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Review

A survey on access technologies for broadband optical and wireless networks

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ABSTRACT

The bandwidth demand of telecommunication network is growing rapidly due to the increasing number of technology-intelligent end-users. The emerging optical and wireless access networks are continuously competing with each other to provide these requirements for the end-users. The optical access networks provide huge data rate and long-distance link, but it is less ubiquitous. The wireless access networks provide flexible and ubiquitous communication with a low deployment cost. However, its deployment scalability is limited by the spectrum and range limitations. The hybrid wireless optical broadband access network (WOBAN) is a powerful combination of optical backhaul and wireless front-end to contribute to a good scalability, cost effective and flexible communication system. This paper reviews the key enabling access technologies and progress advancements of these networks. The emerging optical and wireless access technologies are also presented and compared.

Contents

1. Introduction

Access network is a part of communication network which delivers various data from the central office (CO) to manifold end-users. The hierarchical organization of the modern communication

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network comprises from many levels (Shaw, 2009): local area networks (LANs), access networks, metropolitan area networks (MANs), and wide area networks (WANs). Access networks connect computers and communication equipment of a private organization to a public telecommunication network, bridging end-users to service providers via twisted-pairs, coaxial cables, optical fiber or wireless links. The typical range covered by an access network ranges anywhere from hundreds of meters up to 20 km. The next generation (NG) access networks are mostly proposed to provide users with up to approximately 10 Gb/s bandwidth (Kazovsky et al., 2012; Spiekman, 2013).

The bandwidth requirements with broadband services are increasing dramatically at the end-users of today's access networks. Optical and wireless access networks have emerged to address two issues: (1) channel capacity sharing fairly to the customers, and (2) adequate capacity assignment according to service requirements. For broadband access services, there is strong competition among several technologies, such as optical access technologies and wireless access technologies. A passive optical network (PON) can support a maximum data rate up to 100 Gb/s by using the orthogonal frequency division multiplexing (OFDM) technique in the optical access network (Cvijetic et al., 2010). In the wireless access network, worldwide interoperability for microwave access (WiMAX) IEEE 802.16m provides a data rate of 1 Gb/s for fixed users and 100 mb/s for mobile users (Yu, 2011). The NG wireless fidelity (WiFi), IEEE 802.11ac also can provide high data rate up to 1.3 Gb/s between an access point (AP) and a wireless end-user (WEU) Garber (2012). Data rates up to 6.933 Gb/s are possible theoretically by using maximum number of spatial streams of eight (Van Nee, 2011). The NG WiFi has fast throughput, high capacity, and broad coverage (PLC, 2012).

The optical fiber access network provides high-bandwidth digital services and long-distance communication, but known to be less ubiquitous. The wireless access network provides flexible and ubiquitous communication with a low deployment cost. However, its deployment scalability is limited by the spectrum and range limitations (Ghazisaidi and Maier, 2011; Kazovsky et al., 2012; Shaddad et al., 2011c). The hybrid wireless optical broadband access network (WOBAN) is a powerful combination of optical backhaul and wireless front-end. This integrated architecture contributes to a good scalability, cost effective, and flexible communication system.

The remaining paper is organized as follows: Section 2 reviews the enabling access technologies for optical network. The enabling wireless access technologies are surveyed in Section 3. The hybrid WOBAN access technologies are reported in Section 4. Survivability of the WOBAN is reviewed in Section 5. Finally, Section 6 concludes the paper and views the future work.

2. Enabling optical access technologies

Optical access networks have evolved to achieve high capacity, and good scalability in terms of link range and number of users (Ghazisaidi et al., 2011). PONs offer favourable optical access networks for significantly enhancing the bandwidth of access networks. The existing PON architectures provide much higher bandwidth for data application, but it has limited availability to end-users (Kazovsky et al., 2007). General architecture of PON is shown in Fig. 1. A PON basically comprises an optical line terminal (OLT) at the CO, an optical fiber, an optical distribution node (ODD), and multiple optical network units (ONUs) close to users premises. The OLT assigns the downlink wavelength λ_d, modulates the downstream data on this wavelength, and then propagates it into the optical fiber. The ODD (or remote node (RN)) demultiplexes the downstream optical signal which is received from the optical fiber to multiple ONUs and also multiplexes the upstream traffic from the ONUs to the optical fiber (Lee et al., 2006). The ONUs receive the downstream traffic from the RN and generate the upstream traffic to the optical link on the uplink wavelength λ_u. There are four main schemes of PONs which can be categorized according to the techniques used, time division multiplexing (TDM), wavelength division multiplexing (WDM), code division multiplexing access (CDMA), and OFDM. The main differences between these four approaches are the technique used and the type of optical signal distribution at the ODD location. Among them, the TDM PON, WDM PON, and OFDM PON are considered to be the most favourable candidates for widespread use in the optical access networks (Bock et al., 2005; Davey et al., 2006; Armstrong, 2009).

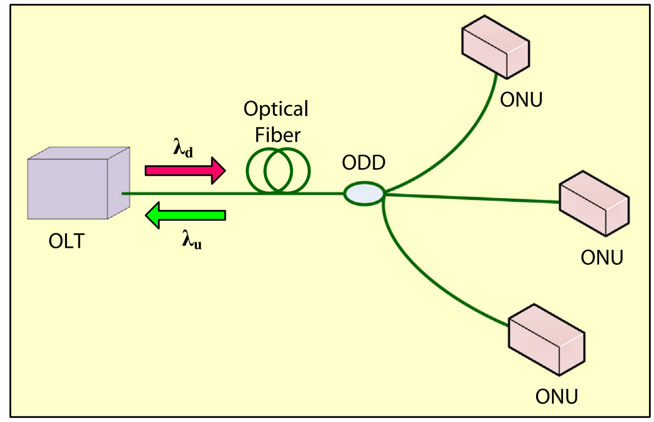

Fig. 1. General architecture of PON.

2.1. TDM PON

The most recent PONs have been proposed as point-to-multipoint (P2MP) optical networks which are implemented by TDM PONs (Sarkar et al., 2007). TDM PON exhibits simple and cost-effective PON (Choi et al., 2007). Since the TDM PON uses the passive optical power splitter at the RN, the number of ONUs is limited to 32, 64, or 128. The supported bandwidth for each ONU is also not guaranteed for broadband services completely such as high definition video (Lee et al., 2009). The architecture of TDM PON is shown in Fig. 2. In the TDM PON, one downlink wavelength (λ_d) is used to transport the downstream data from OLT to ONUs, and another uplink wavelength (λ_u) transports the upstream data from ONUs to OLT. The OLT dedicates time slots to N subscribers (ONU_1, ONU_2, …,ONU_N) which are connected to the TDM PON. A $1 \times N$ passive optical power splitter/combiner (PS/C) is used at the RN to distribute the optical signal to/from manifold ONUs. For bidirectional TDM PON, optical circulators are used to separate the upstream and downstream signals at the central office and the ONUs. The downstream data is broadcast to all the connected ONUs. Each ONU selects the stream slot allocated to it and throws away the slots directed to other ONUs. The TDM PON usually uses burst-mode transmission nature in the upstream direction, so the OLT assigns the time slots of the ONU upstream (Qiu et al., 2006).

There are three versions of the standardized TDM PONs: Ethernet PON (EPON), broadband PON (BPON), and Gigabit PON (GPON). The optical power is split among the subscribers, and the customers have to access the information in a given time slot. One important distinction between the three types of TDM-PON is the available data rate. The BPON provides relatively low data rate of 622/155 mb/s downstream/upstream. The EPON supports 1.0 Gb/s symmetrical operation, while the GPON provides 2.5/1.25 Gb/s