and high effect optical path reconstruction mechanism is essential. In our previous work, we proposed a data center optical interconnection network architecture based on small world, named Open Scale[4], in which a plurality of hexagonal rings form a regular lattice structure. In each hexagonal ring, nodes provide logical full connection in the form of optical burst switching. Each node also has the capability of wavelength exchange and can establish a direct reconfigurable wavelength path with remote nodes. The reconfiguration logic topology referred to in this paper is OCS wavelength The survey of data center traffic shows that the changing service requirements of the data center lead to different traffic characteristics[5,6]. Traffic patterns in data centers are correlated with applications, and they can be divided into two categories: regional traffic patterns and full traffic patterns.

A typical way to generate regional traffic patterns is to run multiple concurrent parallel computing jobs on the data center.Using the flexibility of the OpenScale network, the b-matching algorithm[9] can be adopted. this algorithm aims to preferentially select the node combination with the weight and the maximum (we define the weight of each edge to represent the communication demand between node pairs) in the undirected graph, so that it contains the largest number of edges, weight and maximum, and each node appears only once. it can preferentially establish wavelength connection for node pairs occupying most of the current network resources. This method of constructing wavelength

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connection can give full play to the spirit of optical network in logical topology construction Activity, so that the flow of large data flows through a hop path to communicate as much as possible. However, when the traffic is regional, it can be forwarded by nodes in the region in a short distance. This method of constructing wavelength connection according to global traffic causes wavelength connection must be wasted. as shown in Figure 1 (a) and (b), since the traffic is regional, the wavelength connection established according to b-matching is also regional. (a) indicates the wavelength connection established based on global traffic. (b) indicates the wavelength connection established according to regional traffic. In (a), the communication between c-d can be forwarded through c-a-b-d, so the wavelength connection between c-d can be deleted. similarly, the wavelength connection between g-h can also be deleted. Therefore, this paper proposes a new topology reconstruction mechanism for data center optical interconnection networks, which can be deployed on any optical network capable of reconstructing topology to match traffic patterns.

The mechanism includes a global topology generation module based on b-matching, a traffic identification module based on machine learning, and a topology clipping module based on maximizing the utilization rate of wavelength connection. Simulation results show that the mechanism proposed in this paper can give full play to the flexibility of optical networks, save bandwidth resources and improve the utilization rate of wavelength connection bandwidth without sacrificing network performance.

1. Topological reconstruction mechanism

In order to adapt to different traffic types, make full use of network bandwidth resources and realize more flexible reconstruction schemes, this paper proposes is a data center optical interconnection network topology reconstruction mechanism, as shown in Figure 1 (c), with the specific process as follows:

Step 1: Data Center Network Traffic Monitor Regularly Monitors Network Traffic to Obtain Traffic Demand Matrix TM;

Step 2: calculates the global topology with b-matching according to the traffic demand matrix TM;

Step 3: simultaneously sends the monitored TM to the traffic identification module based on machine learning to identify whether it is global traffic or regional traffic;

Step 4: cuts out the topology generated in Step2 in the topology cutting module based on the maximum utilization rate of wavelength connection according to the traffic identification result, and the output topology is the logical topology of the network. In order to realize this topology reconfiguration mechanism, we need to develop two modules in the network controller, which are traffic identification module and topology clipping module respectively. The traffic identification module is used to identify whether it is global traffic or regional traffic. Regional traffic identification actually identifies the number and size of regions and the nodes they contain. We can know the traffic directly from the information obtained by the application mode. But this may add additional development costs.

Therefore, based on machine learning, this paper uses the method[10] combining spectral clustering and convolutional neural network (CNN), the regional traffic is generated from k concurrent computing jobs, each job runs independently on a group of cluster nodes, so the relevant strong connections are all in one job. In the flow pattern recognition module. In the block, identifying the traffic pattern is to identify the number of jobs k in the traffic matrix first, and then cluster the nodes into k groups. The identification of the number k of industries can be regarded as a classification problem. Traffic matrix has the characteristics of graph. Classifying a traffic matrix can be viewed.

When the traffic pattern is identified, the identified traffic is sent to the topology clipping module based on maximizing the utilization rate of wavelength connection. If the traffic type is global traffic, this module directly outputs the global topology generated based on b-matching as the logical topology of the network. If the traffic type is regional traffic, the wavelength connection established by b-matching will be cut off. The number of hops between nodes in the region is small. In most cases, it can be forwarded by neighboring nodes to reach the destination node, avoiding the problems of low wavelength utilization rate and waste of bandwidth resources. Therefore, we will discuss how many wavelength connections are allocated to different regions by taking each region as a unit. The allocation principle is: the OCS edges established by b-matching will be sorted according to the weight from top to bottom, and the OCS edges will be deleted from bottom to top in turn. At the same time, we will observe the throughput change caused by deleting edges. We will define an effective value for each edge. When deleting this edge, the change caused by throughput is very small. The utility value of this edge is small, which indicates that the traffic carried on these edges can be forwarded through other nodes. These wavelength connections do not contribute much to throughput, so these edges can be deleted. When deleting this edge causes great changes in throughput, the utility value of this edge is larger, which indicates that these edges carry a large amount of traffic. If the network is forwarded through other nodes, it will cause network congestion, and the total traffic that can be transmitted by the network per unit time will decrease, so these edges cannot be clipped. To sum up, the topology clipping module needs to evaluate the wavelength connections in each region separately, clip those edges with smaller utility values, and summarize them to obtain the final logical topology of the network.

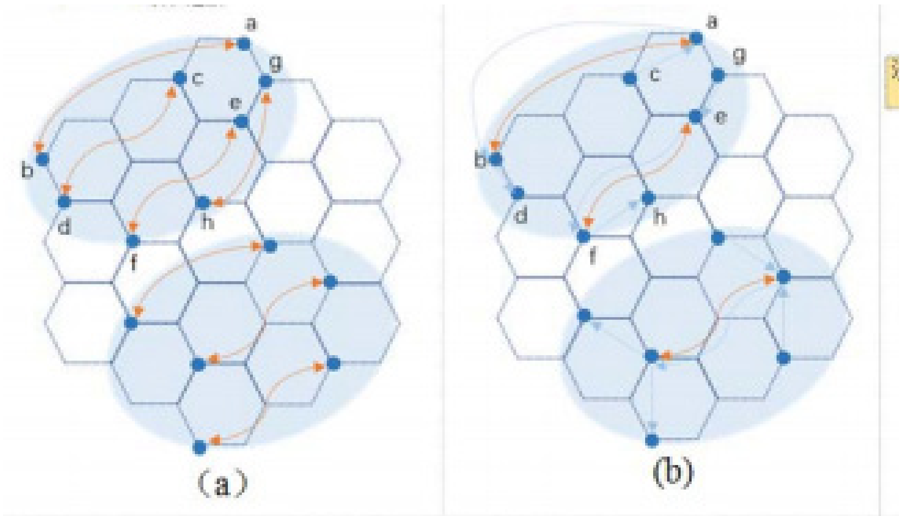
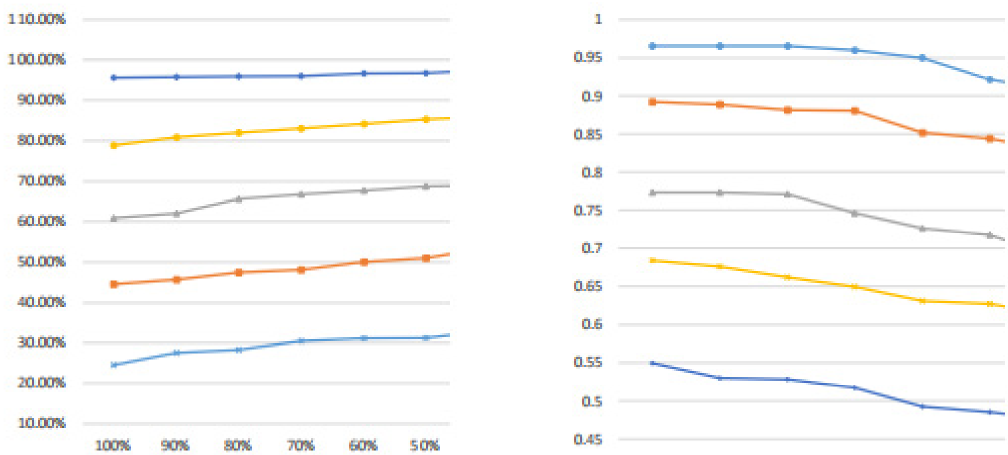


Figure 1. Wavelength connection comparison based on global traffic and regional traffic and flow chart of topology reconfiguration iguration mechanism. (a) wavelength connection based on global traffic using b-matching; (b) wavelength connection based on regional traffic.

2. Simulation analysis

In the simulation, we select the OpenScale[11] optical interconnection network to evaluate the topology reconstruction mechanism based on traffic identification. The OpenScale network uses optical fibers to interconnect top of rack (TOR: Top of Rack) switches into a network topology of hexagonal honeycomb structures. Each TOR switch also integrates an optical switching module, collectively referred to as an optical top of rack (OTOR: Optical Top of Rack), and each cellular unit communicates in an optical burst switching ring network. Each OToR module also has the function of optical add/drop multiplexer, which can support the dynamic establishment or removal of OCS connection between any two racks. In this paper, the OpenScale network is selected for evaluation, and any other network capable of topology reconstruction can also be selected for further evaluation.



(a) (b)

Figure 2. Changes in utilization rate of wavelength connections and throughput assigned to different OCS

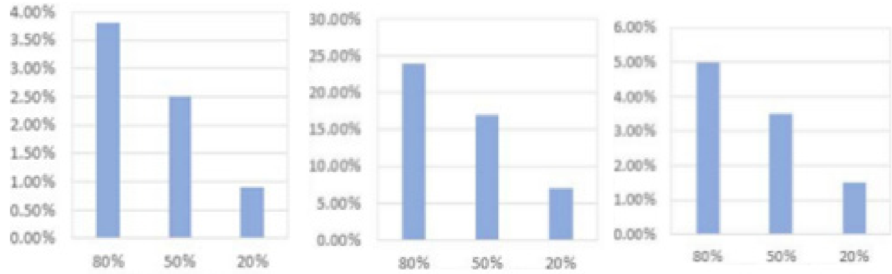
connections. (a) changes in utilization rate of wavelength connections assigned to different OCS connections; (b) changes in throughput assigned to different OCS connections.

In the topology clipping module, we need to allocate different OCS connections for different area sizes and traffic loads. In the simulation of this paper, we set the size of the area to be between 40-60 nodes to generate random integers according to uniform distribution. This paper takes 54 nodes as an example. We use the on/off data source[12] with Pareto distribution to generate traffic with self-similar characteristics. By changing α (representing the tailing degree of the Pareto distribution function) in the probability density function, we can set the load of the traffic matrix and allocate wavelength connections by discussing the throughput and wavelength connection utilization rate of different reconstruction schemes under different loads. This paper only considers the case of 1 degree of freedom (only one wavelength connection is allowed per node), then OCS can be built with b-matching with 27 sides. In the process of solving throughput and wavelength connection utilization, we all adopt the shortest path routing scheme.

The simulation results are shown in Figure 2. The abscissa indicates the allocation rate of OCS connections. When the traffic matrix load is 0.1, there is no significant difference in network throughput from allocating all OCS connections to only the 60% before allocation. When fewer OCS connections are allocated, the throughput drops significantly. At the same time, when 60% of OCS connections are allocated, Wavelength utilization rate increases by about 5%, so when traffic load is 0.1, we can allocate the top 60% of OCS connections generated by b-matching to the network, which can save 40% OCS connections without sacrificing network throughput and increase wavelength connection utilization rate by 5%; Similarly, when the traffic load is 0.2, the first 70% of the OCS connection is allocated, and the wavelength utilization rate is increased by about 5%; When the traffic load is 0.3, the OCS connection of the 80% before allocation will increase the wavelength utilization by about 5%; When the traffic load is 0.4, the throughput of the OCS connection with 20% dropped obviously. At this time, 90% of the OCS connection needs to be reserved, and the wavelength utilization rate increases by about 2%; When the traffic load is 0.5, the wavelength utilization rate is close to 100%, the network congestion is serious, and the logical topology reconstruction can no longer meet the network demand at this time. Therefore, when the traffic load is 0.5 or above, we can only consider increasing the degree of freedom to improve the network performance, which we will not discuss in this article.

In real traffic, the probabilities of global traffic and regional traffic are uncertain. In order to evaluate this topology reconstruction mechanism, we simulate in the following three cases respectively: large probability of regional traffic (global traffic appears with 20% probability, regional traffic appears with 80% probability), large probability of global traffic (global traffic appears with 80% probability, and regional traffic appears with 20%). The global traffic and the regional traffic all occur (the global traffic and the regional traffic each occur with a probability of 50%). in these three cases, the throughput decline rate, OCS connection saving rate and wavelength connection utilization improvement rate of the topology reconstruction mechanism proposed in this paper are analyzed respectively compared with those of the case without such a mechanism. the simulation results are shown in Figure 3. it can be seen that the topology reconstruction mechanism based on traffic identification can be small regardless of the probability of the regional traffic occurring.

The efficiency of the proposed mechanism is proved by saving the number of OCS connections while improving the utilization rate of wavelength connections at the expense of throughput.



(a) (b) (c)

Figure 3. The topology reconstruction mechanism based on traffic identification has different probability of occurrence of regional traffic. (a) different probability of occurrence of regional traffic and different throughput decline

rate; (b) different probability of occurrence of regional traffic and different OCS connection saving rate; (c) When the probability of regional traffic is different.

3. Conclusion

In order to give full play to the flexibility of data center optical network topology, this paper proposes a topology reconfiguration machine system based on traffic identification. The simulation results show that this mechanism can save network bandwidth resources and improve the utilization rate of wavelength connections on the basis of using b-matching to establish logical topology. Although this paper evaluates on a specific network, this reconfiguration mechanism can be applied to any data center optical switching architecture that performs topology reconfiguration.

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