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Global path and bandwidth scheduling in inter-data-center IP/optical transport network

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ABSTRACT

We propose a flow-oriented global path and bandwidth scheduling scheme for inter-data-center IP/optical network. To improve the throughput of network and reduce the mutual impact between flows, we allow each flow to be carried by a multi-path optical channel data unit (ODU) channel. In addition bandwidth is allocated to flows fairly according to weight. Simulation results reveal that compared to high-priority-first mechanism, the method proposed improves average bandwidth allocation ratio by about 15% and allocation fairness between flows by 30%. Furthermore, compared to pure IP network, router ports are significantly saved and network cost can be reduced by up to 40% with scheme proposed in unified controlled IP/optical network.

1. Introduction

The unprecedented amount of data between data-centers imposes big challenges to inter-data-center networks, with the rapid development of cloud computing [1,2].

The majority of data center traffic involves large-scale data synchronizing across sites [3,4]. These large traffic flows often contend resources and impact transmission of each other that are carried by the same link. Even traffic load is in normal level, resources cannot be made full use of due to the fact that some links congest.

However, some characteristics can be displayed about these traffic flows. On the one hand, they benefit from as much bandwidth as they can get, and bandwidth is the key focus; on the other hand, they could be controlled by data-center and can tolerate temporary bandwidth reductions [3]. Because of these characteristics, an inter-data-center flow generally demands a bandwidth interval rather than a fixed bandwidth, and can adapt its transmission rate based on available capacity. This makes it feasible to allocate flexible bandwidth to each flow. In addition, each flow can be split across multiple paths. Therefore, it is possible to optimize network performance.

In Ref. [3] Google proposes B4 network, in which a global traffic engineering (TE) optimization algorithm is deployed to calculate multiple paths and allocate bandwidth to improve the network throughput, resource utilization and keep allocation fairness between flows. Test results show that network bandwidth utilization is raised to more than 95%. However, B4 is an IP backbone network and optical channels are treated as static pipeline to support point-to-point transmission. Since optical transport network (OTN) has the capability of flexible circuit switching, Inter-data-center network performance could be further improved by effective IP/optical integration.

In the last years, a number of researches have been done about traffic flow scheduling for inter and intra data-center network. In Ref. [5], the authors provide the architectural design of an orchestration platform to coordinate resource provisioning while addressing both bandwidth and computing/storage requirements. The authors in Ref. [6] present an architecture of a distributed cross-stratum orchestrator which performs flexible data center operations and dynamic establishment/teardown of inter-data-center connections. In Refs. [7,8], the authors study on anycast-based optimizations. Specifically, in Ref. [7] the authors turn to limit migration delay and in Ref. [8] the authors focus on spectrum efficiency. However, to the best of our knowledge, they do not consider the fairness in allocating limited resources to flow requests, nor do they quantify the priority of each flow. Furthermore, they do not combine flexible bandwidth allocation and multi-path routing as this work actually does.

In this paper, we introduce a software defined network (SDN) based hierarchical architecture and construct inter-data-center network using IP over OTN technology [9–12]. Intra-data-center network control and requests report are handled by local controllers, while the global controller allocates paths and

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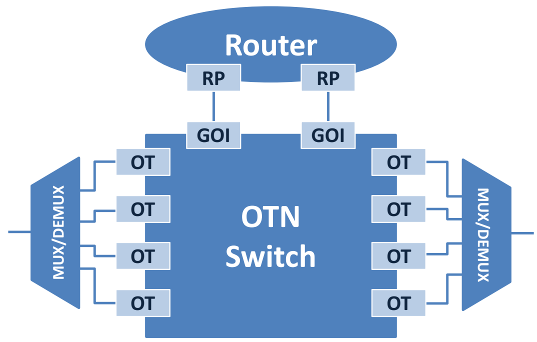

Fig. 1. Architecture of IP over OTN node.

bandwidths. Based on this we propose a flow-oriented global path and bandwidth scheduling scheme (GPB). Each flow is carried by optical channel data unit (ODU) channels while bypassing routers in order to reduce the impact on other flows. In addition, network throughput is increased by multi-path ODU channels scheduling. Finally, resources utilization and fairness are also improved.

The remainder of this paper is organized as follows. Section 2 introduces the technical background and network architecture. Section 3 details global path and bandwidth scheduling scheme for inter-data-center IP/optical network. Simulation results are presented and analyzed in Section 4 and conclusion is given in Section 5.

2. Network architecture and technical background

Fig. 1 shows structure of an IP over OTN node which is mainly composed of a router and an OTN switch. Via router port (RP) flows are transported to gray optical interface (GOI) which connects IP router to OTN switch. In OTN switch connections can be either dropped/added to/from IP router via RP, or transferred directly through ODU connections via optical transponder (OT).

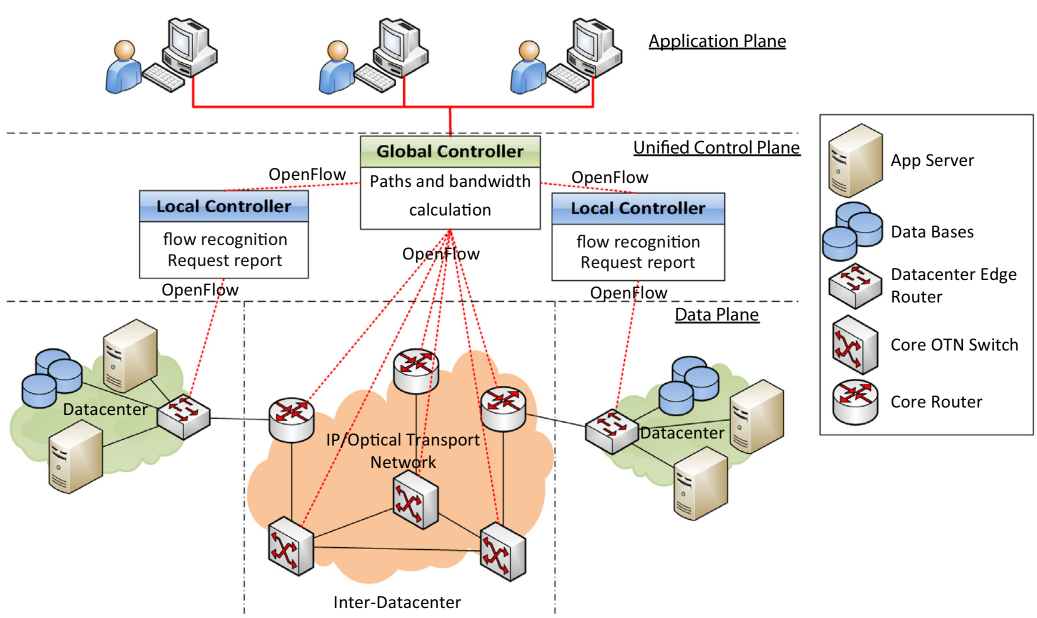

Fig. 2. Unified control architecture.

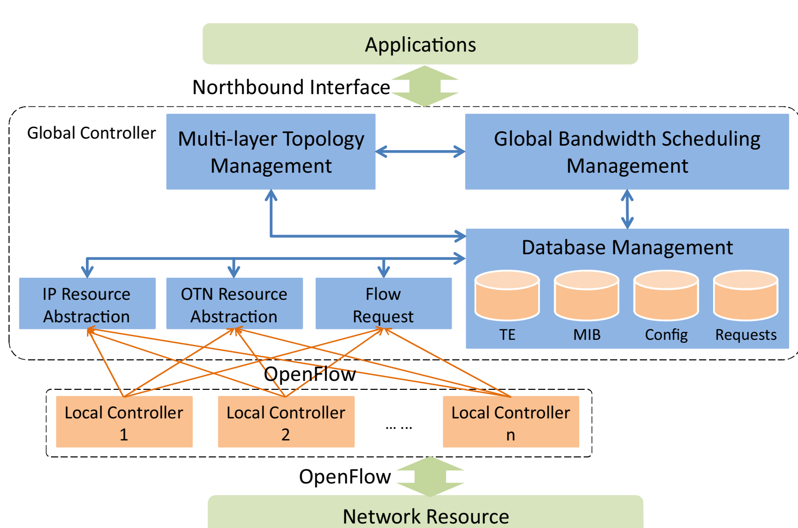

Fig. 3. Function module design of unified control plane.