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Study of Various Smart Applications Over FTTx Infrastructure as Per Degree of Fiber Penetration

By Smart Cities Committee

White paper

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Abstract

As fiber is brought closer to customer premises, more and more applications can be enabled over the city infrastructure. The pertinent question, however, is the degree of fiber penetration required to enable these changes. Fiber penetration is a strong function of the bandwidth requirements from services and applications. Some applications may have intensive bandwidth requirements and cannot be supported by any infrastructure other than fiber, and it is thus clear that a Fiber-to-the-Home (FTTH) infrastructure is needed for them. In this FTTH Council APAC white paper, we will analyze how the degree of fiber penetration is influenced by the type of applications. For this, we will first chart both the existing and new applications with respect to their quality of bandwidth (QoB) requirements and then measure how well each QoB parameter is fulfilled with a varied degree of fiber penetration. The scope of this study will be to clearly define the minimum degree of fiber penetration that can support a specific kind of application.

This and the upcoming series of FTTHCAP whitepapers will demonstrate that the data demand of the future can only be adequately served with 'deep fiber' networks with fiber directly connected to the home, the business enterprise, and the mobile base-station. Through these whitepapers, we will also recommend methods for building and growing fiber optic networks to meet future growth requirements.

I. Introduction

Over the past 150 years, copper cables have been progressively rolled out across the developed and developing countries to provide telecommunications services. For the majority of the users and for most of this period, copper cables solely provided voice telecommunications services (often called POTS – Plain Old Telephone Service in the last 25 years).

With the advent of solid state technologies, the use of copper cables began to change. The Internet provided the stimulus for the widespread adoption of V56 modes operating in the voice bands and allowing data communications between home computers at the then-magical speed of 56 Kbps. Since the 1980s, the demand for faster data communications has grown exponentially and the technologies to deliver these higher speeds have been developed using the variants of Digital Subscriber Line (xDSL) technologies that have continued to make good use of the legacy voice-grade copper cables.

Looking to the future, the data-rates of the applications are expected to increase at an exponential rate similar to Moore's Law (i.e. Nielsen's Law). Today's high-definition television (HDTV) requires bit rates between 8 and 15 Mb/s if used with new compression technology of the Moving Pictures Experts Group' MPEG4. 3D immersive HDTV requires100 to 300 Mb/s, whereas future evolutions like 8k ultra-HDTV is expected to consume about 160 Mb/s per channel [1]. Furthermore, parallel downstream or download sessions of 3D versions of UHDTV may need at least 800 Mb/s.

As Internet evolved to a video-driven communications network fuelled by the widespread adoption of services like YouTube and Netflix, copper cables became incompetent for the roll-out of these bandwidth-hungry Internet access services. Primarily the bandwidth bottleneck lies in the "last mile" of a telecommunications network that runs from a service provider's facility to a home or business. This part of the telecommunications network is also referred to as an access network. Optical fiber technologies were identified as the replacement to the legacy copper access network. This is because fiber has been in use in the telco core networks since the 1980's for customer access at homes and businesses through services like Fiber-to-the-Home (FTTH) and similar Fiber-to-the-Anything (FTTx) services.

Similarly, mobile data services have undergone massive demand growth since the launch of 2G networks and EDGE data services in the 1990's and have grown progressively through 3G, HSPA, 4G LTE services and higher speed 5G services on the technology horizon. These mobile data services can provide excellent services but they are limited by the traditional radio access bottlenecks of spectrum availability, interference, and in-building penetration. Additionally the shared nature of a point-to-multipoint multi-user environment makes it very difficult for service providers to guarantee the availability of quality of bandwidth (QoB) agreements.

Optical fiber-enabled access services are the only future-proof technologies that can continue to evolve to satisfy the demand for fixed location high-speed Internet services to homes and

[1] Nielsen's law states that the user's connection speed grows by 50 percent per year, or doubles every 21 months.

businesses. Also, considering the unfulfilled demand for mobile data services, fiber optic connection of the radio base stations to the telco core networks (Fiber-to-the-Antenna or "FTTA") is the only feasible solution to backhaul the growing mobile data traffic.

Thus, FTTH based network will play the key role in the development of smart cities. According to FTTHCAP, "a Smart City is an innovative urban area with sustainable economic development; it enables a high quality of life and is equipped with modern infrastructure. It shall contain a fiber rich network which provides a strong foundation to support many other city utilities and to empower the use of ICT for betterment and improvement of well-being for its citizens." Smart sustainable cities should be designed with a citizen-centric approach that can accommodate smart tools, smart technology to give seamless connectivity to the users, and smart security systems to deliver round the clock surveillance. This will also create huge business opportunities and great market value for the participants. China and India, the two densest countries in the world, have the most market potential in smart city segment, leading to massive deployment of FTTH/FTTB in Asia-Pacific region (cf. Figure 1) in comparison to the other continents of the world. South Korea and Singapore are currently the leaders with around 70% of their network infrastructure replaced with fiber. China is the leader in terms of the number of FTTH/FTTB subscribers, with over 121 million FTTH/B subscribers and 290 million FTTH/B homes/buildings. At the same time, New Zealand and Australia have shown the maximum growth in subscriber numbers. The markets in India and Indonesia have also started evolving at a significant rate.

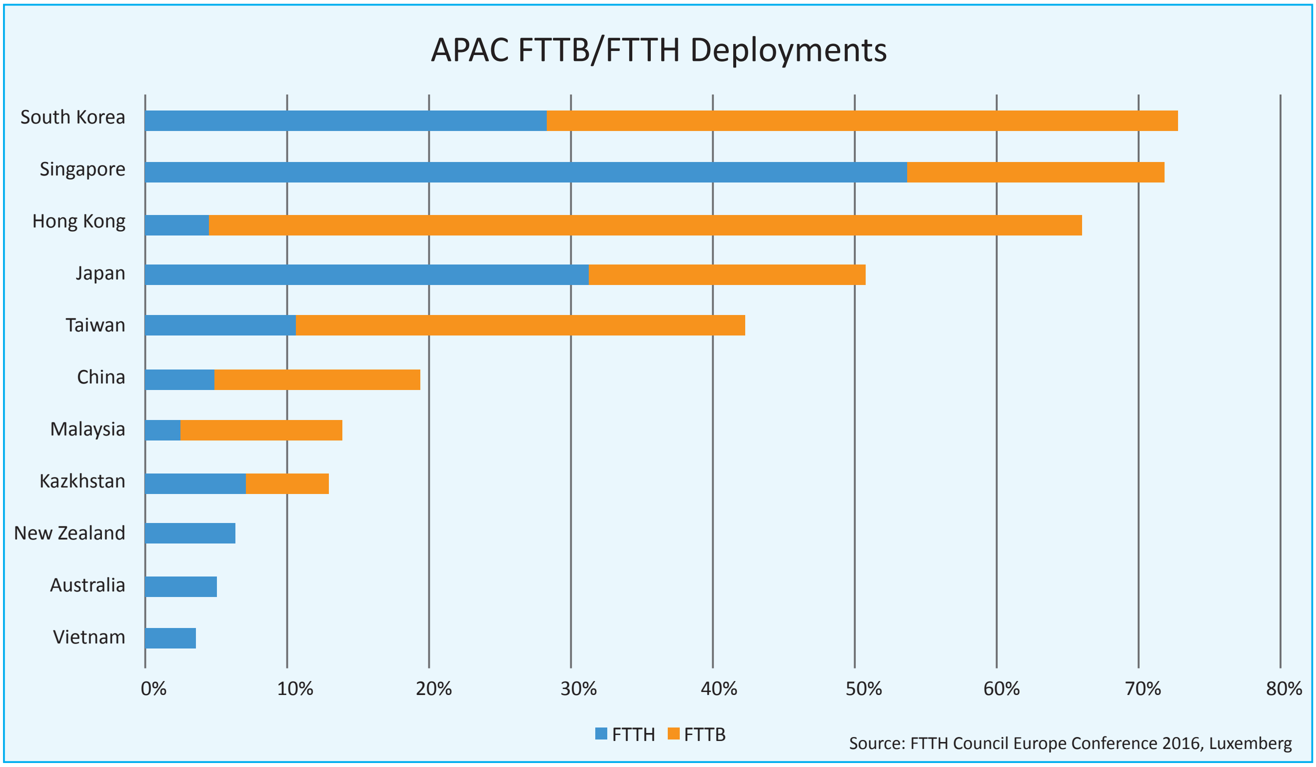

Figure 1: FTTB/FTTH deployment in Asia-Pacific

In this white paper, we investigate the optimal degree of fiber penetration, which leads to a variety of FTTX networks [2], where X can mean curb, building, antenna, and home, etc. We find the future applications have intensive bandwidth requirements and cannot be supported by any infrastructure other than fiber, and so an FTTH infrastructure is ideal for them. Thus, we recommend full fiber rollout to all the network end points –home, business and base stations. However, in some instances this may not be economically viable, so 'less than ideal' technologies may be deployed as the situation demands. In section II, we present an overview of future applications and the bandwidth requirements for them. In section III, we present **FTTH Council Asia Pacific fiber-guideline**, which maps the required fiber penetration depth for different bit rates.

II. Applications and their bandwidth/fiber penetration depth requirements

We consider different kinds of applications that will be supported in smart city infrastructure. They include 5G applications like ultra-high density (UHD) streaming, cloud computing and storage, augmented and virtual reality, a range of IoT services and even more demanding services. Together with these, there will be plethora of other services, which will be supported in smart city infrastructure, for example, fault detection system for smart grid, smart agriculture (wherein sensors can be used for monitoring temperature, humidity, wind, sunshine, water quality, livestock health, and more), tele-health services, Internet on Vehicles, smart manufacturing, smart logistics applications, wearable technologies, and the like.

The below table lists some of the applications, their bandwidth requirements [4]-[6]) and their required fiber penetration depth (the distance of fiber from home)

The applications that require bandwidth in the range of 100 Kbps – 512 Kbps are as given in Table 1.

Table 1: Fiber penetration depth and bit rates for applications requiring bit rates between 100 Kbps – 512 Kbps

	Applications	Bit rates	Fiber penetration depth
1.	Audio/Music On Demand	128 Kbps	More than 20 km
2.	Voice Chatting	256 - 512 Kbps	More than 20 km
3.	Tele Education	256 - 512 Kbps	More than 20 km
4.	Tele Medicine	256 - 512 Kbps	More than 20 km
5.	Video Conferencing	384 Kbps	More than 20 km

[2] Fiber penetration depth calculation does not take into account any data aggregation effects, multiple wavelengths on optical fiber, etc.

The applications that require bandwidth in the range of 0.6 Mbps – 10 Mbps are as given in Table 2.

Table 2: Fiber penetration depth and bit rates for applications requiring bit rates between 0.6 Mbps – 10 Mbps

	Applications	Bit rates	Fiber penetration depth
1.	Streaming Gaming	0.6 – 0.8 Mbps	More than 20 km
2.	Virtual Office	0.7 Mbps	More than 20 km
3.	Video Streaming	2 Mbps	More than 20 km
4.	Vehicular Ad hoc network (VANET)	2 Mbps	More than 20 km
5.	Smart Home network & Security	2 - 3 Mbps	More than 20 km
6.	HD Video	4 - 8 Mbps	More than 20 km
7.	Tele training	4 – 4.5 Mbps	More than 20 km
8.	Tele surgery	10 Mbps	More than 20 km
9.	HD video conferencing	15 Mbps	More than 20 km

The application that require bandwidth in the range of 50 Mbps – 5 Gbps are as given in Table 3.

Table 3: Fiber penetration depth and bit rates for applications requiring bit rates between 50 Mbps – 5 Gbps

	Applications	Bit rates	Fiber penetration depth
1.	HD Video on demand/Real time video	70 – 140 Mbps	1.5 km
2.	IPTV	50-500 Mbps	500 m
3.	Full Motion Video	80 Mbps	20 km
4.	Smart driving application (Internet on Vehicles)	100 Mbps per vehicle	15 km
5.	Smart manufacturing applications	100 Mbps per application	15 km
6.	Wearable technologies	100 Mbps per person	15 km
7.	8K TV	160 Mbps	5 km
8.	Tele-health services with IoT sensors	1 Gbps	100 m
9.	3D panorama TV	4 Gbps	20 m
10.	Fault monitoring system for Smart grid with 10K intelligent sensors	4.75 Gbps	0 m
11.	Cloud storage[1]	2x bit rates	

[3] Cloud storage will make network symmetrical, thus upstream bit rates will become symmetrical to downstream bit rates, necessitating the capacity increase by a factor 2.

III. Loop lengths for various applications and the Asia-Pacific fiber guideline

Based on what is possible over other current competing technologies like DSL, Wi-Fi and WiMax, we propose fiber guideline in which we calculate the minimum required fiber penetration depth for a given bit-rate. We have shown this variation for high and low bit-rates, cf. Figure 2 and Figure 3. As expected, when fiber penetration depth reduces, the bit rate that can be offered also reduces. Also, the fiber penetration depth decreases very sharply at high data rates.

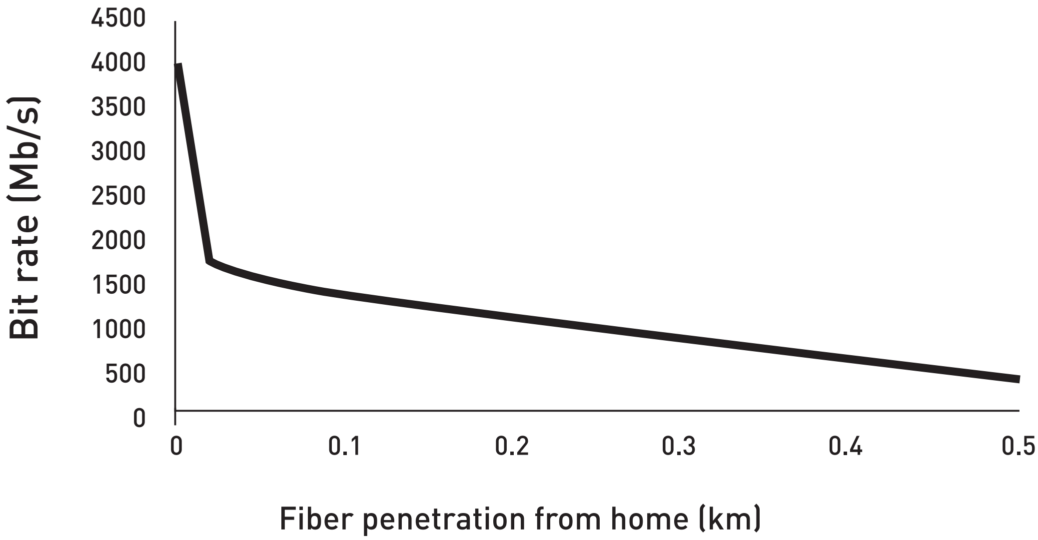

Figure 2: Required fiber penetration for high data rates

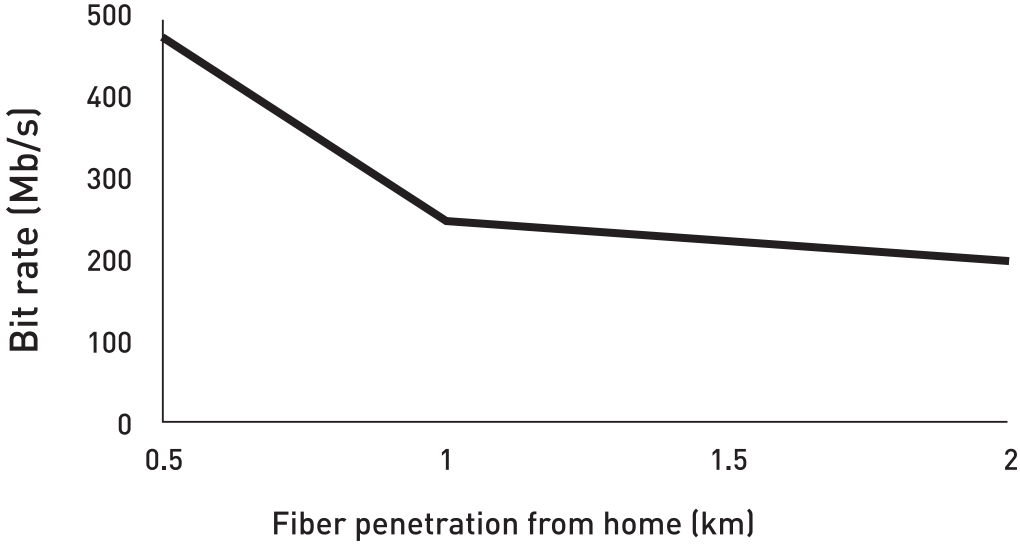

Figure 3: Required fiber penetration for low data rates

Based on the requirements from various applications (cf. section II) and fiber guideline, we can easily deduce fiber penetration depth in various possible scenarios. In Table 4, we present some scenarios of today and future, and indicate the required data rates and fiber penetration depth for these. For example, if we consider smart homes for tomorrow, with support for applications like 3D panorama TV, we can only use FTTH-based solution. Thus, the use of FTTH networks is inevitable.

Table 4: Data rate and some possible solutions

Applications	Data rate	Fiber penetration depth
Smart factory with 100 smart manufacturing applications running	10 Gb/s	0 m
Smart hospital with 10 smart tele-health rooms	10 Gb/s	0 m
Smart future home (3D panorama TV, smart security with 4UHD streaming, cloud storage, wearable technologies)	5-6 Gb/s	0 m
Smart grid applications with IoT sensors	4.7 Gb/s	0 m
Smart home today (2 8KTV, smart security with 4UHD streaming, VoD, IoT, etc)	1 Gb/s	100 m

IV. Economic Impact

Fiber network can also generate huge revenues to the smart-cities. FTTH infrastructure is characterized by very high bandwidth that can support a large number of future applications and users. Even if typical broadband speeds become thousand times faster in 20 years, a single existing fiber optic connection can still support it.

The network infrastructure should be deployed in such a way that it includes optical fiber as a utility, and so "**deep fiber**" is an enabling utility today. Furthermore, the smart city development program should operate on a dig once policy, in which fiber broadband goes in once and supports the user's high bandwidth requirements in the future.

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