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Topology-Risk Balance Based Virtual Network Mapping Algorithm of Elastic Optical Networks

Jinhong He
Department of Terminal and Communication
Beijing SmartChip Microelectronics Technology Company Limited
Beijing, China
e-mail: hejinhong1@sgitg.sgcc.com.cn

Anqin Luo
Department of Terminal and Communication
Beijing SmartChip Microelectronics Technology Company Limited
Beijing, China
e-mail: 675525103@qq.com

Jing Zhang
Department of Terminal and Communication
Beijing SmartChip Microelectronics Technology Company Limited
Beijing, China
e-mail: zhangjing10@sgitg.sgcc.com.cn

Lei Zhang
ICT Research Institute
China Academy of Information and Communications Technology
Beijing, China
e-mail: zhanglei3@caict.ac.cn

***Abstract*—As virtual networks services emerge increasingly with higher requirement of reliability and survivalbility, great challenges and demands are presented to the Elastic Optical Networks (EON). Aimed to solve this problem, this paper proposes a risk awareness based virtual network mapping stragegy of elastic optical network. In this article, a risk awareness model of virtual optical network is established, which includs node risk degree, link risk degree and other factors together. Moreover, the risk awareness model based virtual network mapping strategy is proposed with detailed procedures. Test results show that the proposed approach is able to improved services security supporting ability of EON.**

Keywords-Virtual Network Mapping; Risk Awareness; Elastic Optical Network

I. INTRODUCTION

With rapid development of software defined network (SDN) technologies, optical networks have achieved great progress toward the programmable ability [1]. Benefiting from great progress of optical communications, the elastic optical network (EON) makes full use of Orthogonal Frequency Division Multiplexing (OFDM) in the optical field. By introducing new types of optical devices with variable bandwidth ability, the EON can provide great support to virtual network services [2]. As one kinds of newly emerged technologies, the network virtual technology allows various logically isolated networks to share the same optical layer network and physical resources.

In fact, the virtual network mapping operation is to allocate optical layer network resources, which is limited by spectrum consistence and continuity. With ever increasing scale of virtual network services, the reliability of the optical layer network is of great importance and any failure in EON may leads to serious loss of service and data.

Therefore, it is necessary for the EON to actively take link fault into consideration to grantee reliability of virtual network mapping operation [5-6]. To solve the problem of reliable mapping, several related typical researches have been made during recent years. In the Ref. [7], the pre-configured backup resources method is proposed, together with the group survivable virtual network embedding algorithms, to achieve the best mapping result and to dynamically adjust work or protection resources. However, this approach may result in low utilization spectrum. The Ref. [8] mainly focused on the remapping method, where those related virtual nodes and links suffered from link failure were migrated and remapped. But low remapping successive rate can be caused when resources are not so enough in the optical layer. The shared protection is considered in Ref. [9] to map virtual network into optical layer network with higher virtual network survivability and lower optical network blocking rate. But the low shared degree problem of protection bandwidth is still there. The Ref. [10] also presented a shared protection mapping optimization algorithm to reduce protection cost, but it failed to take the spectrum fragmentation problem of EON into consideration.

Aimed to solve the mapping reliability problem of virtual network caused by the probability link failure in the elastic optical network, this article proposes a risk awareness model based virtual network mapping strategy for EON. In this article, a risk awareness model of virtual optical network is established, which takes service risk degree, link risk degree and other factors together into consideration. Moreover, the risk awareness based virtual network mapping strategy is proposed with detailed procedures. Thus, system performance of the network virtual mapping can be greatly improved in the EON, which shows great feasiblility and efficiency of the proposed approach, with better risk balance and total risk of the whole network system.

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II. Topology-Risk Awareness Model

Under the environment of Internet multiple services, the essence of services risks balance is to distribute these services with differentiated risks among the EON to avoid the concentration of risks.

With the aim to establish the risk balance model for diversified virtual network services, several conceptions are firstly defined in this section, which includes service-importance weight (SIW), link risk degree (LRD) and Node Risk Degree (NRD), etc.

A. Node Risk Factor

The Node Risk Factor (NRF) of EON is defined as the impact degree of virtual network disruption caused by optical node failure, as is depicted by formula (1).

$$R_{node\_i} = 1 - \frac{\ln\left(\frac{1}{N}\sum_{node\_j}^{N} e^{\lambda_j(G-node\_i)\cdot}\right)}{\ln\left(\frac{1}{N}\sum_{node\_j}^{N} e^{\lambda_j(G)}\right)} \tag{1}$$

where the λj(G) is the eigenvalue of the adjacency matrix and λj(G-node_i) is the one of the adjacency matrix without node_i and G-node_i means the network topology set when the node_i is in failure.

B. Link Risk Factor

Similarly, the Link Risk Factor (LRF) of is also defined as the impact degree of virtual network disruption caused by optical link failure, as is depicted by formula (2).

$$R_{link\_ij} = \frac{\rho_{link\_ij}\cdot\frac{\omega_{link\_ij}}{B_{link\_ij}}}{MAX\left\{\rho_{link\_ij}\cdot\frac{\omega_{link\_ij}}{B_{link\_ij}}\right\}} \tag{2}$$

where the w is the occupied bandwidth of link_ij, while B is the total bandwidth of link_ij and ρ is the link failure rate.

According to formula (1) and (2), rink factor value of each node and each link can be computed in which the importance degree and the risk degree of both nodes and links can be aware. Therefore, the rink soars as factor value increased.

III. Topology-Risk Balance Based Virtual Network Mapping

Based on the Topology Risk Awareness Model mentioned above, this section proposed a novel virtual network mapping strategy with risk balance ability all over the system.

A. Main Principle

The main idea of the topology-risk balance based virtual network mapping scheme coms from that: the controller of software defined elastic optical network collects physical network topology information about all nodes and links; the risk factor of each node and each link is also computed combining utilization condition of network topology resources. Thus, the elastic optical network is able to conduct virtual network mapping operation with risk-balance function, according those node risk factors and link risk factors. The virtual network mapping principle is depicted in Fig. 1.

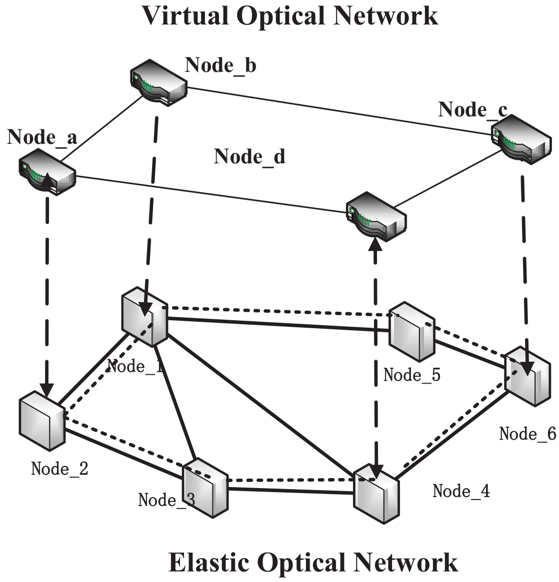

Figure 1. Virtual network mapping of EON

B. Virtual Node Mapping

Because the dual-step mapping method is adopted in this article, including node mapping and link mapping. And the node mapping result will greatly affect the link mapping operation. The virtual node mapping procedure is depicted as follows.

Step 1: Collect topology risk information from the whole elastic optical network;

Step 2: Compute node risk factor according to formula (1) for each physical node;

Step 3: Receiving newly arrived virtual network request which includes number of virtual nodes, number of virtual links and virtual bandwidth;

Step 4: Take all nodes that satisfy virtual bandwidth demand into the pre-mapping node set, and turn to Step 5; otherwise, there exist no physical node with enough bandwidth, and reject this virtual network request;

Step 5: Conduct pre-mapping operation for virtual node Vnode_i to compute node risk variance values Rσ,node_i and to form the node risk variance set $\boldsymbol{S_\sigma}=\{\boldsymbol{R_{\sigma,node\_1}}, \boldsymbol{R_{\sigma,node\_2}}, \ldots, \boldsymbol{R_{\sigma,node\_N}}\}$;

$$R_{node\_avg} = \frac{\sum_{j=1}^{N} R_{node\_i}}{N} \tag{3}$$

$$R_{\sigma,node\_i} = \sqrt{\frac{\sum_{j=1}^{N}\left(R_{node\_j} - R_{node\_avg}\right)^2}{N}} \tag{4}$$

Step 6: Map the virtual node Vnode_i into physical node_i, when the value of Rσ,node_i satisfy the formula (5);

$$R_{\sigma,node\_i} = MIN\left(R_{\sigma,node\_1}, R_{\sigma,node\_2}, \cdots, R_{\sigma,node\_N}\right) \quad (5)$$

Step 7: Delete virtual node Vnode_i and physical node_i that have been mapped from the virtual node set and physical node set;

Step 8: Set i=i+1, and repeat Step 4, until all virtual nodes have already been mapped;

Step 9: Complete the node mapping procedure.

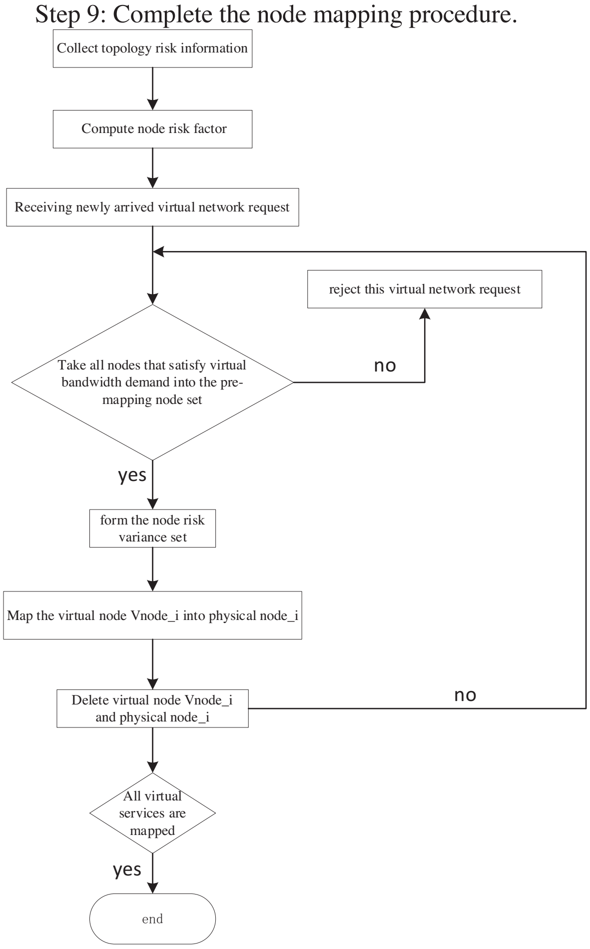

Figure 2. Virtual Node Mapping process

C. Virtual Link Mapping

Following the node mapping operation, the virtual link mapping is also conducted as follows.

Step 1: Compute the physical link risk factor according to formula (2) for each physical link;

Step 2: Adopted the D routing algorithm to compute physical lightpath for virtual link Vlink_ij, according to the link risk factor;

Step 3: Update wlink_ij of all link risk factors of physical topology;

Step 4: Set k=k+1, until all virtual links have already been mapped; otherwise, turn to the Step 1;

Step 5: Complete the link mapping procedure.

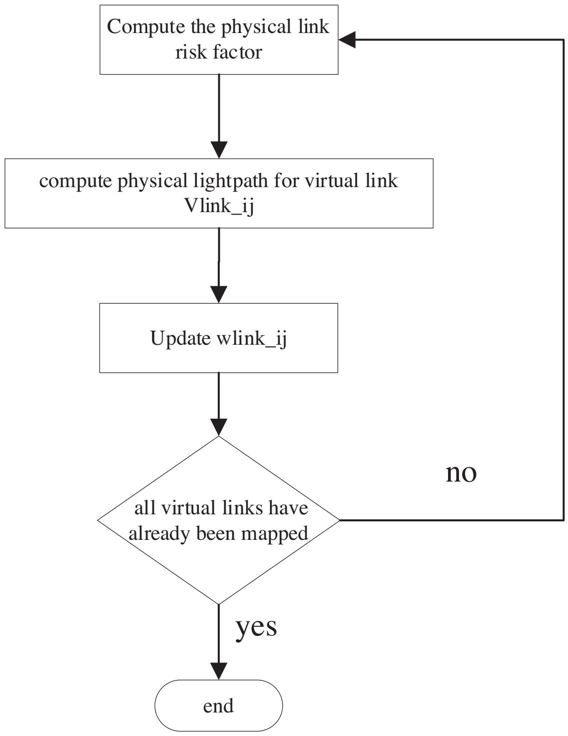

Figure 3. Virtual Link Mapping process

Therefore, the topology-risk balance based virtual network mapping can be achieved into the EON.

IV. SIMULATION RESULTS AND ANALYSIS

To evaluate the proposed topology awareness model based virtual network mapping algorithm, the simulation is conducted in this section, where the simulation environment is constructed by NS3 network simulation software tools and the NSFnet topology is adopted. And this simulated software defined optical network mainly consists of 32 nodes and 41 links. This simulation comparison mainly focuses on performances of blocking rate and connection establishment time. And case-2 is the topology awareness based virtual network mapping algorithm, while case-1 is the one without topology awareness ability, under the condition that there are 8 wavelengths. Moreover, both case-3 and case-4 are the same ones with 16 wavelengths in each link. Comparison results are given by Fig. 4 and Fig. 5.

The comparison of the blocking rate is made in Fig. 4. Obviously, both case_2 and case_4 achieve worse result in term of blocking rate when they are compared with case_1 and case_3. That is because both case_2 and case_4 fails to provide more lightpath available for the SDON under various limits. On the other hand, the case-1 and case-3 can achieve better performance, enhanced by the topology awareness function. Thus, the QoS quality of SDON in case_2 and case_4 still suffer from traffic unbalance problem. As the proposed scheme can be fully aware of the topology risks of SDON, the blocking rate can be efficiently reduced, even under condition of high traffic load.

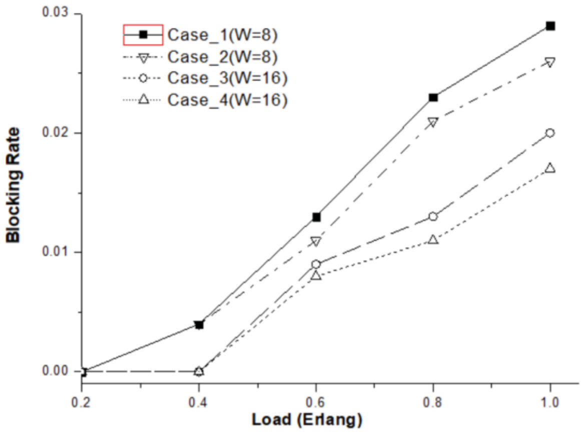

Figure 4. Comparison of blocking rate

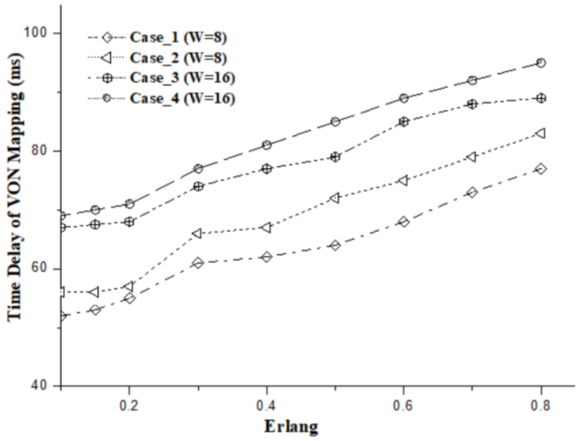

Figure 5. Comparison of VON Mapping Time

As is shown in Fig. 5, both case_3 and case_4 even suggest worse performance to finished virtual optical network mapping operation in term of time delay, while the case_1 and the case_2 can take much shorter time, due to the complexity of physical optical network with more wavelengths. Moreover, the case_1 still takes a little longer time when compared with case_2. That is because of the case_1 needs to compute the comprehensive impact by optical network topology factors, as the cost of this proposed topology risk-balanced function

V. CONCLUSION

With the aim to improve virtual network mapping reliability for multiple Internet services, this paper proposed a so-called risk-balance model based virtual network mapping algorithm in the software defined elastic optical network. This proposed risk-balance model taken various nodes and links failure-risk factors into consideration. Moreover, a novel virtual network mapping algorithm was also proposed and designed based on this risk-balance model. Based on the topology awareness of the whole network, the virtual network service is mapped, and the bottom optical network provides differentiated load balance for virtual network service, so as to improve the supporting ability of software defined optical networks for virtual optical network services. Test results showed that the proposed approach was able to support services-oriented virtual network mapping of elastic optical networks.

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