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Demonstration of QoS-aware wireless protection scheme for video service in fiber-wireless access network

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ABSTRACT

This paper proposes a wireless protection scheme with quality of service (QoS)-aware dynamic resource allocation for video service in the hybrid fiber-wireless access network. The proposed scheme introduces the optical network unit (ONU) with wireless function called WONU for wired and wireless services, and uses the wireless resource between the WONUs to protect the network against failure without deploying extra components. Moreover, a QoS-aware strategy based on the time-domain adaptive linear prediction and media delivery index is embedded in the protection scheme to guarantee the QoS of video service and improve the efficiency of bandwidth utilization. To evaluate our scheme, an integrated test-bed, which consists of passive optical network and wireless network, is constructed. The experimental results show that the protection scheme could effectively protect the video service with high QoS guaranteed and bandwidth utilization.

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1. Introduction

With the increasing demands for bandwidth-intensive services and media-rich applications, it is necessary for future access technologies to provide high capacity and mobility support to end users in a cost-effective manner [1,2]. The emerging hybrid fiber-wireless (FiWi) and wireless-optical broadband access network (WOBAN), which integrate the best of both optical and broadband wireless networks, are the promising next-generation broadband access technologies [3,4]. The hybrid architecture can potentially provide the wired and wireless services over the same infrastructure to end users simultaneously. In addition, due to its high-capacity optical trunk and multihop mesh topology of the wireless network at the front, the hybrid fiber-wireless access network has an important characteristic of fault-tolerant [4]. It can use the wireless resource to protect the network against failures [3,5]. In case of optical line terminal (OLT)/feeder fiber failure, optical network units (ONUs)/distribution fiber failure and wireless router/gateway failure, the affected traffic can be redirected to other live nodes.

On the other hand, fault management is a crucial aspect in the network management to enhance network reliability [3,6]. However, as the dominant optical access technology, the traditional passive optical network (PON) has no survivability due to the tree topology. The feeder fiber link failure between the OLT and the remote node (RN) leads to enormous loss in data. A failure of the distribution fiber link between the RN and an ONU will cause the affected ONU unreachable from the OLT [7]. To date, many methods have been proposed for network protection in the PON system [7–9]. Most of the protection architectures for PONs need full or partial PON duplication (optical protection), such as fiber links or ONUs, to provide network resource redundancy. As a result, it may raise the capital expenditure too much for the cost-sensitive access network.

In this work, we propose the wireless protection switching scheme for video service to guarantee the quality of service (QoS) in a hybrid fiber-wireless broadband access network scenario and evaluate it in the test-bed. The proposed scheme introduces the wireless function to the ONUs (called WONUs) for the wired and wireless services. And it uses the wireless resource between the WONUs to protect the network against the ONU/distribution fiber failure. Moreover, to achieve high service performance and effective bandwidth utilization, we extend our previous work [10] to guarantee the quality of video service.

2. Wireless protection scheme

In this section, we briefly describe the integrated fiber-wireless broadband access network architecture and analyze the QoS-aware wireless protection switching scheme.

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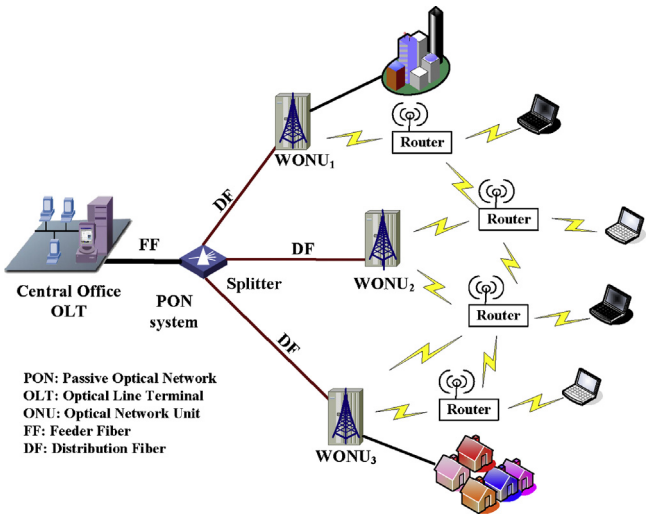

Fig. 1. Integrated fiber-wireless broadband access network architecture.

2.1. Integrated fiber-wireless network architecture

The integrated broadband access network architecture consists of an optical network at the back end and a wireless network in the front end by integrating different optical and wireless technologies, as shown in Fig. 1. As the dominant optical access technology, a PON is composed of an optical line terminal (OLT) at the service provider's central office (CO), a remote node (RN), and a number of optical network units (ONUs) near the end users. Each ONU is connected to the RN with a distribution fiber (DF), and the RN is connected to the OLT with a feeder fiber (FF). The ONUs are equipped with wireless function such as gateway to extend the coverage of the access network and provide ubiquitous (anytime-anywhere) broadband access to end users. It is assumed that an ONU is integrated with a wireless router into a converged box called wireless ONU (WONU). As there is no such an integrated box physically, the WONU is the combination of an ONU and a wireless router as the border device for both optical and wireless networks. The front end of the integrated network which consists of other wireless routers is a flexible and reliable wireless mesh network(WMN). The wireless portion can be deployed using any standard wireless technologies such as WiFi or WiMAX.

2.2. Wireless protection switching scheme

There are several locations for a traditional PON system to occur failures. The most serious location is on the section between the optical splitter and the OLT. This failure will cause all the users subscribed to the system to totally lose their network services. A unique viable solution to this type of failure is to deploy another geographically independent fiber between the optical splitter and the OLT. In this paper, we mainly focus on the ONU/DF failure for video service. A wireless protection switching scheme is proposed which uses the wireless resource in the WMN at the front end. In the WMN-based integrated fiber-wireless architecture, a WONU can reroute the affected traffic to another WONU through wireless links. For example, When the distribution fiber from the splitter to $WONU_1$ is cut, the $WONU_1$ first detects the loss of the downstream signal power and switches to the protected mode. It searches the adjacent WONUs such as $WONU_2$ according to a particular protection scheme with sending the request signal. The protection scheme considers the load on the normal neighboring WONUs. It calculates both the capacity and delay of wireless protection path while routing the affected traffic from users to a neighboring WONU

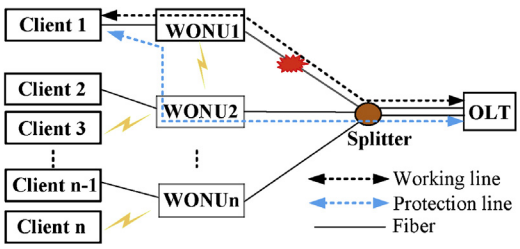

Fig. 2. Wireless link protection for inter-ONU communication.

[11]. Then, the $WONU_2$ makes a judgment whether it could afford the new service payload. If so, the $WONU_2$ sets up a wireless link with $WONU_1$, as shown in Fig. 2. Meanwhile, the OLT reallocates the bandwidth among the WONUs to utilize the bandwidth more effectively. However, if the $WONU_2$ could not afford such adjacent service, $WONU_1$ will turn to other WONUs for protection. Besides, the user classified scheme is used to reduce the collision.

2.3. QoS-aware scheme for video service

As variable bit rate (VBR) video traffic is expected to take a significant portion of multimedia applications for its satisfactory perceptual quality, in our previous work [10], an user-classified dynamic resource allocation scheme is proposed on the ethernet PON (EPON) test-bed to guarantee the high performance and bandwidth utilization for VBR video service. It uses the time-domain normalize least mean square (NLMS) linear prediction to perform the on-line real-time traffic prediction and media delivery index (MDI) as the feedback reference to indicate the video service quality. Experimental results show that the bandwidth resource utilization can be improved by 20–60% compared with the traditional deterministic fixed service rate reservation. For its feasible and scalable ability, we extend the previous strategy to the wireless protection scheme in order to guarantee the quality of video service and protect the service for both wired and wireless end users in case of ONU/fiber failure. Based on the QoS-aware strategy, two functions have been developed: protected mode (PM) and normal mode (NM) [12]. Protected mode is to solve the requirement for establishing new wireless link and reallocating the network resource. Normal mode is to regulate the resource for non-failure subscribers. In the QoS-aware scheme, both the PM and NM could co-exist in the whole procedure.

3. Function structure and design

To realize the proposed QoS-aware wireless protection scheme for video service, a virtual control plane is introduced to the whole integrated network. The basic integrated wireless and optical network is under the control plane, as shown in Fig. 3. The control plane is separated with three major functions: monitor, protector,

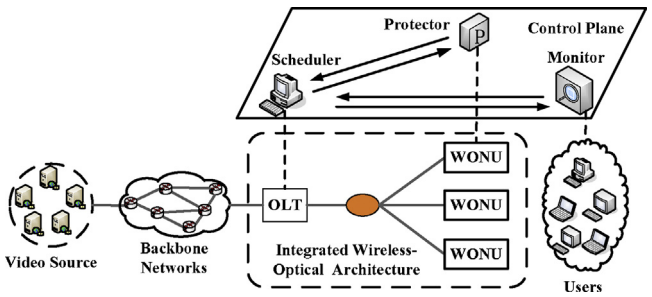

Fig. 3. Structure of wireless protection switching scheme with QoS-aware dynamic resource allocation.

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