A Survey on The Implementation of FTTX Services and Technologies in Indonesia: Best Practices and Lessons Learned from Other Asian Countries

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A Survey on The Implementation of FTTX Services and Technologies in Indonesia: Best Practices and Lessons Learned from Other Asian Countries

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Abstract—This paper surveys the implementation and deployment of fiber-to-the-x (FTTX) services and technologies in Indonesia. Motivation of this study is to provide the mapping report of Indonesian current status and to determine about the playing key role behind the growing of national information communication and technology (ICT). More of it is to leverage ICT infrastructures to be a robust ICT connectivity across the Indonesia archipelago which later on can be used for many diverse applications such as disaster resilience and sustainable development. In this survey we use the systematic literature review (SLR) method by gathering data from Internet (journal articles, paper conferences, and websites) as our (secondary) resources. From our survey we recognize that there are three main problems which can slow down the FTTX growth and implementation in Indonesia, namely geographical barrier, deployment cost, and goverment regulation. We also compared the Indonesia's FTTX growth with several Asian countries such as China, India, Japan, Korea, Malaysia, and Philippines. From our findings, one of the best practices or lessons that we learn is that national governments must build the access to broadband or high-speed internet by owning the responsibilities for the infrastructures. By creating their own National Broadband Networks (NBNs) Plan, governments are hoping to bridge the digital divide, create employment and enhance the industrial productivity, and at the end to improve the overall economic development. In our point of view, cost estimation and techno-economic analysis is strongly related to the strategic network design.

Keywords—FTTX services & technologies, robust ICT, connectivity infrastructures, systematic literature review (SLR).

1. Introduction

Nowadays, internet connection is considered as one of our primary needs, especially for people who live in cities and urban areas. The main driver behind the internet traffic growth is video traffic. It is all about bandwidth. Along with the increased need for higher bandwidth to support the triple play services (data, voice, and video) in telecommunication systems, optical transmission is getting more popular in the access network (see Fig. 1 and Fig. 2). Tomorrow's networks face unprecedented and ever-growing demand for speed and bandwidth, but must overcome fundamental spectral and energy limitations. These problems are pushing optical solutions further into the network edges. [1]. Indonesia Internet Service Provider Association (*APJII*/*Asosiasi Penyelenggara Jasa Internet Indonesia*) stated that in 2017, there was around 143.26 million internet users in Indonesia [2]. Since Indonesian total population in 2017 was expected to be around 262 million [3], then about 54.68% of Indonesian people are internet users. The availability of affordable smartphones is one of the driving forces to the growing number of internet users alongside the cheaper data tariff and better network coverage [1, 4]. In terms of better network coverage, there are still many remote areas which are not covered by 4G or even 3G networks. Statistics from APJII in 2018 showed that about 58% of Indonesian internet users are in Java, followed by Sumatera with 19.9%. The leading internet service providers in Indonesia are mobile broadband services, which are expected to serve about 75% user population in 2017 [5]. In contrast, fixed broadband services penetration in Indonesia by the end of 2017 is around 2.5%. This number is for all kinds of fixed broadband penetration ratio [6]. For example in 2014, fixed broadband penetration is 1.33%, while the penetration of FTTX is only about 0.1% [7]. Therefore, in terms of FTTX development and supply, Huawei gave a minimum score (only 2 out of 10) which means that Indonesia FTTX services are under developed/poor [8]. If that is true, then we come up with some problem questions: (1) Why Indonesia' FTTX services are under developed? What are the main problems? (e.g. geographical barrier, deployment cost, and the government regulation?) (2) What about the situation in other Asian countries as well? What are some best practices and lessons learned that we have from their stories that have to be taken in order to accelerate the growth of FTTX implementation in Indonesia for the next decades?

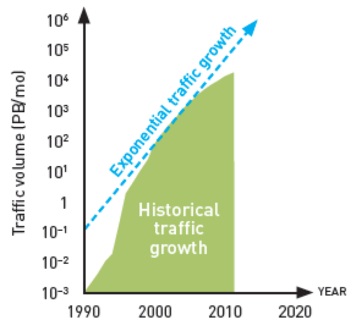

Fig. 1. Traffic growth is slowing as optical transmission capacity starts to run up against spectral limits [1].

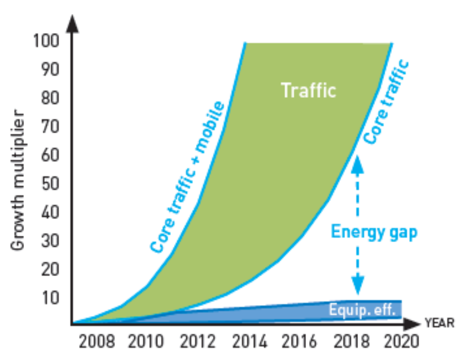

Fig. 2. Energy efficiency is not scaling with the growth in demand [1].

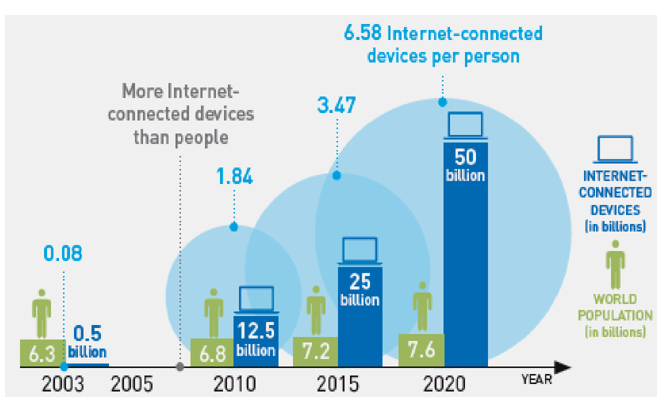

Fig. 3. THE "INTERNET OF THINGS" The number of data-hungry devices connected to the Internet is expected to be 50 billion—more than 6.5 times the world's population—by 2020 [1].

This study is trying to compare the FTTX growth between Indonesia with other Asian countries such as China, India, Japan, Korea, Malaysia, and Philippines and to absorb some great lessons from all of them as many as possible. China and India are chosen because they deal with the large countries population. Japan and Korea are two of the leading countries in Asia in terms of technological deployment and advancements. Malaysia and Philippines are chosen due to their similarities with Indonesia in terms of geographical position. The comparison will consist about the FTTX penetration, data transfer speed, monthly costs, and the viability. We hope that this comparison results will be determining the main problems of FTTX implementation in Indonesia and suggesting on how to overcome those problems by learning best practices from some other Asian countries as well in order to accelerate the growth of FTTX development in Indonesia for next decades to come. The rest of this paper can be outlined as follows: Section II explains why fiber optics is superior than copper cables and also about the basic FTTX concept and applications. Section III presents the method and materials. Section IV shows the results and analysis. And the last, Section V is Conclusion and Recommendation.

2. FTTX Concept and Applications

2.1 Fiber Optics Over Copper Cables

As far as we concern, beside the importance of wireless communications (e.g. radio and satellite communications), wire/cable communications (e.g. copper cable and fiber optics communications) are not less importance. But, each of them has its role and place to be used in telecom networks. Background motivation behind the pursuing topic of this research is existed on fiber itself as the medium of communications which plays an important role in our life, since its first appearance (around 1960s) up to this day [9]. There are two out of several important reasons why fiber optic technology can be considered as "green" technology or network: first is the higher transmission rate and second is the lower energy consumption compared to copper cable [10, 11]. Fiber can transmit more data (greater bandwidth) over longer distances and still use less energy than copper. For example, some 10 Gbps single mode fibers (SMFs) can carry signals almost 25 miles, which is impossible if using copper cables. And overall, less energy is consumed by fiber optic networks than copper cable networks. With less energy used, then carbon dioxide emissions can also be reduced. Fiber optic technology is greener both initially and over the lifespan of the technology's network. In addition, fiber has also better reliability than copper cable. It is immune to temperature changes, severe weather and moisture, all of which can hamper the connectivity of copper cable. Plus, fiber does not carry electric current, so it's not bothered by electromagnetic interference (EMI) that can interrupt data transmission. Although some fiber optic cables may have a higher initial cost than copper, their durability and reliability can make the total cost of ownership lower. And, the costs continue to decrease for fiber optic cables and related components as technology advances. That is why fiber optic cable is more preferred when people planning a new network installation or considering upgrades to an existing network. Fiber technology is also then a part of/included as the green ICT (Information Communication Technology), especially when it comes to the concept of smart cities (the growth of internet of things, IoTs, as shown in Fig. 3) and smart sensors (the deployment of optical fiber sensors).

2.2 Optical Access Networks

Fiber optic access is mature and one of the most important technologies in the next generation network. There are four common topologies used for fiber optic networks: linear-bus, ring, star, and mesh configurations. Each topology has its own particular advantages and limitations in terms of reliability, expandability, and performance characteristics. It increases the access layer bandwidth and builds a sustainable-development access layer network. Optical access network (OAN) adopts technologies such as active point-to-point (P2P) Ethernet and passive optical network (PON) [12-14]. Initially, P2P adopted dual Tx and Rx fibers to the user. The fiber layout in pairs was difficult, but with the development of wavelength division multiplexing (WDM) (the successor of TDM, time division multiplexing) PON technology, one fiber to the user has been realized [15-18]. PON is the optical access technology developed to support P2MP (Point-to-Multi-Point) applications as shown in Fig. 4. PON realizes P2MP transmission through the passive optical splitter. The fiber connected to the OLT (optical line terminal) or CO (central office) port is split through the splitter into multiple channels to the ONUs (optical network units) of different users [19]. The distance between OLT and ONU is quite long, e.g. 20 Km (for standard PON). Using PON technology, the ODN (optical distribution network) does not necessarily has an active node. The feature of passiveness makes the network deployment becomes so flexible, because the equipment room and power supply are not needed anymore.

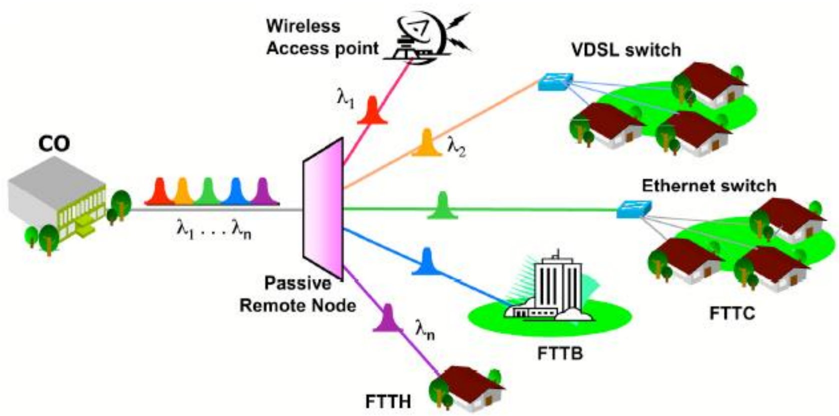

Fig. 4. WDM-PON supports multiple subscribers (by Novera Optics, Inc) [20].

2.3 FTTX Applications Model

Passive optical networks (PONs) have several applications model due to the multitude of choices in the planning FTTX networks such as FTTC (Fiber to The Curb), FTTB (Fiber to The Building), FTTH (Fiber to The Home) and FTTO/N (Fiber to The Office or Node) as shown in Fig. 5. Different FTTx application model is based on the ONU location and the fiber length. In FTTH/FTTO, ONU is deployed in the home or office indoor, which is the nearest position to user. The fiber length is the longest. In FTTB, ONU is deployed in the building or corridor. In FTTC, ONU is deployed Curb, which is the farthest position to user, where the fiber length is the shortest.

Table 1 list all kinds of FTTx applications model main features.

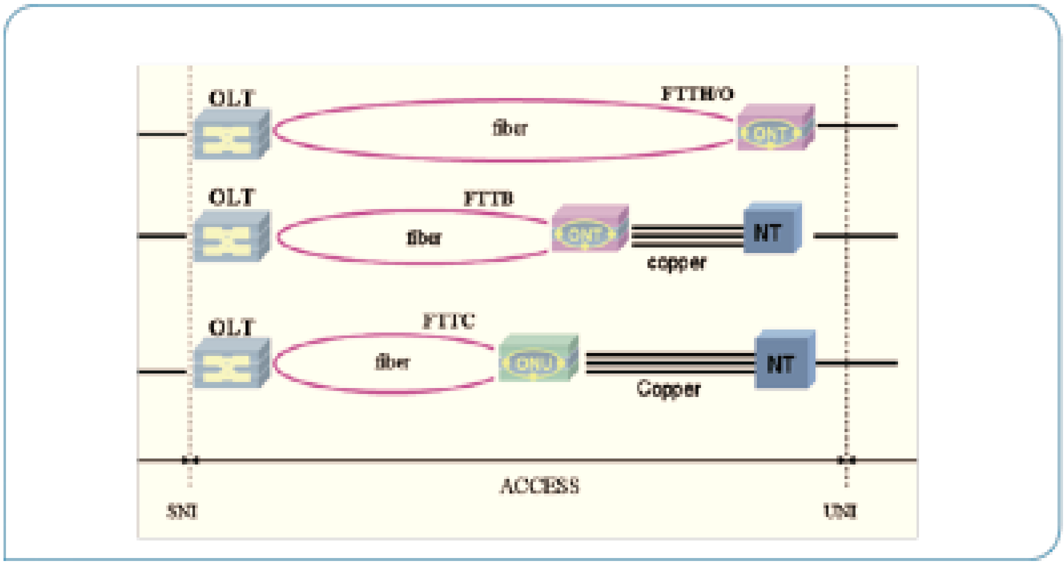

Fig. 5. FTTX applications model in PON technology [13].

Table 1. FTTX Mode and Features [13].

Application Mode	FTTC	FTTB	FTTO	FTTH
ONU Capability	Hundreds	Tens	Single Enterprise/Office	Single Family
Distance between OLT and ONU	5 – 100 Km	< 20 Km	< 20 Km	< 20 Km
Distance between ONU and user	1 – 3 Km	< 500 m	0 – 50 m	0 – 20 m
Bandwidth per user	2 to 25 Mbps	50/100 Mbps	100 M to GE	>= 100 M
ONU Interface	POTS, ADSL/ADSL2+, VDSL2	FE, POTS, VDSL2/TDM	FE/GE, TDM, Wifi	FE, POTS, Wifi, RF
ONU Type	ONU (Large Capability)	MDU/MTU	SBU	SFU
International Abbreviation	FTTN FTTZ	FTTK	FTTP FTTBusiness	FTTP FTTU

3. METHOD AND MATERIALS

3.1 Systematic Literature Review (SLR)

This research methodology is a literature survey from Internet (qualitative method). The survey study uses the Systematic Literature Review (SLR) [21, 22]. In this study the authors will do article search through the

Google Scholar (which are contained the resources from IEEEXplore Digital Library, Optical Society of America, Science Direct Repository, and many other respected and highly prestige journals, conferences, and books as well). The search process uses two keywords. The first keyword is "FTTX Technologies and Implementations". Based on this first keyword, the search found 4980 results. The second keyword is "FTTX Challenges and Opportunities". And based on this second keyword, the search found 1550 results.
To link the first and the second keywords, the words of "in Asia Pacific" is used for both and focusing the search on Full text and Metadata only. The new results are coming up: for the first keyword down to 1430 findings and for the second keyword 1340 findings. Further combining those two keywords using Boolean “AND”, to ensure that the article matches the topics covered and obtained 582 articles. The search might be focused on articles published in, but not limited to Journals & Conferences. Also some reliable websites. For the years they were published, the range is determined from 2008 to 2018. Based on these criteria, the search results downsized to be about 125-130 articles. Furthermore, authors will filter this number of articles to obtain the most important resources used for this research.

3.2 Preliminary Literature Reviews

Currently, Indonesia is the third-largest internet user in Asia [23]. However, Indonesia is not the third-largest FTTX user in Asia. Actually, Indonesia is far behind China in terms of FTTX penetration. Although this comparison seems not to be fair, considering that China is currently involved in 5G race with the likes of USA and Europe. Malaysia, which has only started building FTTX infrastructures in 2008 [24] had already reached 16.4% penetration in 2017 [25], while Indonesia has not even reached double digits. The Philippines, on the other hand, has only provided FTTX to 2.5 million homes [25], 0.22 million more than Malaysia. Indonesia actually supplied 13 million homes with FTTX [25], but the supply per population rate (4.8%) is lower than Malaysia (7.1%), although still higher than Philippines (2.4%). The supply per population rate (SPP) is calculated using this equation: SPP = (supplied homes/total population) x 100%. As one of the technologically advanced nations in Asia, Japan has started FTTX development back in 1999. In 2017, Japan has supplied 52 million homes with FTTX services, with 40.9% SPP. In India, only 3.5 million houses supplied with FTTX services in 2017 [25], which translates into 0.28% SPP. This condition is the worst out of all countries. Our comparison study is shown in Table 2.

Table 2. Comparison of All (Six) Countries’ SPP.

Country	**Served Homes (Millions)**	**SPP (%)**
China	320	22.6
Japan	52	40.9
Malaysia	2.28	7.1
Indonesia	**13**	**4.8**
Philippines	2.5	2.4
India	3.5	0.28

China has rapidly developed telecommunication. Besides being involved in 5G race, China has supplied 320 million homes with FTTX services. This number equals to 22.6% SPP. Based on the SPP, Indonesia is lagging behind Malaysia, China, and Japan, although being better than Philippines and India. This condition means that Indonesia has implemented FTTX to a medium level and the fundamental problems should have been eliminated.

However, Indonesia FTTX implementations cannot be judged by only looking at the SPP. Indonesia is an archipelagic country, and one of the main problems of an archipelagic country is to maintain the spread of technological advances across the nation. This is reflected by the APJII survey results which stated that more than half of Indonesian internet users are in Java and around five are in Sumatra [2]. The Palapa Ring project was built in 2008 and consists of 6 rings in 3 zones (West, Central, and East), which later will be united into a single ring [26]. This project is divided into over 35,000 km of underwater fiber and over 20,000 km of inland fiber [27]. However, construction rates of those three zones are different. For example, the eastern zone is just 32.76 percent completed when the central zone is already 71.96 percent completed [28]. That shows the imbalance spread of fiber infrastructure in Indonesia. Despite being unequally spread across Indonesia, FTTX service price in Indonesia remains the same regardless of region. For example, IndiHome (FTTX service provider owned by Telkom Indonesia) has the same rate for 10 Mbps „Triple Pay" package in Jakarta and Jayapura, despite Jayapura located in Papua, Indonesia's eastern most major island. They are still equally priced at IDR 460,000 [29]. This is contrary to the price of mobile data package usually issued by Telkomsel, which is also owned by Telkom Indonesia. For example, the price of 5GB package which lasts for 3 days in Jakarta is IDR 38,000. The same package costs IDR 43,000 in Jayapura [30]. The aforementioned condition indicates that FTTX service enable better connection with uniform prices across the nation. With the development of Palapa Ring and other fiber infrastructure, Indonesia will benefit a lot from the switch to FTTX services.

4. RESULTS AND ANALYSIS

4.1 The Main Problems of FTTX Implementation in Indonesia

According to our findings, there are three main problems regarding the implementation of FTTX in Indonesia. They are geographical barrier, deployment cost, and government regulation. Each one will be explained as follows:

4.2 Geographical Barrier

The main problem of Indonesian FTTX services is the geographical barrier. Indonesia is an archipelagic country, and one of the main problems of an archipelagic country is to maintain the spread of technological advances across the nation due to the geographical barrier. This is reflected by the APJII survey results which stated that more than half of Indonesian internet users are in Java, and around fifth in Sumatra [1]. The logical reason why the spread of internet users in Indonesia is concentrated in Java is the difficult access to several regions outside Java, especially in East Indonesia, which in turn resulted into the lack of FTTX infrastructure outside Java. Lack of FTTX infrastructure outside Java is supported by the Palapa Ring project data. According to MICT [31], the length of subsidized cable project of Palapa Ring in Central Indonesia is 2,647 km. In East Indonesia, the length of subsidized cable is 8,454 km, which is 319.38% of the length of subsidized cable in Central Indonesia. Cost-wise, the amount of Central Indonesia subsidy fund is US$ 99,250,000, while East Indonesia subsidy fund is US$ 368,884,000 (about 371% of the Central Indonesia subsidy fund). The geographical profile of Indonesia also contributes to the lack of FTTX infrastructure. According to a case study conducted in Japan [32], 72.9% of areas without broadband are mountainous area. Island areas contributes 5.6% to the number. Since Indonesia consists of more than 17,000 islands, deployment of FTTX infrastructure to the islands (especially outer islands) is a challenge. The fact that most of Indonesian mountain ranges are found in Papua, which is located in East Indonesia region, also confirms that geographical profile of Indonesia is indeed a challenge to FTTX service deployment.

4.3 Deployment Cost

As mentioned on the Palapa Ring project data, geographical barrier is closely related to deployment cost, causing another problem for Indonesian FTTX services. Geographically challenging areas are harder to reach, thus increasing the transportation cost and installation cost of FTTX services. Additionally, the deployment cost of FTTX services in those areas are also greater due to the obligation to deploy the FTTX services from scratch, since there are little to no existing FTTX infrastructure in such areas. Submarine FTTX installation also contributes to higher deployment cost. The average deployment cost of Japanese submarine cable is US$ 91,000 per km in 2012 [32]. This number is more than 10 times the average deployment cost of terrestrial cable in the United States (US$ 8,002 per km in 2011, US$ 8,254 per km in 2012 after inflation) [33]. These numbers showed that Indonesia should spend more in FTTX deployment in order to connect both the existing and the newly-built FTTX services by submarine cable. The uneven spread of suburban, urban, and rural area also impacts in higher deployment cost. Mitcsenkov, et.al [34] stated that the deployment cost of FTTX services on suburban areas in Hungary is almost twice the deployment cost of FTTX services in towns and almost quadruple the deployment cost of FTTX services in cities. Although Hungary is not one of the countries studied in this research, Mitcsenkov, et.al also stated that this price comparison is valid for other PON-based topologies. The higher deployment cost of FTTX services in suburban areas is a problem for Indonesia. Indonesia has more suburban areas compared to towns and cities, thus increasing the overall deployment cost of nation-wide FTTX services. This fact is further reinforced by another study [35], which shows that the biggest component of FTTX service cost is the deployment cost (67%), followed by provisioning (24%), and running cost (9%). Thus, Indonesian FTTX service must be backed with a large budget.

4.4 Government Regulation

Furthermore, Indonesia also has problems with the overlapping government regulations, especially concerning infrastructure planning. Infrastructure planning, especially in large cities, can be a problem to Indonesian FTTX services, although it is not as critical as the other two problems. Roads must be reworked several times to accommodate fiber optic installations and other underground installations such as electricity and water. The overlapping responsibility between regional governments such as municipal, regency, and provincial governments and the central government also contributes to the delay of the roadwork, further worsening the condition. One of the proposed solutions to this problem is to install a shared duct system. As the name suggests, shared duct system enables all underground networks to be placed on a single duct system [36]. This way, the government does not have to rework the roads whenever a new underground network is planned. For example, in the current system roads must be reworked when an underground fiber optic network is planned. Then, if the government planned a new underground electrical network, a new duct must be made even if the network is in the same place as the existing fiber optic network. With a shared duct system, the new underground electrical network can be placed in the same duct as the existing underground fiber optic network. This way, additional road works can be avoided.

4.5 Lessons Learned from Other Asian Countries on How to Accelerate the Growth of FTTX Implementation in Indonesia for Next Decades

Broadband is essential to the modern world we live in to gain the productivity and competitiveness value. Broadband development strategy either fixed or wireless broadband, are implemented using regulation, policies, and programs. Based on the research conducted by The World Bank, it stated that in low and middle incomes countries, every 10% increases in broadband penetration accelerates economic growth by 1.38 percentage points. This number is higher than in high income countries [37]. This potential growth is significant and stronger in developing countries than in developed ones and higher than that of telephony, mobile phones, and the Internet. Fiber optic is the future of broadband, using fiber-optic technology to reach the fastest speeds available today, as fast as 1000 Mbps (1Gpbs). Fiber broadband is the fastest method of delivering high-speed Internet to residences and businesses. Similar to DSL, cable, and fixed wireless, fiber broadband connections bridge the “last mile” between the mainstream Internet “backbone” and customer residences. Developing country facing the problem to connect the “last mile” directly to residential consumers, which has been slow to expand due to some reasons. To connect fiber optic as the “last mile” directly to consumer residencies with FTTX technology has been slow to expand due to the high installation costs. There are three specific factors that need to be considered to implement fiber optic as a backbone into their geographies [38]: (1) the economic density of the service area which influences FTTH or FTTC, (2) the extend of existing current fiber/copper wiring that effects FTTO/N, and (3) the total value of services offered over fiber. Based on the Networked Readiness Index (NRI), it is stated that Indonesia's Digital Network Readiness position is ranked 73 out of 139 countries with a score of 4.0 out of total a score of 7 for 2016 with the lowest pillars came from the sub-index: (1) Infrastructure and digital content: international bandwidth usage; and (2) Individual Usage: number of internet users, number of household computer ownership, number of customers Fixed Broadband internet per 100 residents [39]. In accordance to the Presidential Regulation No. 96 Year of 2014 on Indonesia's Broadband Plan, the realization of fixed broadband access is still far from the target set. Some obstacles arise during development of fixed broadband access are: (1) uneven fiber optic infrastructure development, that more centralized in urban areas and western Indonesia, (2) massive mobile broadband access development compared with fixed broadband access, and (3) High installation costs [40]. Based on data from ITU through the "Measuring the Information Society Report" in 2017 shows that fixed broadband customers in Indonesia are the lowest compared to the neighboring countries such as Vietnam, Thailand, Singapore and Malaysia. Number of customers fixed broadband is only 2% per 100 populations, the percentage is low if compared with the average of other Asian countries [41]. Broadband needs to be placed on the state government agenda and made a priority issue to make quality, reliable, affordable, and sustainable broadband available nationwide. In considering to best-fit approaches to accelerate the broadband implementation in Indonesia, based on our comparation from several Asian countries such as China, India, Japan, Korea, Malaysia, and Philippines, it is important to keep in mind those following considerations:

4.6 National Broadband Networks (NBNs) Plan

Each country has their own specific broadband profile, so called National Broadband Networks (NBNs) Plan. Table 3 gives a brief overview of each of the NBNs of India, Malaysia, Australia, and Indonesia. These four countries differ from each other in terms of geographic coverage, ICT penetration, population density and proposed use of optical fiber. This formal broadband plan is effective in drawing attention to and stimulating action on broadband issues, and in establishing broadband goals. Governments are playing a greater role in broadband market development through a range of strategies and policies, and to detail goals on what the economy and society will look like after broadband adoption. This NBN Plan should include the framework for developing national strategies and some common elements to oversee markets and makes them work efficiently, the plan for universalize broadband and ensure equitable, widespread access for all, the detail about the demand side of the broadband ecosystem as well, with promotion policies in the early stages of market development. Low broadband penetration in most countries shows that the government plan covering only about market mechanisms and competition policies. Therefore, at the early stage of market development, aggressive policies to generate demand, expand networks, and reach underserved areas and communities are needed.

Indonesian government has realized the importance of broadband to drive economic development and prepared the Indonesian Broadband Plan (IBP) in 2013 (see Table 4) which provides policies and strategies as well as targets to be achieved by 2017 [43, 44]. Based on Indonesian Broadcasting Plan Development 2014-2019 documents, national broadband targeted to provide fixed access infrastructure in urban areas for 71% of households with broadband speeds reaching up to 20 Mbps, and 30% of the population. Meanwhile in rural areas can reach as much 49% of households with speeds of up to 10 Mbps and 6% of the population. Unfortunately, the broadband development realization until 2017 is still low. Based on data from the Directorate of Broadband Development the achievements of fixed broadband development in 2017 has only been reached 9.38% of households and 9.62% of the population [40]. To accelerate the development of fixed broadband, the improvement strategy is needed in its management.

Table 3. Comparison of NBNs of four countries: India, Malaysia, Australia, and Indonesia [42].

Country	**Cost to Government (billion USD)**	**Implementation Entity**	**Scope of Project**	**Open Access**	**Timely Implementation**
India	4	BSNL SPV	Fiber connectivity from Block to 250,000 Gram Panchayat	Condition being discussed, Tariff on web	Delayed (expected completion on 2016)
Malaysia	0.75	TM (selected with no tender process, other operators not considered) PPP	FTTH in high industrial areas	No transparent condition, but other operators have signed up	Phase 1 completed on time in 2010. High take-up of 43% by 2012
Australia	40	NBN Co Wholesale only SPV	Multi-technology connectivity of whole country through FTTX, fixed wireless and satellite	Clear legislation on non-discriminatory open access and transparent pricing	Delayed (expected completion on 2019)
Indonesia	1	PT Telekom (no tender process)	Fiber backhaul connectivity of Eastern non-commercial cities	Conditions have not been agreed	Delayed (expected completion on 2015)

Table 4. Indonesia Broadband Plan (IBP) Targets [44].

Infrastructure Access	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Urban						
Fixed (HH)	3 Mbps	3 Mbps	3 Mbps	5 Mbps	10 Mbps	20 Mbps

Mobile	512 Kbps	512 Kbps	1 Mbps	1 Mbps	1 Mbps	1 Mbps
Rural						
Fixed (HH)	1 Mbps	2 Mbps	2 Mbps	3Mbps	5 Mbps	10 Mbps
Mobile	128 Kbps	256 Kbps	512 Kbps	512 Kbps	1 Mbps	1 Mbps
FO Backhaul						
Districts	75%	80%	85%	100%	100%	100%
Rural	45%	60%	705	80%	100%	100%
FO Backbone						
Districts	75%	85%	100%	100%	100%	100%
Rural	50%	75%	85%	100%	100%	100%

The Republic of Korea, Japan, and most OECD (The Organization for Economic Cooperation and Development) countries that lead in term of broadband penetration, have their specific broadband strategies. Such as Japan, developed its E-Japan strategy in 2001 and has updated it several times. Korea has developed broadband policy since the mid-1980 that has been described in six main plans. High-level political leadership and support were also critical to raising awareness about the urgency of national broadband projects. This is one of the key success factors for Korea's broadband policy implementation that convincing the president and National Assembly of the importance of the digital society and broadband adoption. Furthermore, they generated a strong will to expand the market and made efforts to persuade citizens and businesses to recognize the benefits of broadband [37]. The remarkable speed of Korea's broadband market development was triggered by government supporting as described above. In 1998, broadband services were first launched in Korea. By 2000 its broadband penetration rate was the highest in the world. By June 2009, there were 15.9 million fixed broadband subscribers, equating to a household penetration rate of 94%. From 2000 until late 2002, Korea experienced one of the most rapid rises in broadband penetration in the world, with the number of subscribers increasing by 200% and the household penetration rate increasing from 27% to 69%. From this Korea's development of fixed broadband networks, there are a number of key lessons developing countries can learn with points below [37]:

a. The intervention programmes of government at several levels, including industry structure, infrastructure, research, competition, user awareness and ICT education.

b. Long-term interventions focused predominantly on opportunity generation rather than direct public investment to accelerate of the sectoral growth.

c. The power of Korean Government direction and free market competition working in parallel. The Government also has actively encouraged intense competition between broadband access providers.

4.7 Facilitating Equitable Access for All

Providing broadband in rural areas poses significant economic and technical challenges. Ensuring equitable access for all is a major role of governments in broadband markets. Once broadband use reaches a critical mass, it starts being considered indispensable for all. For this purpose, many governments have taken an active approach by stimulating network rollout in rural and underserved areas. As public and private services are increasingly provided online, the inability of some population groups to access broadband becomes a serious public policy problem. At this situation, balanced development cannot be achieved because of discrimination based on location. This challenge has led governments to consider a more active approach to ensuring that broadband is available throughout their territories. Broadband strategies typically include goals for broadband coverage, access, and service quality. Thus, the growth of the broadband market not only focused in urban centers, but also in rural and underserved areas.

Korea has adopted a comprehensive broadband strategy focused on providing operators with financial incentives to invest in their networks (ITU 2003), by setting the goals of reaching connection speeds of at least 1 gigabit per second (1 Gbps) by 2012 and this strategy has triggered the acceleration of Korea Broadband Development [37].

4.8 Expand Universal Service Programs for Network Rollout in Rural and Underserved Areas

In some countries, including Korea, broadband services are already universal. Other countries are also moving to achieve universal broadband, by using policies focused on rural areas and underserved groups. Government funding providing through grants, loans, loan guarantees, and tax incentives for infrastructure deployment such as fiber optic cables, conduits, poles, ducts, roof tops, wireless transmission towers, and co-location space. For diffusing broadband to rural areas and underserved areas, many countries are making the policies complementary by differentiate it into three categories [37]:

a. The first policy type: using regulations. Governments require the dominant incumbent to develop a nationwide network that provides services to rural areas and underserved groups. This first approach is usually implemented in parallel with the second policy.

b. The second policy type: under which the government offers subsidies or compensation. In Korea, Korea Telecom is the dominant provider committed to constructing networks in rural areas of a certain scale without government support and expanding networks in remote areas with a certain level of subsidies.

c. The third policy type: Involves the central governments, the local government, or public organizations directly in network construction and service delivery. This type of government intervention can cut transaction costs because it skips complicated procedures, including auctions of provider rights. But such direct government intervention may distort the market.

4.9 Evolution of Broadband Strategies

In-line with the increasing of services and the competitiveness of markets, the role of government evolves from market promotion (to oversight) to universalization of service. At the beginning stage, government focus on supply side promotion combined with competition regulation to ensure that markets remain efficient. Yet as broadband markets grow, the next stages strategies will have to focus more on universalization, ensuring that broadband is used widely. As the range of applications and types of content available increase, so too must the approach of government change in overseeing, promoting, and universalizing broadband. Broadband strategies may also evolve as markets undergo qualitative evolution in the level of broadband services. From now on, the problem will be focus on the use of always-on services such as broadband, as well as the trend toward devices and networks with higher power consumption. Hence, even though first-generation broadband services might be universalized, higher-quality services might be the focus of promotion policies.

4.10 Governments provide up-front support to reduce providers' investment costs

Network construction is the highest entry barrier in the communications industry, requiring significant financial resources. Civil works (e.g. trenches, ducts, and cables) are the biggest fixed and sunk cost in broadband network construction in both the access and the backbone segments of fiber-optic networks. The complete broadband network consists of international connectivity, the domestic backbone network, and the subscriber access network. Construction of domestic and international backbone networks is essential to ensure that high-quality, low-cost connectivity is available domestically and internationally. Initially it might to avoid investing in backbone networks because they are unsure of the returns on their investments. They also play a major role in increasing the cost of network deployment for new service providers as well as incumbents [37]. The role of government in telecommunication infrastructure provision is important in developing countries as weak demand and high deployment cost exists, limit private initiative. As ICT infrastructure is substantial, some local government implemented a local broadband initiative to provide access both to internal demand as well as public services. The local autonomy Act also grants local government broad authority on regulating the broadband development. The initiative mostly has a positive impact even though some practice hinders broadband expansion, considering the variance of regulation increased administrative cost as well as mandated monopoly in some area. Numerous policy options are available for countries looking to develop their backbone connectivity. Governments can provide up-front support to reduce risks or act as an anchor tenant to induce investment. The costs of backbone network construction can be cut by establishing legal grounds for open access to the passive infrastructure (conduits, ducts, and poles) of other services (roads, railways, and power supply facilities). This approach can significantly lower the cost of rolling out telecommunications networks, because adding communications equipment (such as cables) to other infrastructure projects is relatively cheap. In Korea, projects connected organizations such as public offices and educational institutes under the government's direction [37]. This approach reduced risks for businesses and promoted backbone network investment. It also established a base for e-government and information society. Korea's experience in this regard can serve as a reference for many other countries. It is also appropriate that the government allowed service providers to own and manage the network, which the government paid for and used, because doing so reduced government intervention in an area (management) that it could not cover and strengthened its regulatory role. Less direct measures, such as providing investors with tax benefits, low-interest, and long-term loans, can also promote investment in network development.

5. Conclusion And Recommendation

The main driver behind the internet traffic growth is the needs of bandwidth. With the increased need for higher bandwidth to support the triple play services (voice, data, and video), optical transmission is getting more popular in the access network. One of the great solutions for the needs of bandwidth is FTTX technologies. Optical access networks are also referred to PON technologies as *Fiber to the X* (FTTX) network, where the X stands for the termination of the optical transmission, e.g. Fiber to the Home (FTTH), Fiber to the Building (FTTB), Fiber to the Curb (FTTC), Fiber to the Neighborhood (FTTN), etc. Multiple competing technologies exist that are capable to deliver optical access connectivity to customers [45]. Currently, the implementation of FTTX concept and applications in Indonesia are limited to fixed broadband services. Fixed broadband services penetration in Indonesia is still in the level of below 3% of all population. In terms of FTTX development, Huawei company gave the FTTX supply in Indonesia a score of 2 out of 10. It means that the growth of Indonesia FTTX services are still underdeveloped. Several mature and standardized optical access network technologies are available for network operators providing broadband services, being now in deployment phase; therefore, cost estimation, business analysis, efficient deployment strategies, network and topology design issues for FTTX access networks play an increasingly important role regarding profitability and market success [45]. Indonesian government deployed the Palapa Ring project with aims to deploy the fiber optic backbone connecting all Indonesian islands. However, the rural areas of the country which consists of over 17,000 islands is still the geographical barrier that increased the deployment cost. Although the National Broadband Networks (NBN) Plan mentioned about the wireless broadband targets, but the main focus seems to be on providing the fixed broadband. Therefore, FTTX is still a very feasible option to be launched to satisfy the needs of Indonesian connectivity in the future. In our point of view, cost estimation and techno-economic analysis is strongly related to strategic network design: among others the uneven population density, irregular street system or infrastructure have significant impact to the network topology, and thus the deployment costs as well.

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