International Journal of New Technology and Research (IJNTR)
ISSN: 2454-4116, Volume-1, Issue-1, June 2015 Pages 19-22

Analysis of Future Fiber-Wireless (FiWi) Networks- EPON & WiMAX

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Abstract— **Hybrid Fiber-Wireless (FiWi) networks become rapidly mature and represent a promising candidate for reducing power consumption, costs, and bandwidth bottlenecks of next-generation broadband access networks. Two key FiWi technologies with similar design goals are Ethernet Passive Optical Network (EPON) and WiMAX. Fiber-Wireless (FiWi) broadband access network is a promising ''last mile'' access technology, because it integrates wireless and optical access technologies in terms of their respective merits, such as high capacity and stable transmission from optical access technology, and easy deployment and flexibility from wireless access technology. Since FiWi is expected to carry a large amount of traffic, numerous traffic flows may be interrupted by the failure of network components. In this paper, we discuss the FiWi technology for future internet.**

Index Terms— **EPON, FiWi, Power , Consumption, WiMAX.**

I. Introduction

Fiber-to-the-x (FTTx) networks bring fiber close or all the way to the end user, whereby x denotes the discontinuity between optical fiber and some other, either wired or wireless, transmission medium. For instance, hybrid optical fiber-twisted copper pair architectures are widely deployed by telephone companies in today's Digital Subscriber Line (DSL) based broadband access networks. However, recent studies indicate that in terms of power consumption and economic sustainability there is a clear advantage of replacing legacy copper infrastructure with optical fiber, giving rise to ''green" all-optical access networks [1]. The emergence of quad-play services (voice, video, data, and mobility) leads to a stronger integration of optical and wireless access networks. The resultant bimodal Fiber-Wireless (FiWi) access networks aim at providing wired and wireless services over the same infrastructure simultaneously, thus potentially leading to major cost savings. FiWi networks hold great promise to mitigate the digital divide and change the way we live and work by replacing commuting with teleworking [2]. Recently, various FiWi network architectures have been investigated by integrating different optical and wireless technologies [3]. Stanford University's multi-tier opticalwireless network architecture proposed in [4] might be viewed as a state-of-the-art FiWi network which allows for the gradual capacity upgrade of the wireless backhaul with optical point-to-point and/or Point-to-MultiPoint (PMP) Wavelength Division Multiplexing (WDM) fiber links. While introducing optical fiber at higher network layers, e.g., aggregation layer, helps alleviate emerging bandwidth bottlenecks, the last hop is expected to be wireless for ubiquity and convenience, e.g., low-cost WLAN and home mesh networks [5]. Between these two FiWi network hierarchy levels lies the ''sweet-spot" where optical technologies interface with their wireless counterparts. Two important sweet-spot technologies that play a key role in emerging FiWi networks are IEEE 802.3ah Ethernet Passive Optical Network (EPON) and IEEE 802.16 WiMAX. Clearly, EPON and WiMAX networks may be cascaded, as proposed in [6]. However, given the similarities of EPON and WiMAX (e.g., PMP topology with a central control station performing dynamic bandwidth allocation by means of centralized polling and scheduling) we argue that the two technologies are more likely to target the same network segment rather than being cascaded to cover different network segments. In other words, we expect that network operators will make a choice between EPON and WiMAX depending on a number of factors, e.g., right-ofway, and elaborate on the techno-economic comparison of the two technologies. During the last decade, the techno-economic evaluation of various network technologies has been an active research area. To meet the different requirements of emerging network services, a service migration cost analysis was presented in [7]. The cost modeling of the migration from best-effort access networks to multi-service Quality-of-Service (QoS) enabled access networks based on Ethernet and ATM was proposed in [8]. The obtained results show that deployment cost savings can be achieved by using Ethernet-based access network architectures. It is important to note that most of the previous techno-economic evaluations focused either on optical fiber only (e.g. [9,10]) or wireless only network architectures (e.g., [11]). Up to date, only a few preliminary techno-economic evaluations of FiWi networks have been reported. A cost comparison of VDSL and a FiWi architecture consisting of cascaded EPON and WiMAX networks was carried out in [12]. The obtained results indicate the superior cost-efficiency of FiWi networks over conventional VDSL solutions. In [13], a deployment cost comparison of wired (i.e., xDSL and cable modem), optical fiber, WiFi, and integrated EPON and WiMAX/WiFi network architectures was done. The reported results show that a hybrid FiWi network architecture (consisting of EPON and WiMAX) represents a costeffective solution for future broadband urban area networks. It is important to note that next-generation EPON and WiMAX network technologies were not considered in [13]. Different FiWi network design heuristics were investigated in terms of processing time, complexity, and installation cost in [14]. The optimum real-estate cost deployment of Optical Network Units (ONUs) in integrated FiWi networks was studied in [15,16]. Despite these preliminary studies, a more thorough techno-economic

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evaluation of FiWi networks is necessary in order to gain deeper insights into the design, configuration, and performance optimization of emerging FiWi networks that are based on EPON and/or WiMAX technologies. Moreover, recently, the IEEE standard 802.3av for 10 Gbit/s EPON was approved in September 2009 which supports both symmetric 10 Gbit/s downstream and upstream, and asymmetric 10 Gbit/s downstream and 1 Gbit/s upstream data rates to provide backward compatibility with the current 1 Gbit/s EPON. While the line coding for the current EPON is 8B/10B, the next-generation optical access network (i.e., IEEE 802.3av 10 Gbit/s EPON) uses the 64B/66B line coding which reduces the bit-tobaud overhead significantly [17]. The techno-economic analysis of emerging IEEE standards 802.3av 10 Gbit/s EPON and 802.16m 1 Gbit/s WiMAX networks is another attractive research study.

II.. EPON AND WiMAX TECHNOLOGIES

We briefly describe only the salient features of both technologies in the following.

EPON Typically, an EPON has a physical tree topology with the central office located at the root and the subscribers connected to the leaf nodes of the tree. An EPON connects the Optical Line Terminal (OLT) located at the central office to multiple ONUs (the customer premises equipment) through a 1:N optical splitter/combiner at the Remote Node (RN). Each ONU can serve a single or multiple residential and business subscribers. EPON uses one wavelength for upstream and another wavelength for downstream transmissions. Due to the directional property of the optical splitter/combiner, the OLT is able to broadcast data to all ONUs in the downstream direction (PMP). In the upstream direction, however, ONUs cannot communicate directly with one another. Instead, each ONU is able to send data only to the OLT (multipoint-to-point). Time Division Multiplexing (TDM) allows all ONUs to share either wavelength without channel collisions. To facilitate Dynamic Bandwidth Allocation (DBA) and arbitrate the upstream transmissions of multiple ONUs, the so-called MultiPoint Control Protocol (MPCP) specified in IEEE 802.3ah is deployed in EPON. In addition to auto-discovery and registration MPCP uses two types of polling messages (i.e., REPORT and GATE) to facilitate arbitration. Each REPORT message is used by an ONU to report bandwidth requirements of up to eight priority queues to the OLT. The GATE message is generated by the OLT and contains up to four transmission grants per ONU. Note that no specific DBA algorithm is specified in IEEE 802.3ah [20].

WiMAX The initial IEEE 802.16 WiMAX standard was established in the frequency band of 10–66 GHz, providing up to 75 Mbit/s Line-of-Sight (LOS) connections in both PMP and mesh modes. IEEE 802.16a provides non-LOS connections in the frequency band of 2–11 GHz (licensed and unlicensed). The WiMAX PHY layer supports different modulation schemes, e.g., WirelessMAN-OFDMA (Orthogonal Frequency Division Multiple Access), designed for various frequency bands. Additionally, the WiMAX PHY layer transfers bidirectional data by means of Time Division Duplex (TDD) or Frequency Division Duplex (FDD). IEEE 802.16 is a connection-oriented standard, i.e., prior to transmitting data between Subscriber Stations (SSs) and Base Station (BS), connections must be established. Each connection is identified by a 16-bit Connection Identifier (CID). The Medium Access Control (MAC) layer is responsible for assigning CIDs as well as allocating bandwidth to SSs. The scalability and flexibility of the radio access technology and network architecture of the IEEE standard 802.16e, also known as Mobile WiMAX, provide various services through broadband connections. Mobile WiMAX is able to support multimedia transmissions with differentiated QoS requirements through the use of scheduling processes. It is important to note that in WiMAX no specific scheduling algorithm is standardized; however, the following five scheduling services are defined in IEEE 802.16e: Unsolicited Grant Service (UGS), extended-real-time Polling Service (ertPS), real-time Polling Service (rtPS), nonreal-time Polling Service (nrtPS), and Best Effort (BE) [21].

Table 1 summarizes the technical features of EPON and WiMAX.

Table 1 Technical features of EPON and WiMAX.

Features	EPON	WiMAX
Standard	IEEE 802.3ah	IEEE 802.16
Topology	Point to multipoint/multipoint to point	Point to multipoint/multipoint to point Mesh mode
Bit rate	1.25 Gbit/s (symmetric)	100 Mbit/s (symmetric)
Data rate	1 Gbit/s (symmetric)	75 Mbit/s (symmetric)
Access scheme	Polling	Polling & reservation
Traffic classes	8 traffic classes	5 traffic classes
DBA	No specific DBA algorithm specified	No specific DBA algorithm specified
Encryption	Not specified	Data Encryption Standard (DES) & Advanced Encryption Standard (AES)
Scheduling	Two implementation methods: Option 1: Inter ONU and intra ONU scheduling by OLT Option 2: Inter ONU scheduling by OLT and intra ONU scheduling by ONU	Two implementation methods: Option 1: Inter SS and intra SS scheduling by BS Option 2: Inter SS scheduling by BS and intra SS scheduling by SS
Range & number of subscribers	32 ONUs at a maximum range of 20 km	Not specified

III.WIRELESS ACCESS NETWORK

As another promising access technology, wireless access network is gaining the notable popularity due to its flexibility and easy deployment There are three major technologies for wireless access network, including WiFi, WiMax and cellular technology. WiFi is mainly used in the local area network for the interconnection of User Ends (UEs). Generally, WiFi can be operated in both infrastructure and ad hoc modes. In the infrastructure mode, WiFi needs to employ an Access Point (AP) as a central infrastructure to manage the UEs within a limited coverage which is dependent on the transmission power level of AP. In the ad hoc mode, all the WiFi UEs have the ability of self-management, and they can communicate with each other directly in a multi-hop way. The existing WiFi standard such as IEEE 802.11 a/b/g/n can support the data rate of 54/11/54/300 Mb/s respectively in a range of 100 m. Compared to WiFi, WiMax (IEEE 802.16) employs Base Station (BS) as the central infrastructure, and it supports only the single- hop communication. However, due to the less-crowded spectrum, WiMax can provide larger bandwidth and longer transmission range. Typically, WiMax can support the data rate of up to 75 Mb/s in a range of 3–5 km. Thus, WiMax is mainly used for metropolitan-area network. Some research organizations have proposed that WiMax will be a promising alternative for the wired access technology such as DSL and CM to provide the ‘‘last mile’’ broadband access service for UEs. Cellular technology is widely used in the mobile communication systems, which deploy a BS in each cell to mainly support the voice and low-rate data applications. According to the 3rd Generation Partnership Project (3GPP) R5 and R6 specification, the High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA) technologies (jointly known as High-Speed Packet Access, HSPA) can provide the data rate of up to 5 Mb/s in upstream and up to 14 Mb/s in downstream, respectively. As the evolutionary solution of HSPA, the enhanced HSPA (i.e., HSPA+) technology are expected to support the data rate of up to 10 Mb/s in upstream and up to 40 Mb/ s in downstream, respectively. Furthermore, the 4th Generation (4G) mobile communication system, which has gained extensive attention, is estimated to provide the data rate of up to 20 Mb/s in upstream and up to 100 Mb/s in downstream, respectively. Compared to optical access technology, wireless access technology enables users to access Internet in a more flexible way and requires a lower deployment cost. However, the scarce spectrum severely limits its bandwidth capacity

IV. FIBER-WIRELESS BROADBAND ACCESS NETWORK

As an integration of optical and wireless access technologies, FiWi makes an excellent compromise between both access technologies by combining the large bandwidth capacity and high stability in optical world with the flexibility and low deployment cost in wireless world. Thus, FiWi enables users to enjoy the satisfactory broadband access service in an ‘‘anywhere–anytime’’ way .Generally, FiWi has the ‘‘tree-mesh’’ architecture. As shown in Fig. 1, it is a typical FiWi architecture composed of two segments, and each segment includes a Wireless Mesh Network (WMN) at the front-end and a PON (which has a tree topology) at the backend.

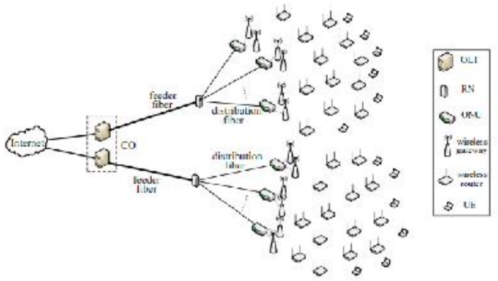

Fig. 1. A typical FiWi architecture (including two segments).

In each segment, each ONU can drive multiple wireless gateways by wired connection to act as the interface between the front-end and the back-end (however, there is another architecture where the wireless gateway functionality is integrated into ONU as ‘‘ONU/gateway’’ component, The UEs, most of which locate at the residential and business buildings, can connect to FiWi by using wireless devices. Specifically, the UEs first send their packets to a nearest wireless router. Then, these packets will be forwarded from this wireless router to a wireless gateway in the same segment by means of wireless multi-hop paths. Finally, these packets will go through the back-end PON and arrive at OLT, where they will be injected into Internet. In such way, FiWi enables UEs to access Internet with better flexibility and larger capacity. In the upstream, the front-end WMN is an anycast network where each UE can send its packets to any wireless gateway. For the back-end, if WDM-PON is used, it is a P2P network where each ONU can communicate with OLT by using a separate upstream wavelength channel; if TDM-PON is used, it is a P2MP network where all ONUs share the same upstream wavelength channel by means of TDM technology. In the downstream, if WDM-PON is employed as the back-end, OLT can send the packets to each ONU in a P2P way by assigning each ONU a separate downstream wavelength channel; if TDM-PON is employed as the back-end, OLT can broadcast the packets to all ONUs in a P2MP way by making all ONUs share the same downstream wavelength channel. In this case, each ONU decides to accept or reject the received packet by examining whether its destination address is matched. For the /front-end WMN, it is a unicast network where each packet from wireless gateway is destined to a specified wireless router. The advantages of FiWi over the other existing access technologies can be summarized as follows: (1) Compared to wireless access network, FiWi can provide larger bandwidth capacity and better stability by means of the back-end PON, so as to reduce traffic blocking rate and packet loss rate. (2) Compared to optical access network (i.e., PON), FiWi can provide wider coverage and more flexible access by means of the front-end WMN which also

makes FiWi have a shorter fiber reach and thus reduce the deployment cost .More importantly, the front-endWMN can not only self-heal from the failures but also enhance the survivability of the back-end PON, because its mesh topology can provide alternative routes. For example, once a distribution fiber in a segment fails, the traffic interrupted by this failure can be transferred to other available distribution fibers in the same segment by means of wireless multi-hop paths in the front-end WMN. Thus, FiWi is a promising solution for the next-generation broadband access network which aims at larger bandwidth capacity, better stability, lower deployment cost and more flexible access.

V. CHALLENGING ISSUES

we can briefly characterize the existing FiWi research on the survivability and energy- saving issues as follows.

1.The survivability and energy-saving in FiWi are two up-to-date issues, whose related works are conducted just recently. However, both issues have been gaining the increasing attention due to their significance in optimizing network performance. 2.The heterogeneity of FiWi architecture results in its variety of failures. The existing works on survivability in FiWi mainly aim at the protection of the back-end PON against optical component failure. However, the protection of the front-end WMN against wireless router failure is seldom mentioned. While the protection against radio interface failure and wireless link failure due to co-channel interference remains untouched.

3.Most of related works consider enhancing the survivability of the back-end PON by deploying backup resource such as backup fibers and backup ONUs. However, these works usually refer to an excessively redundant deployment of backup resource, thus they require huge cost of backup resource. Furthermore, these works extensively use ILP models as the optimization technique. Most existing works consider the front-end WMN to be singleradio-single-channel, while the multi-radio-multi-channel front-end is less mentioned. However, the multi-radio-multichannel front-end can provide FiWi with a higher connectivity that contributes to the survivability, thus it is necessary to investigate the survivability in FiWi with a multi-radio-multichannel front-end.

4. Most existing works on survivability aim to protect the wireless front-end and the optical back-end independently. However,the interactive design between survivable front-end and survivable back-end is seldom mentioned, which is an important issue for the global survivability of FiWi. Thus,

there is an urgent need to investigate the joint wireless-optical protection method.

5. FiWi is expected to support a variety of services. Thus, the survivability scheme designed for FiWi needs to consider the difference in service demand. For example, the high-level service such as delay-sensitive service usually requires a faster restoration of the interrupted traffic when failure occurs. Therefore, we are motivated to investigate the survivability scheme with differentiated protection for various services.

6.The failure probability varies among different network components due to their difference in the geographical location and internal structure. Thus, the working network resource usually has different reliability that is dependent on the failure probability of its associated network components. We do not have to reserve the backup network resource for the working network resource whose reliability satisfies the requirement.

VI. CONCLUSIONS

We discussed the basics of EPON and WiMAX which are key technologies in emerging FiWi broadband access networks. The power consumption of EPON is smaller than that of WiMAX. EPON is superior to WiMAX for deployment scenarios where network failures are less likely. WiMAX is more cost-efficient than EPON, especially in suburban and rural areas with a small population density.. In fact, EPON is able to provide data rates well above 75 Mbit/s since once put in place, EPON can be upgraded to much higher data rates by means of advanced TDM and/or WDM technologies (see, e.g., IEEE 802.3av 10 Gbit/s EPON Task Force) without requiring any modifications of the installed fiber infrastructure. In terms of power consumption, the difference between next-generation EPON and WiMAX becomes smaller than in current EPON and WiMAX networks. Moreover, next-generation EPON and WiMAX networks consume less power than current EPON and WiMAX networks per each Mbit data.

REFERENCES

[1] A. Gladisch, C. Lange, R. Leppla, Power efficiency of optical versus electronic access networks (Invited Paper), in: Proceedings of ECOC, Brussels, Belgium, September 2008.

[2] M. Maier, N. Ghazisaidi, M. Reisslein, The audacity of Fiber-Wireless (FiWi) networks (Invited Paper), in: Proceedings of ICST ACCESSNETS, Las Vegas, NV, USA, October 2008.

[3] N. Ghazisaidi, M. Maier, C.M. Assi, Fiber-Wireless (FiWi) access networks: a survey, IEEE Communications Magazine 47 (2) (2009) 160–167.

[4] W.-T. Shaw, S.-W. Wong, N. Cheng, K. Balasubramanian, X. Zhu, M. Maier, L.G. Kazovsky, Hybrid architecture and integrated routing in a scalable optical-wireless network, IEEE/OSA Journal of Lightwave Technology 25 (11) (2007) 3443–3451.

[5] T. He, S.-H.G. Chan, C.-F. Wong, Homemesh: a low-cost indoor wireless mesh for home networking, IEEE Communications Magazine 46 (12) (2008) 79–85.

[6] G. Shen, R.S. Tucker, C.-J. Chae, Fixed mobile convergence architectures for broadband access: integration of EPON and WiMAX, IEEE Communications Magazine 45 (8) (2007) 44–50.

[7] D. Shayani, C.M. Machuca, M. Jäger, A. Gladisch, Cost analysis of the service migration problem between communication platforms, in: Proceedings of IEEE Network Operations and Management Symposium (NOMS), Salvador, Brazil, April 2008.

[8] T. Monath, M. Kind, Techno-economics for multi-service fixed access networks, Netnomics 8 (1–2) (2007) 91–103.

[9] M.K. Weldon, F. Zane, The economics of fiber to the home revisited, Bell Lab Technical Journal 8 (1) (2003) 181–206.

[10] A.V. Tran, C.J. Chae, R.S. Tucker, Ethernet PON or WDM PON: a comparison of cost and reliability, in: Proceedings of IEEE TENCON, Melbourne, Australia, November 2005.

[11] D. Niyato, E. Hossain, Integration of WiMAX and WiFi: optimal pricing for bandwidth sharing, IEEE Communications Magazine 45 (5) (2007) 140–146.

[12] P. Lin, T. Wang, J. Hu, Y. Suemura, S. Nakamura, C. Qiao, Optical-towireless- integration cost modeling, in: Proceedings of HPSR, Brooklyn, NY, USA, June 2007.

[13] P. Chowdhury, S. Sarkar, A.A. Reaz, Comparative cost study of broadband access technologies, in: Proceedings of International Symposium on Advanced Networks and Telecommunication Systems (ANTS), Bombay, India, 2008.

[14] S. Sarkar, S. Dixit, B. Mukherjee, Hybrid wireless-optical broadbandaccess network (WOBAN): a review of relevant challenges, IEEE/OSA Journal of Lightwave Technology 25 (11) (2007) 3329–3340.

[15] S. Sarkar, B. Mukherjee, S. Dixit, Optimum placement of multiple optical network units (ONUs) in optical-wireless hybrid access networks, in: Proceedings of OFC/NFOEC, Anaheim, CA, USA, March 2006.

[16] S. Sarkar, H. Yen, S. Dixit, B. Mukherjee, A mixed integer programming model for optimum placement of base stations and optical network units in a hybrid wireless-optical broadband access network (WOBAN), in: Proceedings of IEEE WCNC, Kowloon, Hong Kong, March 2007

[17] K. Tanaka, A. Agata, Y. Horiuchi, IEEE 802.3av 10G-EPON standardization and its research and development status, Journal of Lightwave Technology 28 (4) (2010) 651–661.

[18] C.M. Machuca, Expenditures Study for Network Operators, in: Proceedings of International Conference on Transparent Optical Networks, Nottingham, United Kingdom, June 2006.

[19] S. Verbrugge, S. Pasqualini, F.-J. Westphal, M. Jäger, A. Iselt, A. Kirstädter, R. Chahine, D. Colle, M. Pickavet, P. Demeester, Modeling operational expenditures for telecom operators, in: Proceedings of Conference on Optical Network Design and Modeling, Milan, Italy, February 2005.

[20] M.P. McGarry, M. Reisslein, M. Maier, Ethernet passive optical network architectures and dynamic bandwidth allocation algorithms, IEEE Communications Surveys & Tutorials 10 (3) (2008) 46–60.

[21] M.S. Kuran, T. Tugcu, A survey on emerging broadband wireless access technologies, Computer Networks 51 (11) (2007) 3013–3046.

[22] J. Baliga, R. Ayre, W.V. Sorin, K. Hinton, R.S. Tucker, Energy consumption in access networks, in: Proceedings of OFC/NFOEC, San Diego, CA, USA, February 2008.

[23] N. Ghazisaidi, F. Paolucci, M. Maier, SuperMAN: optical-wireless integration of RPR and WiMAX, OSA Journal of Optical Networking 8 (3) (2009) 249–271.