Indonesian Journal of Electrical Engineering and Computer Science
Vol. 3, No. 1, July 2016, pp. 151 ~ 156
DOI: 10.11591/ijeecs.v3.i1.pp151-156

Survey Smoothly Fiber-Wireless (FiWi) Accessing Wireless Networks: Convergence and Challenges

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Abstract

Traditionally, wireless networks and optical fiber Networks are independent of each other. Wireless networks are designed to meet specific service requirements, while dealing with weak physical transmission, and maximize system resources to ensure cost effectiveness and satisfaction for the end user. In optical fiber networks, on the other hand, search efforts instead concentrated on simple low-cost, future-proofness against inheritance and high services and applications through optical transparency. The ultimate goal of providing access to information when needed, was considered significantly. Whatever form it is required, not only increases the requirement sees technology convergence of wireless and optical networks but also played an important role in future communication networks. Some technical development of wireless access networks-optical and seamless coexistence of both techniques, this paper is a review of the State of the latest developments and advances in optical and wireless communications, major technical challenges to provide flawless communication in fiber- wireless (FiWi) access networks, places of interest important research issues to provide intelligence information, access and transport and the convergence of these networks in the future.

Keywords: *wireless network, optical fiber, ONU, PON, FTTH*

1. Introduction

Today’s contemporary society has benefited from the developments in information and communication technology (ICT) in diverse ways. Organizations and individuals rely on a mixture of communications means to carry out different tasks of our daily life, run businesses, access and transport information, get pursuit, and provide public safety, just to name a few. Thanks to the development of wireless and optical communications, we live in an ICT world where new expressive and interactive opportunities are better adapted to our needs, objects and physical environments produce new forms of interface, and the media are getting richer [1, 2].

To achieve future goals in the communications industry, advanced broadband access technologies need to offer a mix of traditional services such as voice, data, and video, as well as new and emerging applications, e.g., triple play, video on demand, P2P audio/video file sharing and streaming, multichannel HDTV, mobile TV, telemedicine, multimedia/multiparty on-line gaming, and telecommuting. Indeed, there is aincreasingaspiration for being connected to any device, anytime, and anywhere, which is causing an increasing demand for gaining access to the radio spectrum. However, the variety resources being limited, to enable bandwidth-hungry services and applications, future broadband access networks need to combine optical and wireless access technologies in an effective way so as to benefit from their strengths, avoid their shortcomings, and deliver the best of both worlds to the mobile users [3, 4].

In this this paper presents a vision towards the evolution of wireless-optical access networks. Specifically, following a concise review of state-of-the-art developments in wireless and optical communications, the need for the junction of both domains is emphasized, and several technical challenges involved are presented for the so-called future fiber-wireless (FiWi) access networks.

Received February 2, 2016; Revised May 25, 2016; Accepted June 10, 2016

FiWi access networks may deploy both Radio-over-Fiber (RoF) and Radio-and-Fiber (R&F). By simultaneously providing wired and wireless services over the same infrastructure, FiWi access networks are able to consolidate optical and wireless access networks that are usually run independently of each other, thus potentially leading to major cost savings [5]. FiWi networking research deals with the optical wireless integration (OWI) of optical and wireless broadband access technologies, for example, wireless mesh network (WMN). FiWi research focuses on the physical (PHY), MAC, and network layers with the goal to develop and investigate low-cost enabling FiWi technologies as well as layer-2 and layer-3 protocols and algorithms. Higher-layer network capabilities developed through fixed mobile convergence (FMC) standardization efforts can be exploited on top of the PHY, MAC, and network layers of FiWi networks. FiWi research inquires new methods of optical RF generation exploiting fiber nonlinearities and various modulation techniques [6-7].

2. FiWi Access Networks

Most prior FiWi access network studies well thoughtout a cascaded structural intend consisting of a single-stage passive optical network (PON) and a multihop WMN, the PON is a conservative IEEE 802.3ah subservient wavelength-broad casting TDM EPON based on a wavelength splitter/combiner at the remote node (RN), using one time-shared wavelength channel for upstream (ONUs to OLT) transmissions and another time-shared wavelength channel for downstream (OLT to ONUs) transmissions, both operating at a data rateof 1Gb/s [1, 2]. A subset of ONUs may be located at the premises of suburban or business subscribers, whereby each ONU provides fiber-to-the-home/business (FTTH/B) services to a single or multiple attached wired subscribers. Some ONUs has a mesh portal point (MPP) to border with the WMN. The WMN consists of mesh access points (MAPs) that provide wireless FiWi network access to stations (STAs). Mesh points (MPs) relay the traffic between MPPs and MAPs through wireless transmissions (see Figure 1). Most previous FiWi studies unspecified a WMN based on IEEE 802.11a/b/g WLAN technologies, offering a maximum raw data rate of 54 Mb/s at the physical layer [8].

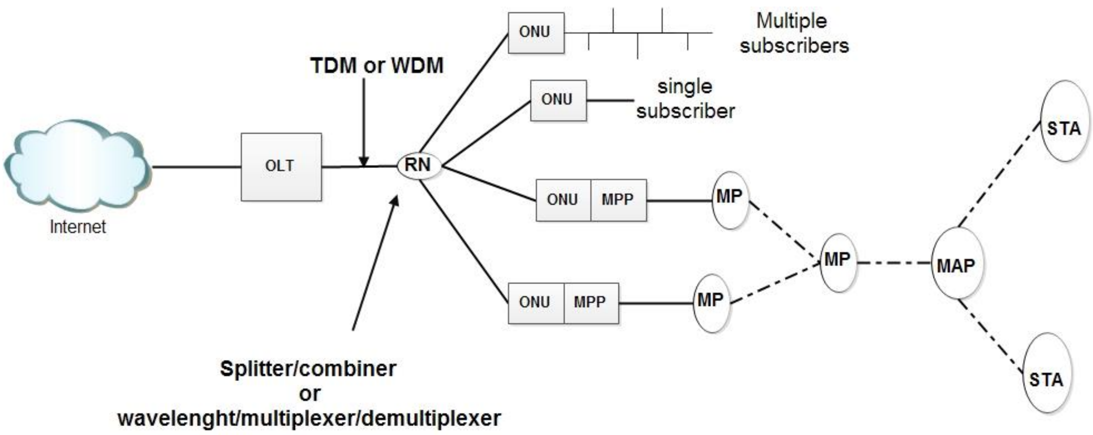

Figure 1. Typical FiWi Access Network Architecture

Future FiWi access networks will leverage next-generation PON and WLAN technologies to meet the ever-increasing bandwidth necessities. A variety of next-generation PON technologies are presently investigated to enable short-term evolutionary and long-term revolutionary upgrades of coexistent Gigabit-class TDM PONs [9]. Hopeful solutions for PON development toward higher bandwidth per user are: 1) data rate upgrades to 10 Gb/s and higher and 2) multiwavelength channel movement toward wavelength-routing or wavelength-broadcasting WDM PONs with or without cascaded TDM PONs [9, 10]. Similarly, to moderate the bandwidth traffic jam of the wireless mesh front end, future FiWi networks are probable to be based on next-generation IEEE 802.11n WLANs, which offer data rates of 100 Mb/s or higher at the MAC tune-up access point, as well as promising IEEE 802.11ac VHT WLAN technologies that accomplish raw data rates up to 6900 Mb/s.

3. FiWi Acess Network Convergence

Optical fiber supplies an exceptional bandwidth potential that is far in overload of the wireless and any other recognized transmission medium. A single strand of fiber offers a total bandwidth of 25000 GHz. To put this possible into perspective, it is worthwhile noting that the total bandwidth of radio on the planet Earth is not more than 25 GHz [4]. More significantly, optical networks lend themselves well to offloading electronic equipments by means of optical bypassing as well as reducing their complexity, footprint, and power burning upconsiderably while providing optical transparency to modulation format, bit rate, and protocol.

According to [5], fiber to the home (FTTH) or close to it (FTTX) is poised to become the next major success story for optical fiber communications in terms of profitableapproval leading to revenue generation. Future FTTX access networks not only have to unleash the economic potential and societal benefit by opening up the first/last mile bandwidth bottleneck between bandwidth-hungry end users and high-speed backbone networks, but they also must enable the support of a wide range of new and emerging services and applications. Due their longevity, low attenuation, and huge bandwidth, passive optical networks (PONs) are widely deployed to realize FTTX access networks. Typically, these PONs are time separation multiplexing (TDM) single-channel systems, where the fiber infrastructure carries a single upstream wavelength channel (from subscribers to central office) and a single downstream wavelength channel (from central office to subscribers) as shown in Figure 2 below.

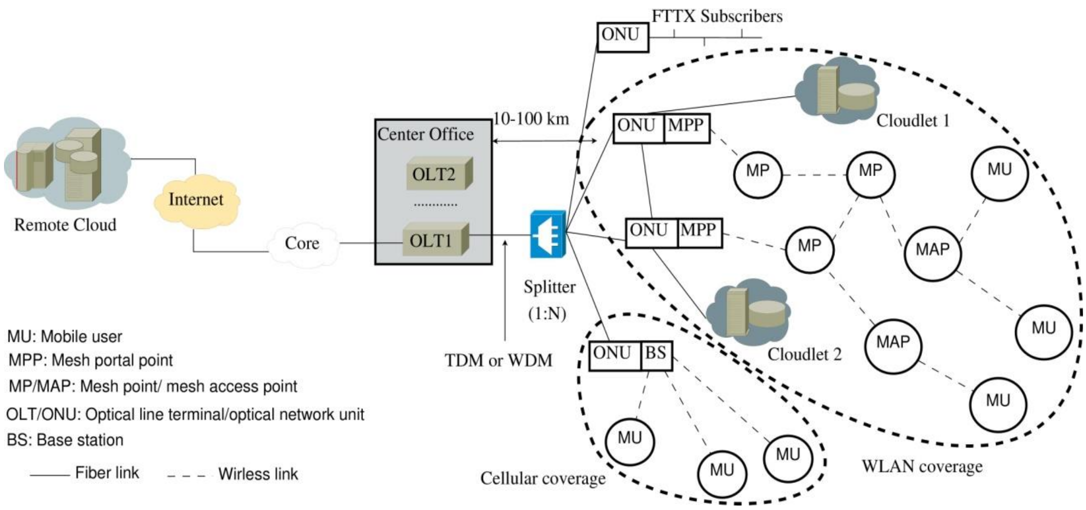

Figure 2. FiWi Access Network Convergence

IEEE 802.3ah Ethernet PON (EPON) with a symmetric line rate of 1.25 Gb/s and ITU-T G.984 Gigabit PON (GPON) with an upstream line rate of 1.244 Gb/s and a downstream line rate of 2.488 Gb/s represent the current state-of-the-art of commercially available and widely deployed TDM PON access networks, but standardization efforts have already been initiated in the IEEE 802.3av task force to specify 10 Gb/s EPON. GPON offers strong operation, administration, maintenance, and provisioning (OAMP) capabilities and provides security at the protocol level for downstream traffic by means of encryption using the advanced encryption standard (AES). Furthermore, GPON efficiently supports traffic mixes consisting not only of ATM cells but also TDM (voice) and unevensize packets by using the GPON encapsulation method (GEM). EPON aims at converging the low-cost equipment and simplicity of Ethernet and the low-cost infrastructure of PONs. Security and OAMP are not specified in the EPON standard IEEE 802.3ah, but may be implemented using the data over cable service interface specification (DOCSIS) OAMP service layer on top of the MAC and PHY layers of EPON. Given the fact that 95% of LANs use Ethernet in coincidence with Ethernet’s low cost and simplicity, EPON is expected to become increasingly the norm [6]. Both GPON and EPON are commonly perceived to carry a single wavelength channel in each direction. The majority of real-world PON deployments, however, use an additional downstream wavelength channel for video allocation according to the wavelength allocation specified in the ITU-T G.983.3 recommendation which specifies a so-called enhancement band from 1539 nm to 1565 nm plus L-band reserved for future use. The augmentation band and L-band can be used to enable additional services such as overlay of multiple PONs on a single fiber infrastructure or optical time domain reflectometry (OTDR) for testing and troubleshooting.

Adding the wavelength dimension to conventional TDM PONs leads to wavelength division multiplexing (WDM) PONs which has several advantages. Among others, the wavelength aspect may be exploited to (i) increase the network capacity, (ii) improve the network scalability by accommodating more end users, (iii) disconnect services, or (iv) separate service providers [6]. An interesting approach to increase split ratio, i.e., number of subscribers, and range is the so-called SuperPON. The latter is an architectural concept to realize long-reach PONs which is currently being paid considerable attention by network operators in an attempt to optically bypass central offices and consolidate metro and access networks, resulting in major cost savings and simplified network operation [7]. Long-reach PONs can be interesting for new entrant operators who wish to connect only the major geographically distributed business clients. Most of the reported studies on advanced PON architectures considered stand-alone PON access networks, with a particular focus on the design of energetic bandwidth allocation (DBA) algorithms for QoS support and QoS protection by means of admission control [8]. Research on the (optically) opaque and transparent interconnection of numerous WDM PONs has begun recently, e.g. Stanford University access network (SUCCESS) and STARGATE [9].

4. FiWi Access Network Challenges

To incorporate the two worlds, significant challenges, at the basic and technological levels, will be at the front position of research in FiWi access networks for many years to come. Central to such research endeavor is achieving end-to-end performance, providing flexibility, scalability and resilience, and reducing implementation complexity and costs. First, it will be crucial to have mechanisms in place to control system load, which will translate into higher capacity, greater mobility, instant access to information and omnipresent computing. However, because of the physical distinctiveness of the different RATs of wireless systems and the unevenness of users’ requirements, the data rate of ongoing wireless connections will also vary, complicating the supply management/sharing in FiWi access networks. This raises technical issues such the required protocol interfaces between the resource management entities of these tightly coupled networks, and calls for the design of very flexible and effective protocols to allow enhanced routing and link adaptation that make the best procedure of the accessible resources while dynamically accommodating the users’ traffic properties and QoS requirements [11-12].

Resource management issues in FiWi networks are wide and deep. Indeed, it is not only essential to develop techniques for QoS control, mobility handling, and load balancing, but also transmission strategies that facilitate P2P communication for user-created content. In addition, establishing policies on how to use and reconfigure the available resources when multiple service providers delivering different types of services can share the same optical fiber is required. In this context, secure data management, bringing together and private exchange of user profile and context information are of fastidioussignificance. New techniques for bond setup and admission control are also needed. Call permission at the wireless side needs to be in synchronization with the optical network activity. Routers can set up a connection, but the question on how they can do so without having to reconverge every time needs deep investigation. Open questions also arise in Radio-over-fiber (RoF) for supple architectures. For instance, how to use RoF for the millimeter-wave (MMW) band and higher spectra, especially for indoor broadband communications, remains an open question. For efficient radio access, extensive research is required in the PHY layer domain. Indeed, due to the atmospheric absorption, the propagation loss at of high frequency bands, such as the MMV band, is quite high, which limits the free-space transmission distance of carriers at acceptable radiation power.

In this context, investigating the impact of new frequency bands on the radio transmission is essential for the development of coding techniques suitable for high bit-rate wireless links. Furthermore, bringing together being an issue at high frequencies, extremely tight synchronization over the optical backhaul will be required. Near to the ground-cost effective techniques for optical adaptation are required to realize operational FiWi systems. Efficient technologies for converting the RF or IF signals into optical signals, and also professional and cost-effectively feasible modulation formats to convert optical signals into wireless will be needed.

Challenges also concern the antenna design. In particular, designs that evadeobstruction with other wireless systems in the environment, especially for indoor broadband communications, are needed. Combination of optical and wireless also necessitates the development of network technologies and architectures that allow affordable availability of broadband FiWi access. Network management, new protocols, inter-domain routing and traffic engineering for end-to-end delivery of traditional and new added-value services, with QoS, resilience, and security, are needed.

In addition, FiWi networks need to be adaptive so as to cope with traffic variations and new traffic patterns. Refined load balancing and reconfiguration techniques to provide adaptive backhaul and shift the fiber capacity from one node to the other as traffic changes, are essential. Clearly, an in-depth study of reconfigurable optical network units (ONUs) is needed to shed some light on the performance-cost tradeoffs of reconfigurable optical access networks. Traffic modeling in this context is of major significance, and calls for the development of models reflecting empirical traffic evolution to converge high facility fiber networks with lower capacity wireless networks. Network planning also induces new challenges. Questions stay on how to build networks that can sustain unknown traffic patterns, and how to effortlesslyconnect optical backhaul with various wireless RATs. Transducers for the different wireless standards will need to be not only efficient but also cost-efficient [11-12].

In FiWi networks, services will vary in terms of QoS and bandwidth prerequisites. Accordingly, there is a need to investigate the impact and requirements of real-time applications (e.g., IPTV, mobile TV) on FiWi architecture, and to develop techniques for end-to-end resource allocation. Herein, a problem arises on how intellectual the optical network needs to be. Aptitude is certainly required but the optical network needs to be less sensitive to technology changes (e.g., tighter spectrum), and functional for 10 Gb/s to100 Gb/s and beyond without having to change the infrastructure. Another fascinating research avenue is the design of incorporated failure healing techniques that allow rerouting traffic via wireless networks in the event of one or more fiber cuts in the optical access networks. Indeed, given the fact that today's optical entrée networks typically have a tree topology; a single link failure in the optical feeder fiber would bring the entire optical access network down, unless traffic is rerouted wirelessly.

At the business plane, FiWi access networks bring new issues as well. For instance, new business models allowing an efficient and economically beneficial sharing of the fiber capacity between different NOs are needed. In addition, new billing techniques will be required, as it is not easy to integrate the user's consumption of the fiber and wireless portions of the network into a single bill. Finally, it is significant to bring up the need for advanced mechanism that are also cost-effective so that to provide for an economically affordable operation and maintenance of FiWi networks.

4. Conclusion

The most important problem in FiWi access networks is how to join together the wireless and optical technologies. The boundary between both worlds will be yielding, and as the commercial dimensions increases, the cost of mechanism will be driven down, thus mounting the extensive and accomplishment for realistic and economically reasonable deployment and operation of future FiWi access networks is an urgent necessity. This work highlights key enabling optical as well as wireless technologies and explains their role in emerging FiWi networks. After briefly reviewing previous art, important challenges and imperatives for the design of future FiWi network architectures, protocols, and algorithms are identified and discussed.

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