Optics Communications 284 (2011) 4894–4899

Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Analysis of physical layer performance of hybrid optical–wireless access network

R.Q. Shaddad [a,b,*], A.B. Mohammad [a], A.M. Al-hetar [b]

[a] Photonic Technology Center (PTC), Infocomm Research Alliance (IcRA), Universiti Teknologi Malaysia (UTM), Johor 81310, Malaysia
[b] Communication and Computer Engineering Department, Faculty of Engineering and Information Technology, Taiz University, Taiz, Yemen

ARTICLE INFO

Article history:
Received 16 December 2010
Received in revised form 11 May 2011
Accepted 13 June 2011
Available online 25 June 2011

Keywords:
Hybrid optical–wireless access network
Passive optical network
Wavelength division multiplexing
Wireless access point
Orthogonal frequency division multiplexing

ABSTRACT

The hybrid optical–wireless access network (HOWAN) is a favorable architecture for next generation access network. It is an optimal combination of an optical backhaul and a wireless front-end for an efficient access network. In this paper, the HOWAN architecture is designed based on a wavelengths division multiplexing/time division multiplexing passive optical network (WDM/TDM PON) at the optical backhaul and a wireless fidelity (WiFi) technology at the wireless front-end. The HOWAN is proposed that can provide blanket coverage of broadband and flexible connection for end-users. Most of the existing works, based on performance evaluation are concerned on network layer aspects. This paper reports physical layer performance in terms of the bit error rate (BER), eye diagram, and signal-to-noise ratio (SNR) of the communication system. It accommodates 8 wavelength channels with 32 optical network unit/wireless access points (ONU/APs). It is demonstrated that downstream and upstream of 2 Gb/s can be achieved by optical backhaul for each wavelength channel along optical fiber length of 20 km and a data rate of 54 Mb/s per ONU/AP along a 50 m outdoor wireless link.

1. Introduction

In the last decade, the bandwidth demand of end users for broadband services such as quad-play (voice, video, Internet, and wireless) and multimedia applications has increased. For broadband access services, there is strong competition among several technologies, such as optical access technologies and wireless access technologies. Optical access network provides high-bandwidth digital services and long-distance communications but it has limited availability to end-users. Wireless access network is ubiquitous and flexible penetration to end-users but it supports limited bandwidth [1]. Thus, future access technologies must provide flexible deployment, large backbone capacity, upgrade-ability, and scalability to user number and demand. Bandwidth demand in access networks will continue to grow rapidly due to the increasing number of technology-smart users. A HOWAN is an optimal combination of an optical backhaul and a wireless front-end for an efficient access network.

Passive optical network (PON) and WiFi technique are two promising broadband access technologies for high-capacity wired and wireless access networks, respectively. The HOWAN consists of an optical backhaul supports a wireless mesh network (WMN) in the front-end. In this paper, the optical backhaul is implemented by using a cost-effective WDM/TDM PON. The WDM/TDM PON has been considered as a promising option due to its large throughput [2] and it realizes wide-area access network [3]. The wireless front-end is implemented by using WiFi technique which has many interesting characteristics such as low cost, high data rate, and easy deployment in wireless local area network (WLAN) [4,5]. WDM/TDM PON and WiFi provide different levels of bandwidth, which shows a good match in capacity scales. WDM/TDM PON supports data rate up to 2 Gb/s in both downstream and upstream for each wavelength, which is shared by a group of optical network units (ONUs). On average, each ONU accesses about 54 Mb/s bandwidth, which matches the total capacity offered by a WiFi access point (AP) over 20 MHz wireless channel as well.

The HOWAN is proposed to provide blanket coverage of broadband and flexible connection for end-users. Most of the existing works, based on performance evaluation are concerned on network layer aspects [1,6–8]. The technical and deployment considerations of the hybrid wireless–optical broadband–access network (WOBAN) are discussed such as network setup, network connectivity, and fault-tolerant behavior of the WOBAN [6]. The performance of hybrid network protocols of a programmable and configurable WOBAN is demonstrated and analyzed for several typical applications such as data transfer, voice, and video over WOBAN [7]. The overall WOBAN topology in terms of link capacity, available topologies, deployment cost has been recently optimized by using a mathematical programming model to get consistent and effective hybrid networks [8]. Shaw et al. [1] proposed an integrated-routing algorithm to achieve load balancing on the hybrid scalable optical–wireless access network which consists of reconfigurable optical backhaul and WMN and aims to provide a broadband, ubiquitous, and blanket-coverage access service. Their simulation results showed throughput and delay improvement, which have resulted from the load balancing among multiple gateways. In this paper, we have investigated physical layer

* Corresponding author at: Photonic Technology Center (PTC), Infocomm Research Alliance (IcRA), Universiti Teknologi Malaysia (UTM), Johor 81310, Malaysia.
E-mail address: rqs2006@gmail.com (R.Q. Shaddad).

0030-4018/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.optcom.2011.06.023

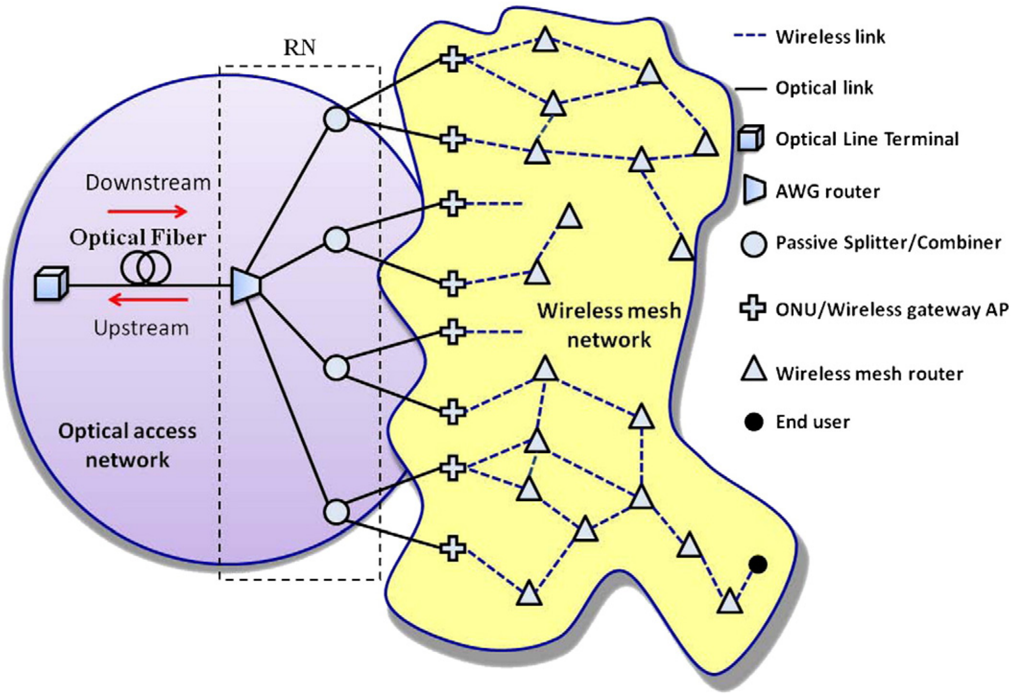

Fig. 1. HOWAN architecture.

performance of the HOWAN in terms of the BER, eye diagram, and SNR of the communication system.

The rest of this paper is organized as follows: in Section 2, the WDM/TDM PON-based HOWAN architecture is presented. The simulation design and concept of the fiber optic and wireless transmission systems are explained in Section 3. Section 4 is dedicated to describe the results and discussion. Result comparison with work done elsewhere is covered in Sections 5 and Section 6 conclude the paper.

2. HOWAN architecture

The proposed HOWAN architecture is shown in Fig. 1 [9]. The optical backhaul of the HOWAN comprises of an optical line terminal (OLT) at the central office (CO), an optical fiber, a remote node (RN), and multiple ONUs close to user's premises. The OLT converts the data to corresponding downstream optical signal which is then transmitted along the optical fiber. It receives upstream optical signal from the optical fiber and converts it to the corresponding electrical signal. The RN comprises of an arrayed waveguide grating (AWG) router and passive splitter/combiners (PS/Cs) to demultiplex the downstream optical signal received from the optical fiber to multiple ONUs and also multiplexes the upstream traffic from the ONUs to the optical fiber. The ONU is integrated with the wireless AP. In the wireless front-end of HOWAN, WMN is deployed for a ubiquitous and flexible communications to the subscribers. Typically, the WMN consists of multiple gateways for the Internet access, a group of wireless mesh routers that provide multihop wireless communications and a group of wireless mesh clients associated with wireless mesh routers. In general, the mesh client sends traffic to and receives traffic from its associated mesh router or gateway [6].

Both the AP gateways and the mesh routers have twofold function: they work as a classical access points towards the wireless mesh clients and the AP gateways implement the integration of wireless front-end and optical backhaul in the proposed HOWAN. In downlink direction, the conversion from the optical signals to the baseband electrical signals is done at the ONU. The gateway then modulates the baseband electrical signals by using the orthogonal frequency division multiplexing (OFDM) technique. The antenna of AP gateway propagates the RF modulated signal on the available wireless interface and channel. The mesh client finally receives traffic from its associated mesh router or gateway. In uplink direction, the mesh client sends traffic to its associated mesh router or gateway. The gateway receives the RF signals that are demodulated to the suitable baseband electrical

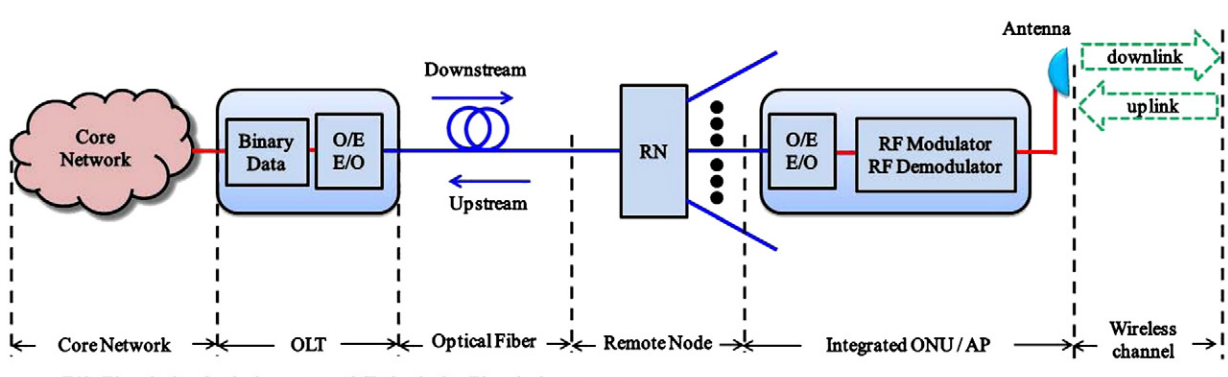

Fig. 2. Integrated optical–wireless system scheme.