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Cost Effective Broadband Access Network Using Wi-Fi over Passive Optical Network

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Abstract

Demand for broadband network is rapidly increasing the volume of data traffic from users. To meet this demand and provide customers with cost effective solutions, service providers concentrate mostly on the access network. Competition among the service providers leads to different broadband access technologies to serve customers with the best solution. Customers' demands for real time applications, as well as downloading of video and other applications require high bandwidth allocation with high data rate. Also Governments put a substantial influence in providing the cost effective solution to the different geographical location of country. As a result, service providers concentrate on minimizing the deployment cost for access equipment while maximizing the revenue from the service offerings. In this paper, we have proposed broadband access technology using Wi-Fi over Passive Optical Network(PON)to provide a cost effective solution considering geographical as well as economical conditions. Introducing smart antennas such as narrow-beamwidth and switched array antennas can substantially improve the coverage distance for Wi-Fi access. For areas where the distance among houses is large, we propose to deploy Wi-Fi access instead of laying fibers. The optimization model to determine the number of Wi-Fi access points and to minimize the total cost of the network has been tuned to performance improvement.

Keywords: *PON, Wi-Fi,VoIP, WiMAX, IPTV, OLT*

INTRODUCTION

The demand for broadband access has grown steadily as users experience the convenience of high-speed response combined with "always on" connectivity [2]. The use of real time applications such as Voice over IP (VoIP), video conferencing, online surgery etc. ask for higher bandwidth allocation. Also earning revenue is another challenge for the service providers by providing a range of services. Continuously they hassle the emergent necessity for quicker, cheaper, and more consistent consumption of broadband networks, forcing hardware manufacturers to respond by pursuing pioneering, radical solutions and driving down constituent convolution, setting up time, installation ability level required andeventually, the general cost of arranging the said networks in the ground. The recent remarkable raise in the fiber-to-the-home (FTTH) consumption rate, along with the universal aspiration to ultimately migrate completely to these systems, lays the passive optical network (PON) consumption issues in the focus of current intellectual and system retailer explore. Several periodicals [9–13] look at new skill expansions leading to the decline in the general costs essential for arranging FTTH networks at the moment, particularly in terms of the passive network formation (so-called fiber based) [14–16], setting up time, and necessary craftsman expertise level [3].

Purchasing the capital equipment is one of the most crucial decisions for any service provider. Issues that manipulate this assessment, apparatus expenditure and the ensuing revenue prospective are two of the most important concerns to be addressed. Service providers face this assessment when promoting the current access networks or mounting into new areas. They want to reduce the rate of arranging access apparatus while exploiting profits from the service offerings. Of these two constraints, the rate of arrangement is easier to conclude than profits prospective because future profit involves considerable assumption. As a result, the unrefined bandwidth capabilities of an access technology are often used as an alternate for profit prospective. In this way, the most vital conclusion a service provider makes when purchasing network equipment is how to beat a balance between reducing the apparatus rate and exploiting the bandwidth [1].

The Passive Optical Network (PON) is now one of the favorite access technologies chosen by the service providers at present. PON has several advantages over the other access methods such as cable and wireless. Here the physical access networks are wireless, copper and fiber, where wireless has the lowest operation rate because it has the lowest exterior plant overheads. WiMAX (802.16) and WiFi (802.11) are the standards for broadband and wireless accesses. WiMAX is a recently adopted IEEE standard that was designed for fixed and mobile access networks. It has a useful range of about 5 km at a data rate of 70 Mbps [1].

WiFi is more mature than WiMAX, but it has a range of only 100 m and a bit rate of 10–50 Mbps. In spite of this limitation, WiFi is more widely used for access today than WiMAX due to its maturity. While mutually WiFi and WiMAX are comparatively low cost to arrange, they lack enough bandwidth to support video applications. These wireless technologies use a point-to-multipoint construction, i.e., bandwidth is shared by multiple users. Accordingly, WiFi and WiMAX are practical for Web surfing applications, but impractical for higher-bandwidth and higher-revenue applications such as IPTV [1].

Recent research results show that smart antennas can play an important role in gaining higher bandwidth and coverage for WiFi access. As WiFi operates on an unlicensed band, it is cost effective to deploy with the adoption of smart antennas [4]**.** We will discuss this issue later in our proposed model.

Another access technology option available to service providers is copper — more specifically, digital subscriber line (DSL) over copper. Unlike wireless, DSL uses a point-to-point architecture. So instead of sharing 50 Mbps over all subscribers, DSL can provide 50 Mbps to each subscriber. Sorry to say that DSL shares a deficiency with wireless: it’s a noise-restricted access technology. Alternatively, the efficient bandwidth, DSL affords to a subscriber depends on the noise intensity, which depends on the length of the copper loop consecutively. DSL is able to afford 50 Mbps for loop lengths below 300 ft, but can only afford 10 Mbps at 10,000 ft. If operators desire to propose a convincing video service with 30 Mbps, they must shorten loop lengths around 3000 ft or less. It’s a practical approach, but the rate is a little lower than all fiber approaches [1].

The ultimate choice to consider for access equipment is fiber. An access network can be architected using either dedicated or shared fibers. A dedicated fiber plant, frequently referred to as a point-to-point network, provides a dedicated fiber strand between each subscriber and the central office (CO) [1].

In case of common fiber architecture, a single fiber from the CO serves numerous dozen subscribers. This fiber is carried to the adjacent where the signals are broken out onto separate fibers that run to the individual subscribers. Point-to-point fiber networks have a low market dispersion, mainly due to the additional rate it adds over a common fiber communications. Depending on the average loop length, the production overheads of outside plant based on dedicated fiber exceed those of outside plant based on common fiber.

For the common backbone structural design, there are two traditions for the signals are broken out. One is active Ethernet (AE), and the other is the PON. With AE the individual signals are divided using electronic equipment near the subscriber. For the PON, the signals are simulated inactively by the splitter. A common network based on a PON has a number of merits over one based on AE. The exterior plant of a PON acquires lower capital overheads as it has no electronic mechanisms in the field. The PON as well subordinates the operational overheads, since there is no requirement for the operators to afford and supervise electrical power in the field or preserve backup batteries [1].

In this paper, we have proposed broadband access technology using Wi-Fi over Passive Optical Network (PON). The proposed access technology provides a cost effective solution considering geographical as well as economical conditions. Introducing smart antennas such as narrow-beam width and switched-array antennas can substantially improve the coverage distance for Wi-Fi access. For areas where the distance among houses is large, we propose to deploy Wi-Fi access instead of laying fibers. The optimization model to determine the number of Wi-Fi access points and to minimize the total cost of the network has been tuned to performance improvement.

Background Work

Previously the Internet access for residential users was almost exclusively made via the public switched telephone networks (PSTN) over the twisted copper pair [1]. The latest service necessities involve high speed broadband access and led to the expansion of several last-mile solutions (xDSL, HFC, FTTx, PLC, FWA, Satellite…) able to support the services that Internet has to offer [17]. Lots of research work is going on to optimize the cost for broadband access networks.

Usually, broadband access technologies can be categorized by the physical standard in two major groups:

Wired (or fixed line) technologies: The fixed lines solutions correspond via a substantial network that provides a direct “wired” connection from the consumer to the service provider. Some authors divide the wired technologies in Copper-based and fiber-based.

Wireless technologies: Wireless solutions use radio or microwave frequencies to provide a connection between the customer and the operator’s network. Wireless access technologies can be generally classified into three categories [18]: fixed terrestrial(fixed wireless access - FWA), mobile terrestrial(mobile wireless access - MWA), and satellite(nomadic wireless access- NWA). The permanent global wireless access is a wireless technology to replace the use of copper or coaxial cables in the local loop. The variety of access technology depends on different variables like demography and geography. Other important variables are [19]: Number of subscribers; Clients distribution and service area; Current infrastructures; Network architecture (Wire line, Wireless or hybrid); Services to support (like voice, data and video) and associated bit rate; Geographic characteristics; Infrastructure rates; Labor rate; Operation rates; and Access rates [5].

We can define the techno-economic framework as follows [20]:

- ✓ Region: layout and current network infrastructure.
- ✓ Service definitions for each user segment with agreement rates and tariffs.

- ✓ Network dimensioning rules and cost trends of appropriate network equipment.
- ✓ Cost models for investments (CAPEX) and operation cost (OPEX).
- ✓ Discounted cash flow model.
- ✓ Output metrics to be calculated.

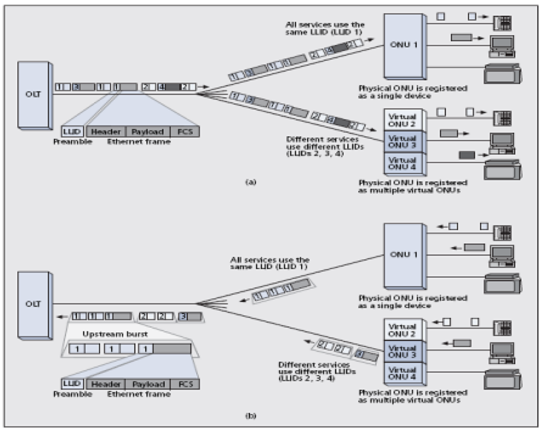

Fig 1. *EPON a) downstream operation, b) upstream operation*

There has been several research works going on the cost effective deployment of PON. Yu-Li Hsueh et al. proposed and demonstrated a new hybrid TDM/WDM PON architecture that jointly serves multiple physical PONs to enjoy statistical multiplexing gain as well as cost sharing[6]. The approach employed dynamic wavelength allocation to share bandwidth among subscribers in both wavelength and time domains.

Tsutomu Tatsuma et al. in another approach proposed a design and performance of a GE-PON system for mass deployment of broadband network. The paper claimed that GE-PON could satisfy the high demand for broadband access in a cost effective fashion [7]. The research proved that GE-PON is possible to be developed. Considering these, in the commercial arena while deploying large number of FTTH lines, the providers usually prefer Ethernet PON [17] over Gigabit PON [18] [3].

In another approach G. Shen et al. proposed a cost minimization planning for PONs [8]. They expanded a more scalable optimization approach for PON network consumption in the research, which was able to minimize the total PON consumption rate for the designs with hundreds of PONs. The research showed that the proposed idea could map more cost-effective PON networks than a standard sectoring approach. Additionally, it is found that there is a saturating progress of the impact of visual split ratio on the PON utilization rate. At whatever time the optical split ratio reaches a certain threshold level, a further raise of the ratio will not help much to decrease PON consumption rates. The paper claimed that the proposed model can reduce the deployment cost up to 50%.

Problem Definition and Our Approach

Considering our background research on PON deployment it is evident that the latest approach [8] has modeled the most cost effective solution. Although we have determined several key issues to consider while deploying the approach. As mentioned in [8], the deployment cost is made up of several sub-costs including (i) the hardware cost of PON, such as Optical Line Terminals (OLT) and optical splitters, (ii) the labor cost for laying fibers, and (iii) the cost of fibers. Here, cost of laying fibers is one of the key costs. Also for the optimization process the paper considers limitation on optical split ratio of PON with the maximal coverage of PON and the maximal differential distance of a PON. With over split ratio of 1:16 the approach remains the same as deducing the operational cost. Hence for complex architecture with larger number of ONUs, the cost could not be minimized at a great rate. As a result, we propose to combine the adoption of WiFi with the PON architecture.

Here we consider EPON as it is the vastly deployed technology by the service providers. Figure 1 illustrates the upstream and downstream operation for the EPON technology. We propose to minimize the number of ONUs by deploying WiFi at the customer end using smart antennas for last mile access. Several approaches can be offered:

1. It may be considered to provide the Access Points (AP) with high-gain antennas to expand the coverage range, even as still limiting the maximum effective isotropic radiated power (EIRP) for each AP to that approved by FCC conventions. We may use a 12 dBi antenna with each AP. Assuming outdoor line-of-sight propagation, the average AP range is almost 750 m @ 11 Mbps and about 1900 m @ 1 Mbps [2].
2. Via newly introduced phased array antenna technology combined with beam switching may also be considered to boost the range and capacity of an AP. The *packet beam* or Packet Steering™ is being introduced for WiFi networks by different vendors like Vivato and shows guarantee in exterior and interior applications equipped with these switched array antennas have a utmost outdoor line-of-sight broadcast range of up to 4.2 km at 11 Mbps and 7.2 km at 1 Mbps. Every switched array antenna covers up to 100° in the horizontal plane, and up to three parallel WiFi beams afford connections on a packet-by-packet basis with a utmost feedback per channel of 11 Mbps. Thus, both enlarged exposure and competence are reachable [2].

In the MILP_PON [21] optimization approach on RALA algorithm reduces the PON network deployment cost by 50-70% by shortening the distance of fiber from ONU. Now we propose to introduce another constraint to the optimization process as follows:

1. For the objective function, we add another term C_iP_i, where C_i is the Wi-Fi deployment cost for each AP including high gain antenna and P_i indicates the number of APs with antennas. For the implementation of switched array antennas, we can use the same approach.
2. In the constraints we add another constraint to determine if the cost of deploying Wi-Fi access for an area is greater than that of deploying fiber. And if so, we introduce Wi-Fi access instead of laying fiber and vice versa.

Also, we can reduce the OPEX if we could eliminate the cost of fiber at the customer premises. We can deploy WiFi although it has lower coverage. But if the distance between customers is not far then we can easily use WiFi on those crowded area such as city with more access points as we don't need spectrum licensing. Also using 802.11n band which is due to come late 2009 operates at a 5Ghz channel which can produce high bandwidth. Also adoption of high gain antennas and switched array antennas [2] can considerably increase the coverage area and speed. Also, if we have our backhaul access as PON we can considerably adopt the WiFi approach to rural areas where the distance between customers is reasonably high [2].

CONCLUSION

In this paper, we have discussed the approach of deploying Wi-Fi over PON for a cost effective broadband access solution. As a future challenge we consider to implement the MILP_PON [21] optimization process with the proposed improvement and compare the results.

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