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Deployment of survivable fiber-wireless access for converged optical and data center networks

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ABSTRACT

As a promising solution for the bandwidth bottleneck of Data Center (DC) network, the converged optical and DC networks have gained an increasing popularity due to their advantages in rich bandwidth and high reliability. Although the converged optical and DC networks bring the opportunity for high-speed transmission of DC traffic, they also impose more severe challenge on the survivability design, because the network component failure will cause greater data loss. Some works focus on the survivability of core network for the convergence of optical and DC networks and remain less touched on that of access network. In fact, access network plays an important role in the reliable transmission of the traffic between end-users and DC, which accounts for considerable portion of all DC traffic. However, since the vulnerability to component failure, the traditional Passive Optical Network (PON) may no longer satisfy the higher survivability requirement. As an emerging broadband access technology, Fiber-Wireless (FiWi) may be a preferable candidate for the survivable access of converged optical and DC networks. In FiWi access network, the Wireless Mesh Network (WMN) at front-end can protect the Passive Optical Network (PON) at back-end by wirelessly rerouting. This paper focuses on the deployment of survivable FiWi access network against single distribution fiber failure, which is a typical failure scenario in optical access network. We propose a new protection approach called Wireless Rerouting with Backup Radios (WRBR) for the deployment of survivable FiWi access network. In WRBR, we deal with the optimization of wireless routers placement and backup radios configuration. Both Integer Linear Programming (ILP) and heuristic approach are proposed, aiming to minimize the deployment cost. Simulation results demonstrate the advantage of WRBR in saving deployment cost of FiWi access for converged optical and DC networks over the previous works.

1. Introduction

With the explosive increase of cloud computing application, the Data Center (DC) network is experiencing a bandwidth bottleneck for the transmission of huge data traffic. Since the advantages in rich bandwidth and high reliability, the optical transmission technology has been widely acknowledged as a promising solution for the bandwidth bottleneck of DC network. Although the converged optical and DC networks bring the opportunity for high-speed transmission of data traffic, it also imposes more severe challenge on the survivability design, because the network component failure will result in greater data loss [1–5].

Some works have begun on the study of survivability of core network for the convergence of optical and DC

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networks [6,7]. However, they remain less touched on that of access network. In fact, due to more frequent access to the servers in DC, the traffic between end-user and DC accounts for a significant portion of all DC traffic in the converged optical and DC networks [3,4]. Therefore, the survivable access is also an issue of concern for the deployment of the converged optical and DC networks. Although the traditional optical access technology, e.g., Passive Optical Network (PON), can provide higher bandwidth capacity and better transmission stability, it is vulnerable to the component failure because its tree topology cannot self-heal [8,9]. This means that PON will have to suffer from a dilemma due to the requirements of not only higher bandwidth but also stronger survivability.

As a preferable candidate for survivable broadband access in future, Fiber-Wireless (FiWi) access network has been gaining an extensive attention from academic and industrial communities. Fiber-Wireless (FiWi) access network is well known for the integration of technological merits of wireless and optical networks, including higher bandwidth, better transmission stability, more flexible access and lower deployment cost. Recently, FiWi is also recognized as one of the cost-efficient solutions for the deployment of survivable access, which is a notable issue in the development of converged optical and DC networks [6,7].

A typical architecture of FiWi access network consists of Wireless Mesh Network (WMN) at front-end and Passive Optical Network (PON) at back-end [10,11]. As shown in Fig. 1, FiWi access network is responsible to collect the traffic from end-users to DC or distribute the traffic from DC to end-user. When an Optical Network Unit (ONU) loses the connection with Optical Line Terminal (OLT) due to distribution fiber failure, it can wirelessly reroute its traffic into other normal ONUs for traffic recovery. Some works [12–15] have been proposed to protect FiWi network against distribution fiber failure by wireless rerouting. Compared to the traditional fiber duplication protection for PON, these works can achieve higher cost-efficiency. However, most of the related works focus on the design of survivable routing and remain less touched on the deployment of survivable FiWi network, e.g., wireless routers placement and backup radios configuration, which is a crucial step for the improvement in survivability performance.

In this paper, we consider a typical failure scenario, i.e., single distribution fiber failure [13,14]. We propose a cost-efficient protection approach called Wireless Rerouting with Backup Radios (WRBR) for the deployment of survivable FiWi network. In WRBR, we allocate each primary ONU several backup ONUs. Each backup ONU needs to reserve the residual capacity for its primary ONU as the backup capacity. We strategically place the wireless routers in the front-end and configure them with backup radios. It is guaranteed that each primary ONU should have at least one wireless backup path to each of its backup ONUs. Here, the wireless backup path refers to a multi-hop wireless path composed of wireless routers with backup radios. Each backup radio on the wireless backup path should reserve the backup radio capacity for rerouting traffic. Once a distribution fiber fails, the disconnected ONU can transfer its traffic into the backup ONUs through wireless paths between them. Thereafter, the backup ONUs will transmit the traffic to OLT by using the reserved backup capacity.

With the objective of minimizing the deployment cost, we consider the optimization of wireless routers placement and backup radios configuration under the constraints on allocation of backup ONUs, length of wireless backup path and allocation of backup radio capacity. We formulate this optimization problem by Integer Linear Programming (ILP) and obtain the optimal solution. To support the application of WRBR in large-scale network, we also propose the heuristic algorithm for the near-optimal solution with much less time consumption.

The reminder of this paper is organized as follows. In Section 2, we employ ILP to formulate the optimization problem of wireless routers placement and backup radios

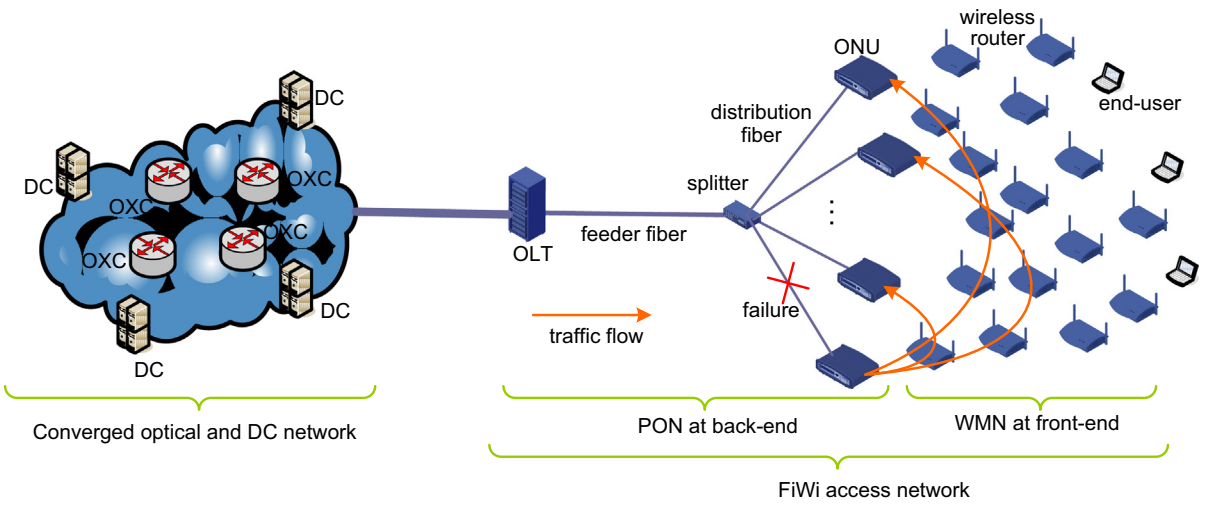

Fig. 1. Survivable FiWi access for converged optical and DC networks.