A Comparative Economic Analysis of different FTTH Architectures

Kashif Azim Janjua, Shahzada Alamgir Khan
School of Economics and Management
Beijing University of Posts and Telecommunications, Beijing 100876, China
kajanjua@gmail.com

Abstract—**Bandwidth demand is rising sharply in the world. The ultimate solution is the substitution of copper with fiber in access networks. There are multiple architectures of implementing fiber and it is crucial to find one which is most cost effective. External factors like housing costs, area characteristics and labor cost play an important role in cost estimations. In this paper engineering cost method is employed to calculate the cost per subscriber of different architectures under different conditions. As sunk costs are very high so take rate (number of homes covered by the access network that subscribe to the service) plays a vital role. Feeder fiber length and maintenance costs are other important factors. The architectures utilizing the existing copper or cable distribution networks are most cost efficient but the ultimate solution will be fiber up to the home fulfilling all future bandwidth demands. The maintenance cost over the life is also lowest for all fiber networks. At present telecom companies are encouraged to employ fiber in their feeder networks.**

Keywords- FTTH architectures, engineering cost model, externalities

I. INTRODUCTION

Internet access speeds have risen greatly over the past decade. Multimedia intensive (converging video, voice and data) and peer to peer applications consume a large chunk of bandwidth from the internet [1]. This thirst for bandwidth will increase even further in the future [2]. As a result service providers are compelled to push fiber deeper into the access networks. Fiber-to-the-home (FTTH) architectures are considered as an ultimate solution for the future broadband access networks [3-5]. There have been several schemes proposed for the FTTH architectures such as Home Run fiber (HRF), Passive Optical Networks (PONs), Active Optical Networks (AONs), Fiber to the Curb (FTTC) also known as FTTC-DSL and Hybrid Fiber Co-ax (HFC).

The Home Run architecture has a dedicated fiber that is deployed all the way from Central Office (CO) to each subscriber. This architecture requires considerable more fiber and Optical Line terminal (OLT) ports compared to other shared architectures. All other architectures deploy some sort of remote terminal (RT) near the subscriber premises. This RT is connected to OLT via one feeder fiber per 32 subscribers in case of PONs whereas in all other architectures only one feeder fiber is used. The RT is equivalent to digital subscriber line access multiplexer (DSLAM) in FTTC, passive splitter in PONs, regenerator or multiplexer (MUX) in AONs and Optical Scalable node in HFC. The distribution network is fiber in PONs and AONs whereas copper cable in FTTC and co-axial cable in HFC. Customer premises equipment consists of Optical Network Unit (ONU) in home run fiber, PONs and AONs whereas it is DSL modem in FTTC and cable modem in HFC.

Despite the numerous benefits of fiber, telecom companies are moving slowly to fiber implementation due to high costs involved in infrastructure building. The goal of this paper is to construct an engineering cost model for all architectures of FTTH and find out which architecture is the most beneficial and cost efficient under given conditions.

The rest of this paper is organized as follows. Section II presents the basic Network layout on which we will implement all the architectures. Section III discusses the architecture of five schemes. Section IV provides engineering costs involved. Section V presents the analysis. Conclusions are given in section VI where as references are provided in the last section.

II. NETWORK LAYOUT

A model framework of connections, housings and equipment is considered for this study. We assume a telecom firm which is planning to provide services in a particular area. The telecom companies may have some copper or cable infrastructure prior to FTTH implementation but for symmetry we suppose that the company does not have any infrastructure prior to planning.

In our model, all links between OLT, RT and ONU are via single mode (SM) fiber. The distance between OLT and RT is taken as 10 km as it is the normal radius of a central office (CO). As all types of FTTH architectures are more suitable for the multi-tenant buildings, we have considered the provision of infrastructure to a building consisting of many floors. The RT is placed at the basement of the building while houses are located at each floor. There are m floors (m=8 in our case). Each floor has N rows (N=4) and each row has n

houses (n=8). The size of each house is 10 x 10 m. The model is shown in figure 1.

The Average fiber cable length between the RT and CPE is calculated using the following formula.

$$\text{Average cable length} = \frac{(n+1)(m+1)}{8} \times 10\,\text{m}$$

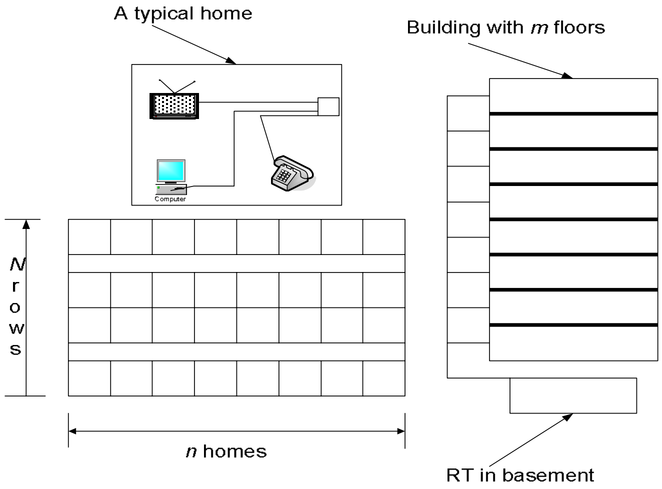

Figure 1: Network layout

III. NETWORK ARCHITECTURES

Different network architectures are compared in figure 2 to 6. These architectures will be used for economic model analysis. In home run fiber FTTH each 256 homes are served by separate fibers. The conventional PON architecture uses multiple splitters in RT and they are connected to the OLT using multiple feeder fibers. Each splitter serves 32 homes. Active Optical Network is similar to that of PON architecture, however uses an active device at the RT. This device can be regenerator, switch or multiplexer. Moreover, a higher split (1×256) splitter can be used. The other two architectures use fiber only in the feeder portion. FTTC uses DSLAM at RT for the aggregation of upstream signal from each subscriber where as distribution network consists of copper. HFC uses optical scalable nodes and mini nodes at RT. The distribution network is co-axial cable in this case. Moreover in these two architectures ONUs are not required.

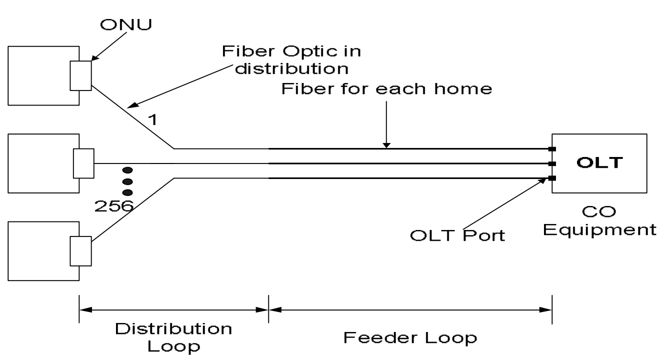

Figure 2: Home Run Fiber

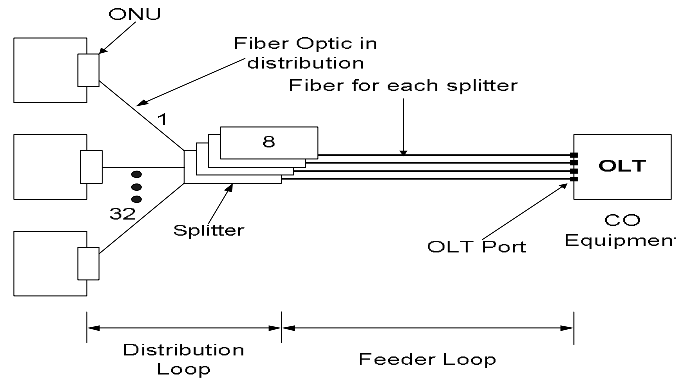

Figure 3: Passive Optical Networks

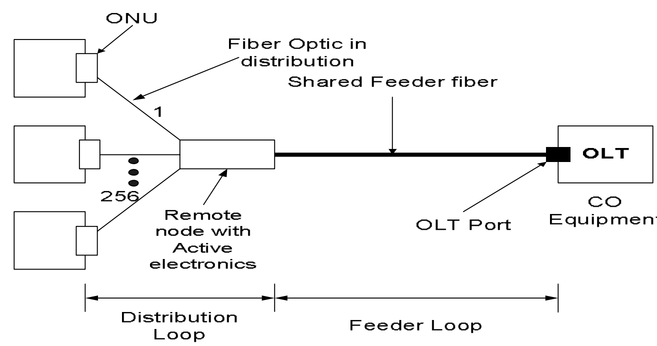

Figure 4: Active Optical Network

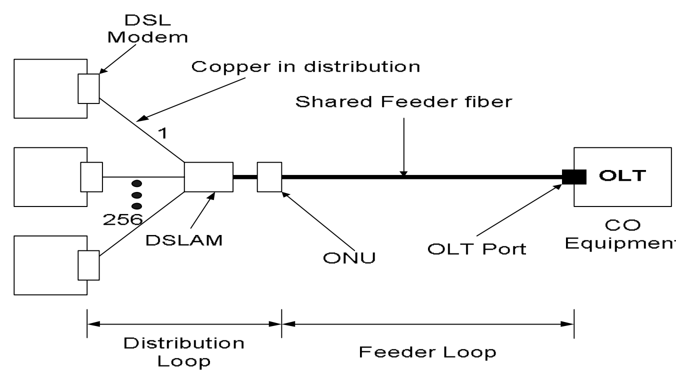

Figure 5: FTTC- DSL

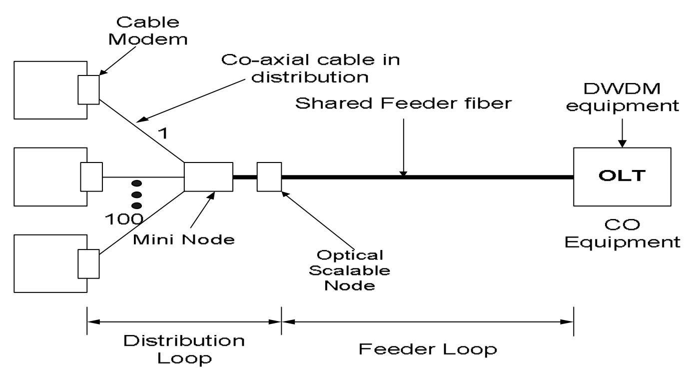

Figure 6: HFC

IV. ECONOMIC COSTS

Table I shows the parameters of equipment for different network architecture and their costs. The method used is engineering cost estimation. These costs are based on surveys and prevailing prices of different equipment in the market. Many externalities like trenching costs and distribution wiring costs may vary from place to place but they will have the same effect on all architectures.

The cable cost is same for all networks except for home run fiber where the cost of fiber used is less than others. Distribution wiring cost is less for FTTC and HFC as these architectures do not use fiber in distribution.

TABLE I. COMPONENT AND INSTALLATION COSTS

	HRF	PON	AON	FTTC	HFC
Cable Cost					
OLT to RT ($ per km)	40	400	400	400	400
RT to CPE ($ per km)	40	40	40	40	40
Cost per splice	5	5	5	0	0
Connector	20	20	20	0	0
Trenching Cost ($ per km)					
OLT to RT	10	10	10	10	10
Distribution network cost ($ per km)					
wiring	400	400	400	40	80
Labor plus material	10	10	10	10	10
OLT cost					
Housing cost	15000	15000	15000	15000	15000
Transceiver cost	14000	9500	2500	2500	1000
CPE cost					
ONU price	50	65	50	0	0
install cost	50	50	50	25	25
DSL modem	0	0	0	20	0
RF modem	0	0	0	0	15
RT cost					
Chassis cost	0	200	500	2000	500
Remote powering cost	0	0	200	2000	400
Real Estate cost	0	0	1000	8000	6000
RT cost	0	16000	9000	12000	6000

All costs are calculated for 256 subscribers. OLT transceiver cost depends on the number of ports used. HRF uses 256 ports; PON uses 8 ports while all other architectures use only 1 port for 256 subscribers. CPE consist of ONU in case of HRF, PON and AON. ONU in PON costs more because it has a chip that implements PON protocol. As 32 subscribers are supported by one splitter, so we need 8 splitters in PON. AON requires one active device (multiplexer or regenerator) and one splitter of higher ratio. FTTC requires DSLAM requiring larger space with higher installation costs. HFC uses optical scalable nodes and mini nodes requiring medium space and less installation costs.

V. ECONOMIC ANALYSIS

Figure 7 shows the total cost of providing fiber to 256 subscribers. As evident FTTC and HFC are more cost effective whereas HRF bears the maximum cost due to extensive use of optical fiber cable. AON is cost effective when fiber access has to be given up to the home. It is also evident that once access network is laid, the cost does not vary much with the number of subscriber. There is a small difference in capital cost for the subscription of 256 and 128 subscribers as the network for 256 subscribers is laid.

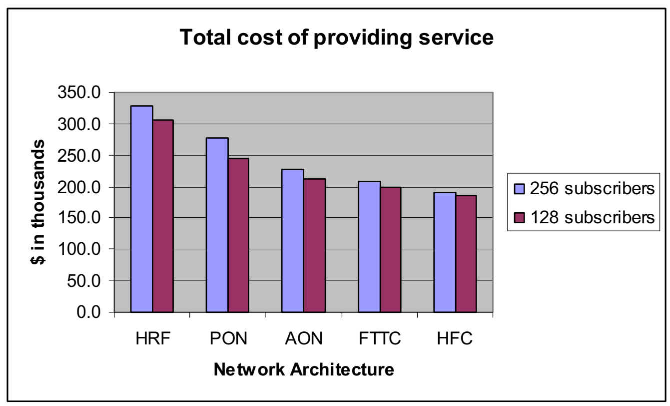

Figure 7: Total cost of providing service

Cost per subscriber is maximum for HRF and minimum for HFC. Per subscriber cost for HFC and FTTC is pretty much the same. Cost per subscriber is also highly dependent on the take rate. Take rate is defined as the percentage of homes covered by the access network infrastructure that subscribe to the service. As evident from figure 8, cost per subscriber increases quite sharply for all the architectures as the take rate drops down. All infrastructure costs (e.g. housing, construction, trench, feeder cables and electronics) are incurred for all homes, even though they can only be recovered from the revenue by those that subscribe. This rise in cost per subscriber is greatest for HRF as it involves the biggest sunk costs.

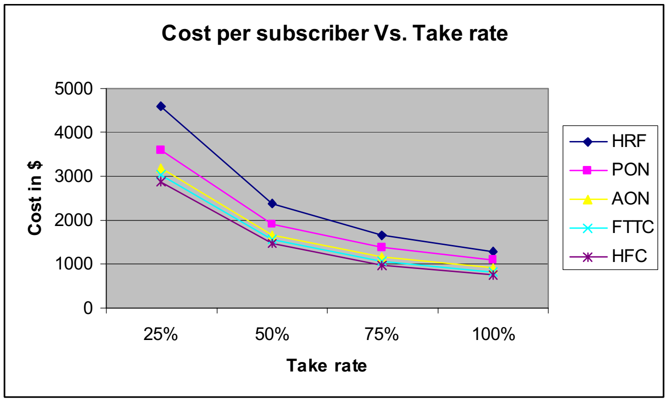

Figure 8: Cost per subscriber Vs. Take rate

Another major factor of selection is feeder length. As we decrease the feeder length, cost per subscriber decreases. This decrease is more evident for HRF. Hence HRF can be implemented where distances of homes from CO is small. This trend is shown in figure 9.

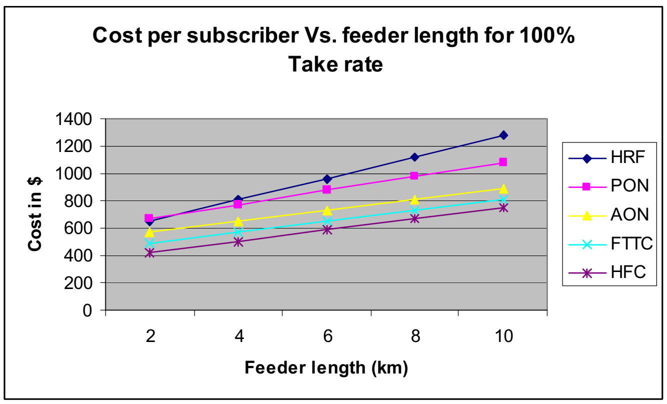

Figure 9: Cost per subscriber vs. feeder length

Sunk Costs play important role in cost per subscriber as seen in figure 10. For all the architectures cost of trenching, cable and distribution play major role.

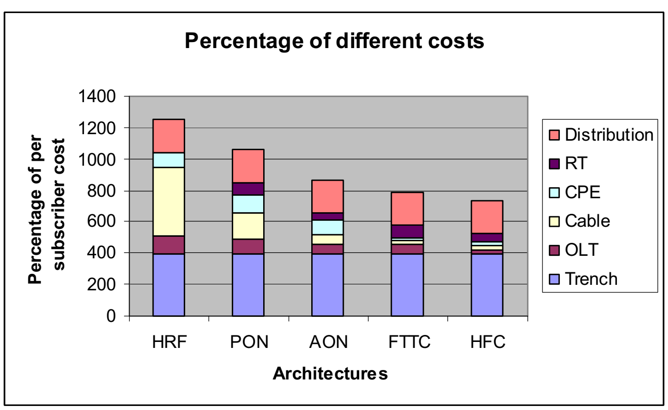

Figure 10: Break up of per subscriber cost

There is a big role of externalities in infrastructure development. In our model we have supposed uniform characteristics for all the architectures. When we have to decide the architecture, these externalities play an important role. We can divide the area in three major categories like urban, suburban and rural. The major cost factors vary considerably in these categories as shown in table II. Trenching and distribution costs are high in rural areas due to the spreading of homes whereas housing cost is high in urban areas. Labor is always cheap in rural areas. Hence all these externalities play a crucial role in selecting particular solution.

TABLE II. COMPARISON OF COSTS

Costs	Urban	Suburban	Rural
Housing	High	Medium	Low
Trenches	Low	Medium	High
Distribution Network	Low	Medium	High
Labor	High	Medium	Low

Another major consideration is the maintenance cost over the future years. Maintenance cost of HRF is negligible and low for PON. It is high for AON, FTTC and HFC due to involvement of active electronics in RT.

VI. CONCLUSIONS

Capital cost of FTTC and HFC is least and are suitable for present telecom operators who already have distribution networks for such architectures. Percentage take rate is the most crucial factor in cost per subscriber. Near central office HRF is a good alternative. Externalities like area characteristics play an important role in deciding the network architecture. Maintenance cost over life time is substantial in HFC and FTTC whereas it is negligible in all other architectures. Under similar conditions and different parameters of our model FTTC and HFC thus come out to be the most cost efficient architectures.

REFERENCES

[1] Donald. E.A. Clarke and Tetsuya Kanada, “Broadband: The Last Mile,” IEEE Communications Magazine 31, pp. 94–100, Mar. 1993.

[2] Whitman, “Fibre Access Deployment Worldwide: Market Drivers, Politics and Technology Choices,” in Proceedings of ECOC, pp. 6–9, Sept. 2004.

[3] Y. Mochida, "Technologies for local-access fibering," IEEE Communication Magazine., vol. 32, pp. 64 - 73, Feb. 1994.

[4] T. H. Wood, “What architectures make sense for fiber access networks” in Proc. 11th Annual Meeting of the IEEE Lasers and Electro-Optics Society (LEOS’98), vol. 2, pp. 122 - 123, 1998.

[5] A. A. M. Saleh, and J. M. Simmons, "Architectural principles of optical regional and metropolitan access networks," IEEE J. Lightw. Technol., vol. 17, pp. 2431 – 2448, Dec. 1999.