Technical Report

A Pre-Feasibility Study on the Asia-Pacific Information Superhighway in the ASEAN Sub-region: Conceptualization, International Traffic & Quality Analysis, Network Topology Design and Implementation Model

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Glossary

4G LTE
4th Generation Long Term Evolution LTE, an abbreviation for Long-Term Evolution, commonly marketed as 4G LTE, is a standard for wireless communication of high-speed data for mobile phones and data terminals. The standard is developed by the 3GPP (3rd Generation Partnership Project)

AS Number Autonomous System Number
Within the Internet, an autonomous system (AS) is a collection of connected Internet Protocol (IP) routing prefixes under the control of one or more network operators on behalf of a single administrative entity or domain that presents a common, clearly defined routing policy to the Internet. ISP must have an officially registered autonomous system number (ASN). A unique ASN is allocated to each AS for use in BGP routing. AS numbers are important because the ASN uniquely identifies each network on the Internet

BGP Border Gateway Protocol
Border Gateway Protocol (BGP) is a standardized exterior gateway protocol designed to exchange routing and reachability information between autonomous systems (AS) on the Internet

ccTLD Country code Top-Level Domain
A country code top-level domain (ccTLD) is an Internet top-level domain generally used or reserved for a country, a sovereign state, or a dependent territory. All ASCII ccTLD identifiers are two letters long, and all two-letter top-level domains are ccTLDs

CDN Contents Delivery Network
A content delivery network or content distribution network (CDN) is a large distributed system of servers deployed in multiple data centers across the Internet. The goal of a CDN is to serve content to end-users with high availability and high performance. CDNs serve a large fraction of the Internet content today, including web objects (text, graphics and scripts), downloadable objects (media files, software, documents), applications (e-commerce, portals), live streaming media, on-demand streaming media, and social networks.

DNS Domain Name System
The Domain Name System (DNS) is a hierarchical distributed naming system for computers, services, or any resource connected to the Internet or a private network. It translates domain names, which can be easily memorized by humans, to the numerical IP addresses needed for the purpose of computer services and devices worldwide. The Domain Name System is an essential component of the functionality of most Internet services because it is the Internet's primary directory service.

HFC Hybrid Fiber Coaxial
Hybrid fibre-coaxial (HFC) is a telecommunications industry term for a broadband network that combines optical fiber and coaxial cable. It has been commonly employed globally by cable television operators since the early 1990s.

IPTD IP Packet Transfer Delay

IP Packet transfer delay is a concept in packet switching technology. The sum of store-and-forward delay that a IP packet experiences in each router gives the transfer or queuing delay of that packet across the network. IP Packet transfer delay is influenced by the level of network congestion and the number of routers along the way of transmission

PEERING

In computer networking, peering is a voluntary interconnection of administratively separate Internet networks for the purpose of exchanging traffic between the users of each network. The pure definition of peering is settlement-free, "bill-and-keep," or "sender keeps all," meaning that neither party pays the other in association with the exchange of traffic; instead, each derives and retains revenue from its own customers.

An agreement by two or more networks to peer is instantiated by a physical interconnection of the networks, an exchange of routing information through the Border Gateway Protocol (BGP) routing protocol

MPLS-TP Multi-Protocol Label Switching-Transport Profile

Multiprotocol Label Switching - Transport Profile (MPLS-TP) is a variant of the MPLS protocol that is used in packet switched data networks. MPLS-TP is designed for use as a network layer technology in transport networks. It will be a continuation of the work started by the transport network experts of the ITU-T. MPLS-TP will provide service providers with a reliable packet-based technology that is based upon circuit-based transport networking

MRTG Multi Router Traffic Grapher

The Multi Router Traffic Grapher, or just simply MRTG, is free software for monitoring and measuring the traffic load on network links. It allows the user to see traffic load on a network over time in graphical form

MSPP Multi Service Provisioning Platform

Multi-service provisioning platform or MSPP equipment has all the capabilities of legacy add drop multiplexers, but can also include cross-connect functionality to manage multiple fiber rings in a single chassis. These devices can replace multiple legacy ADMs and also allow connections directly from Ethernet LANs to a service provider's optical backbone

NAP Network Access Point

A Network Access Point (NAP) was a public network exchange facility where Internet service providers (ISPs) connected with one another in peering arrangements. The NAPs were a key component in the transition from the 1990s NSFNET era (when many networks were government sponsored and commercial traffic was prohibited) to the commercial Internet providers of today. They were often points of considerable Internet congestion

NTP Network Time Protocol

Network Time Protocol (NTP) is a networking protocol for clock synchronization between computer systems over packet-switched, variable-latency data networks. NTP is intended to synchronize all participating computers to within a few milliseconds of Coordinated Universal Time (UTC).

OADM Optical Add Drop Multiplexer

An optical add-drop multiplexer (OADM) is a device used in wavelength-division multiplexing systems for multiplexing and routing different channels of light into or out of a single mode fiber (SMF). This is a type of optical node, which is generally used for the construction of optical telecommunications networks. "Add" and "drop" here refer to the capability of the device to add one or more new wavelength channels to an existing multi-wavelength WDM signal, and/or to drop (remove) one or more channels, passing those signals to another network path. An OADM may be considered to be a specific type of optical cross-connect.

OAN Open Access Network
An open-access network (OAN) refers to a horizontally layered network architecture in telecommunications, and the business model that separates the physical access to the network from the delivery of services. In an OAN, the owner or manager of the network does not supply services for the network; these services must be supplied by separate retail service providers. There are two different open-access network models: the two- and three-layer models. In the two-layer OAN model, there is a network owner and operator, and multiple retail service providers that deliver services over the network. In the three-layer OAN model the physical layer—the fiber or wireless infrastructure—is owned by one company, the operations and maintenance of the network and the provision of services is run by a second company, and the retail service providers provide the third layer.

OSI Open System Interconnection
The Open Systems Interconnection model (OSI Model) is a conceptual model that characterizes and standardizes the communication functions of a telecommunication or computing system without regard of their underlying internal structure and technology. Its goal is the interoperability of diverse communication systems with standard protocols. The model partitions a communication system into abstraction layers. The original version of the model defined seven layers. The model is a product of the Open Systems Interconnection project at the International Organization for Standardization (ISO), maintained by the identification ISO/IEC 7498-1.

OTH Optical Transport Hierarchy
ITU-T defines an Optical Transport Network (OTN) as a set of Optical Network Elements (ONE) connected by optical fiber links, able to provide functionality of transport, multiplexing, switching, management, supervision and survivability of optical channels carrying client signals. OTN was designed to provide support for optical networking using wavelength-division multiplexing (WDM) unlike its predecessor SONET/SDH. ITU-T Recommendation G.709 is commonly called Optical Transport Network (OTN) (also called digital wrapper technology or optical channel wrapper). As of December 2009 OTN has standardized

PBB Provider Backbone Bridges
Provider Backbone Bridges (PBB; known as "mac-in-mac") is a set of architecture and protocols for routing over a provider's network allowing interconnection of multiple Provider Bridge Networks without losing each customer's individually defined VLANs. It was initially created by Nortel before being submitted to the IEEE 802.1 committee for standardization. The final standard was approved by the IEEE in June 2008 as IEEE 802.1ah-2008

POP Point of Presence
A point of presence is an artificial demarcation point OR interface point between communicating entities. An Internet point of presence is an access point to the Internet. It is a

physical location that houses servers, routers, switches and digital/analog call aggregators. It may be either part of the facilities of a telecommunications provider that the Internet service provider (ISP) rents or a location separate from the telecommunications provider. ISPs typically have multiple PoPs, sometimes numbering in the thousands.[citation needed] PoPs are also located at Internet exchange points and colocation centres. This term became important during the court-ordered breakup of the Bell Telephone system. A point of presence was a location where a long-distance carrier (IXC) could terminate services and provide connections into a local telephone network (LATA).

TCP/IP Telecommunication Protocol/Internet Protocol

TCP/IP provides end-to-end connectivity specifying how data should be packetized, addressed, transmitted, routed and received at the destination. This functionality is organized into four abstraction layers which are used to sort all related protocols according to the scope of networking involved. Transmission Control Protocol (TCP) and the Internet Protocol (IP), were the first networking protocols defined in the standard

UTP Unshielded Twisted Pairs

UTP cables are found in many Ethernet networks and telephone systems. For indoor telephone applications. UTP cable is the most common cable used in computer networking. Modern Ethernet, the most common data networking standard, can use UTP cables. Twisted pair cabling is often used in data networks for short and medium length connections because of its relatively lower costs compared to optical fiber and coaxial cable.

VLAN Virtual Local Area Network

In computer networking, a single layer-2 network may be partitioned to create multiple distinct broadcast domains, which are mutually isolated so that packets can only pass between them via one or more routers; such a domain is referred to as a virtual local area network, virtual LAN or VLAN.

VoIP Voice over Internet Protocol

Voice over IP (VoIP) is a methodology and group of technologies for the delivery of voice communications and multimedia sessions over Internet Protocol (IP) networks, such as the Internet. Other terms commonly associated with VoIP are IP telephony, Internet telephony, broadband telephony, and broadband phone service. The term Internet telephony specifically refers to the provisioning of communications services (voice, fax, SMS, voice-messaging) over the public Internet, rather than via the public switched telephone network (PSTN). The steps and principles involved in originating VoIP telephone calls are similar to traditional digital telephony and involve signaling, channel setup, digitization of the analog voice signals, and encoding. Instead of being transmitted over a circuit-switched network, however, the digital information is packetized, and transmission occurs as IP packets over a packet-switched network.

WDM Wavelength Division Multiplexing

Wavelength-division multiplexing (WDM) is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e., colors) of laser light. This technique enables bidirectional communications over one strand of fiber, as well as multiplication of capacity. The term wavelength-division multiplexing is commonly applied to an optical carrier (which is typically described by its wavelength), whereas frequency-division multiplexing typically applies to a radio carrier (which is more often described by frequency).

xDSL x Digital Subscriber Line
Digital subscriber line (DSL; originally digital subscriber loop) is a family of technologies that are used to transmit digital data over telephone lines. In telecommunications marketing, the term DSL is widely understood to mean asymmetric digital subscriber line (ADSL), the most commonly installed DSL technology, for Internet access. DSL service can be delivered simultaneously with wired telephone service on the same telephone line here x means "any" , for example, at HDSL H means "high bit rate".

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Executive Summary

The Asia Pacific Information Superhighway (hereinafter referred to AP-IS) could be defined as the cross-border, intra- and inter-regional broadband infrastructure which mainly consists of broadband network links and nodes. AP-IS links are mainly composed of fiber optic cables, ducts and conduits that cross neighboring countries, sub-regions and inter-regions. AP-IS nodes are geographical locations of submarine cable landing stations, terrestrial cross-border connection points and Internet traffic exchange points (IXPs) that provide broadband Internet connection and traffic exchange.

For seamless, affordable and reliable regional broadband connectivity, well-balanced sea/land-based connectivity and the Internet traffic exchange connectivity are both essential. In consideration of the massive landlocked areas and the significant weakness of the land-based connectivity in the region compared to the well-developed sea-based network driven by the market, it is required to enhance the regional terrestrial broadband network connectivity which can increase network stability and direct connectivity between neighboring countries. To this end, deployment, expansion and integration of the terrestrial backbone network at cross-border, intra- and inter-regional levels could be implemented in collaboration with member countries as a regional ICT development initiative.

As a result of the Internet traffic measurement of the international paths (backbone trunk lines), which was conducted in early 2015 in order to assess the quality of the backbone network and Internet traffic exchange connectivity among ASEAN countries, some significant figures were observed. The worst case of the assessment showed the international backbone trunk line download speed of 0.15Mps, latency of 230msec and Tromboning Index[1] of 35. The best case showed the download speed of 50.1Mps, latency of 7.5msec and Tromboning Index of 1. All these cases indicate that there is a significant difference in the Internet connectivity and quality even within the ASEAN region, which seems to be caused by the fact that the backbone network connectivity and the Internet traffic exchange and management systems in the region are significantly inefficient.

	Download speed	Latency	Tromboning Index
Worst	0.15Mbps	230msec	35
Best	50.1Mbps	7.5 msec	1

* msec: millisecond

In order to reduce the extreme level of Internet traffic tromboning and transit cost and to improve service quality, the regional backbone network connectivity should be improved in parallel with efforts to establish a sufficient numbers of IXPs at domestic and sub-regional levels. Principles and norms on IXP operation and traffic management are also needed.

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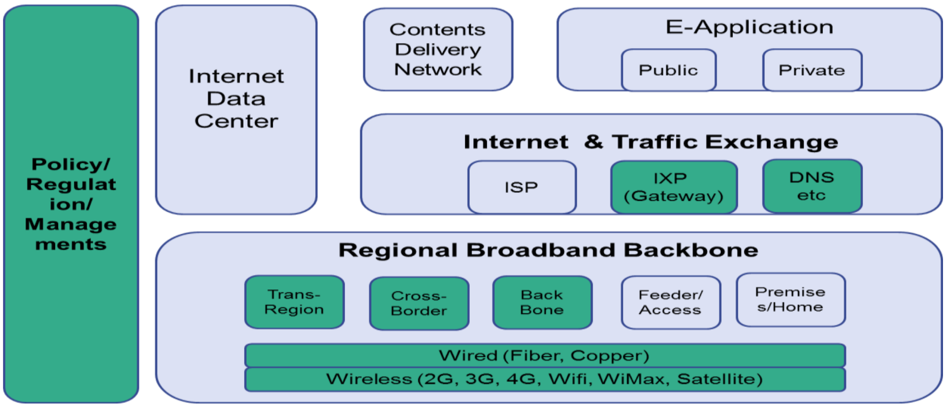
[1] Tromboning Index is defined as Internet routing distance/straight line distance from the source to the destination of a packet.

Such improvements in the regional broadband backbone network and the Internet exchange connectivity ultimately lead to enhanced quality of cross-border, inter and intra-regional Internet services. Therefore, it would be necessary to set goals for some key indicators – regional backbone network speed (up/down), latency, Tromboning Index, and transit price – with constant monitoring on the progress required. Globally recommended standards for these indicators are shown in the table below.

Key Indicator	Recommended Level	Remark
International backbone network speed (or bandwidth)	Min 25Mbps	Refer to FCC
International backbone network latency	Max 0.1 sec	ITU-T Standard
Tromboning Index	Max 5	As recommended by this study
Transit price	Max US $ 2 / Mbps	* Tier 1 transit price, in mature market as of 2014

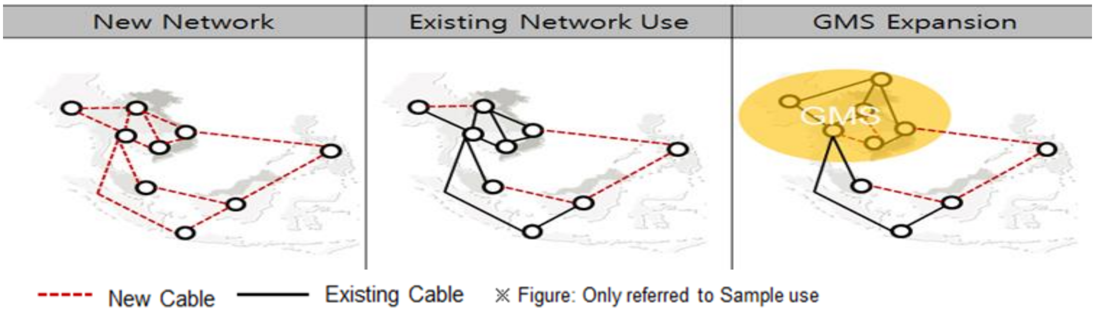
*http://drpeering.net/AskDrPeering/blog/articles/Ask_DrPeering/Entries/2013/10/25_2014_Transit_Prices_and_Peering_Projections.html

Efficient provision of the broadband services requires a hierarchical ecosystem as shown in the figure below, where the core components of AP-IS are in darker shades. The components for regional broadband backbone connectivity include regional, cross-border, and domestic backbone; the components for Internet traffic exchange connectivity include IXPs for efficient exchange and management of Internet traffic, domain name servers, routing management systems, and traffic monitoring systems, as well as capacity development for personnel who are operating such systems. In this regard, a discussion could start among ASEAN member countries in terms of achieving the two types of connectivity at the regional level, and large-scaled investments to ICT infrastructure should be made through the AP-IS initiative.



This report suggests the following network designs for regional backbone network connectivity from the perspective of the pre-feasibility study. There are roughly three options in deploying the regional terrestrial broadband network connectivity; (a) use the existing infrastructure, (b) build a new one, and (c) expand the GMS (Great Mekong Sub-region) network.

As most of the countries in the region have already established or are in the process of planning cross-border fiber connectivity, there is little need for drawing a new route, civil engineering and conduits installation works for separate physical network. Instead, it would be necessary to expand the capacity to meet the targeted quality level, install more fibers and introduce new transmission and switching technologies.



In selecting regional hubs or center nodes for stability and efficiency, important factors to be considered are geographical location, domestic infrastructure, traffic production amount and international connectivity. Thailand, Viet Nam and Singapore could be selected as candidates for intra-ASEAN center nodes reflecting the above mentioned factors.

This report also suggests establishing regional Internet traffic exchange connectivity which can effectively and efficiently route Internet traffic among countries. To keep the local traffic within the border, intra-regional (or cross-border) traffic exchanged at the regional exchange points, inter-regional traffic passed through the regional gateway points (or nodes), and to keep the cost of traffic lower, the most important aspect is to design an optimal topology and establish sufficient IXPs in the region.

At least three Neutral Regional IXPs connected to each other by dual ring will be required; each IXP aggregates sub-regional (South, East, and West) traffic, and has direct links to global transit points which is located out of the region. Governing organizations for IXP operation and long-term cooperation would also be needed. The IXP operation model thus recommended is a mix of Euro and US models with the condition of principles, open, neutral, and non-discriminatory manners. For a stable interconnection with countries in/out of the region as well as with other continents namely Europe and North America, the establishment of multiple POPs associated with Neutral Regional IXPs is, therefore, recommended.

This study has been assessed the *status quo* in the region and suggested some urgent actions within the AP-IS initiative. Actual investments on infrastructure could be followed in order to contribute to improving the ICT connectivity in this region. A resolution on the AP-IS initiative was adopted in the 71st UN ESCAP Commission in 2015, based upon which the AP-IS Working Group was established with experts nominated by the member countries. This report has endeavored to suggest the best action plans focusing on the ASEAN sub-region. It further needs to be reviewed and to give shape to a plan through discussions at the AP-IS Working Group meeting.

1. Conceptualization

1.1 Introduction

In July 2014, UN ESCAP and NIA (National Information society Agency), a Korean ICT agency specialized in ICT planning and policy development, came to an agreement to conduct a 'Pre-feasibility study on the Asian Pacific Information Superhighway (AP-IS) in the ASEAN sub-region' from August 2014 to July 2015. The objectives of the study are to

a) provide concrete and possible configurations and concept of AP-IS;
b) conduct a gap analysis between 'as-is' and 'to-be' of international connectivity for more universal, affordable, and reliable international connectivity in the sub-region;
c) recommend potential AP-IS network topology for the ASEAN sub-region; and
d) recommend AP-IS implementation models.

The team composed of NIA experts conducted the following two main diagnostic activities:

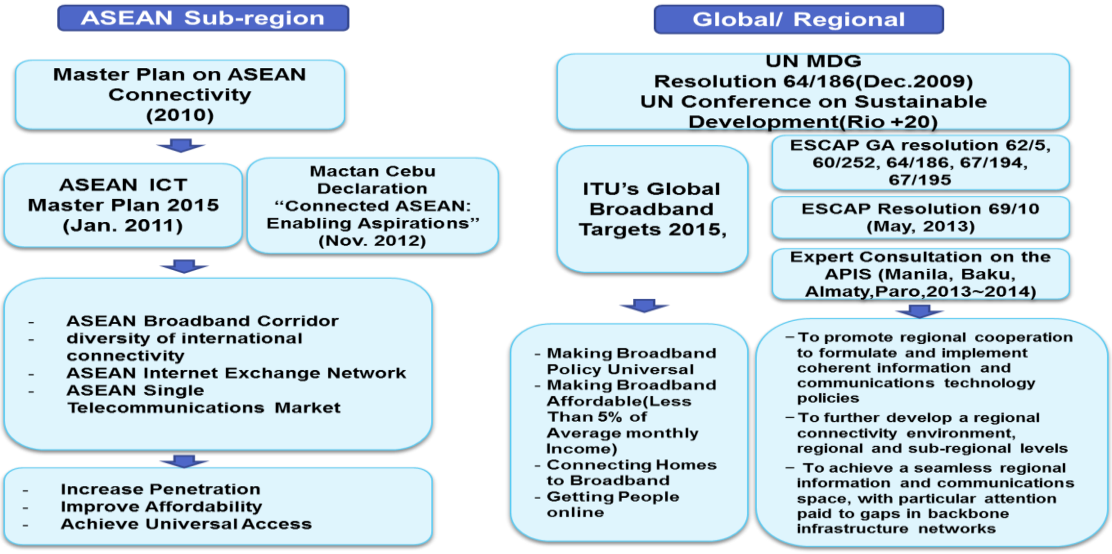
a) international Internet traffic and quality measurement in the ASEAN sub-region - traffic routes, speed, and latency; and
b) Paper survey on international connectivity issues from each government, ISPs of the ASEAN countries and private sector organizations.

This report endeavors to define and conceptualize the AP-IS and its goals, topologies and implementation models. Also by conducting a gap analysis based on the current status of the region, it aims to serve as a reference guide for developing strategies and their implementation.

1.2 History and Key topics

In 2013, ESCAP member countries highlighted that regional information and communications technology connectivity and building knowledge-networked societies in Asia and the Pacific was one of the key priorities in the Asia Pacific region (UN ESCAP resolution 69/10 in 2013). In this regard, ESCAP and Terabit Consulting conducted 'An In-Depth Study on the Broadband Infrastructure in the ASEAN-9 Region' in 2013 and identified many broadband inequalities in the region. The importance of the information superhighway of the ASEAN region has been constantly emphasized by many international organizations like ASEAN Community, ESCAP, and ITU with specific plans already made [Figure 1-1]. Each country in the region is making an effort towards enhanced ICT connectivity by establishing and updating its own ICT master plan. However, the broadband penetration in this region is still very low, with large gaps between countries. Therefore, it is important to make a plan that can be commonly adaptable across the region and to enhance collaboration among the countries.

[Figure 1-1] History of ICT Development in the ASEAN region



After collecting and categorizing key topics for ICT infrastructure development in the ASEAN region, the team extracted the keywords largely into five areas – Geo-spatially balanced connectivity, regional internet (IP) connectivity, low cost and broadband affordability, open access and network neutrality, and policy universality as shown in [Table 1-1].

These key topics need to be considered as a common fundamental basis for selecting strategies and action items to be implemented and essentially supported by each country.

[Table1-1] Key topics

· Diversity of international connectivity · Seamless Infrastructure Networks and Backbone, Reliable Network · Well balanced Network · Fully integrated and coherent mesh configuration; · Uniform construction and use of Asian Highway, Trans-Asian railway and power transmission · Single uniform network that offers quality-of-service guarantees · Missing Links, Cross Border Connectivity · Judicious mix of land and sea based fiber optic cables	➡	**Geo-spatially Balanced Connectivity**
· ASEAN Internet Exchange Network, ASEAN IXPs · diversity of international connectivity · IP Transit /Peering · Cost of Transport back to the primary exchange · Heavy Reliance on IXP in advanced countries · International Back haul cost · Emergency Communications and Resiliency	➡	**Regional Internet(IP) Connectivity**

· Making Broadband Affordable(Less Than 5% of Average monthly Income) · Connecting Homes to Broadband · Getting People online · Bridge the digital divide within ASEAN · Improve Affordability · Universal Service Achieve/Universal Access · Increase Penetration	➡	**Low Cost and Broadband Affordability**
· Open access and non-discriminatory pricing · Network neutrality and scalability that allows participation by all stakeholders	➡	**Open Access and Network Neutrality**
· Single Telecom Market · ASEAN Single Telecommunications Market · Making Broadband Policy Universal(ITU) · Enabling Environment, Capacity building	➡	**Policy Universality**

1.3 Conceptualization of AP-IS

1.3.1 Focus Areas of the Study

Based on the common key topics that had been identified and extracted by analyzing the plans, recommendations and resolutions, the team came up with some key action items that apply to the ASEAN region. In general, these items can be commonly applied to other sub-regions in Asia Pacific region.

First of all, the geo-spatially balanced connectivity can be achieved by filling in the missing links that have been identified and establish seamless land or sea-based connectivity. Second, the regional Internet (IP) connectivity can be realized specifically by guaranteeing open or public Internet peering and transit and establishing IXPs (Internet Exchange Points) for both local and international traffic connectivity. Third, low cost and the broadband affordability can be achieved through cost reduction by increased number of subscribers, increased investment in network coverage, government initiatives and demand creation, local peering or transit. Fourth, open access and network neutrality can be achieved by non-discriminatory access to fiber backbone and IXP, as well as open access to backhaul network. Last but not the least, policy universality can be achieved through globally acceptable measures for open competition, privatization and regulations.

[Table1-2] Key Action Items for Pan-ASEAN ICT Connectivity and Exchange

Geo-spatially Balanced Connectivity	➡	· Filling the Missing Links identified · Seamless Connectivity land/sea based
Regional Internet(IP) Connectivity	➡	· Open/Public Internet Connectivity · Local IXP Establishment and Peering
Low Cost and Broadband Affordability	➡	· Cost reduction by Increasing Subscribers · Cost reduction by Massive Investment · Gov initiative and demand creation · Cost reduction by Local Peering/Transit

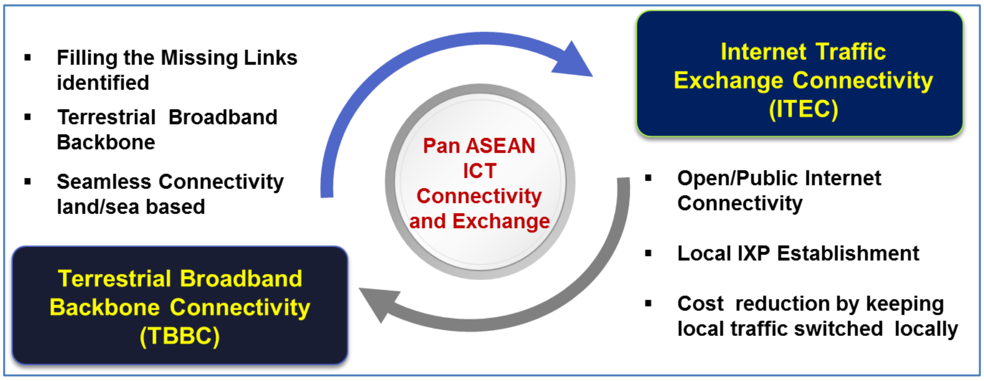
Open Access and Network Neutrality	· Non-Discriminatory Access to Fiber Backbone and IXP · Open Access to Backhaul Network
Policy Universality	· Open Competition & Privatization · Single Policy and Regulation

In order to be more specific, as shown in [Figure 1-2], the team selected two main target areas as Terrestrial Broadband Backbone Connectivity (hereinafter TBBC) and Internet Traffic Exchange Connectivity (hereinafter ITEC) that includes seamless terrestrial network, regional IXPs and low cost & broadband affordability; two other areas – open access & network neutrality, policy universality, which will be further studied in mid and long terms. In fact, each member country of ASEAN is already well aware of the issues related to policy and regulation and therefore, has plans to make policies to tackle those very issues. However, it is likely to take time for each country to actually develop and implement the policies in reality. Moreover, making changes to the existing systems requires process of collecting various opinions of private sector businesses, users, and other stakeholders, which is a challenge for this study to go more in-depth when handling the matter.

Building ICT infrastructure in the ASEAN region is considered as one of the most important projects for the ASEAN community and it has developed and announced the regional ICT masterplan, but actual ICT Infrastructure deployment is carried out in their own way. However, interconnectivity is difficult to be enhanced through efforts individually made by each country in whole region due to the complicated structure of gain and loss between the existing communications service providers; it is likely to be a tough journey from project planning to implementation. Moreover, considering the large gap between broadband Internet penetration and the percentage of Internet price to GDP in ASEAN countries, main areas or tasks of the project should be simplified and commonly applicable.

In this regard, the team finally set the focal areas largely consisting of two main targets – Terrestrial Broadband Backbone Connectivity (TBBC) and Internet Traffic Exchange Connectivity (ITEC). Setting the focal areas simple will make it clear where to focus on and also help with efficient planning. The focal areas are as shown in [Figure 1-2].

[Figure1-2] Focal Area



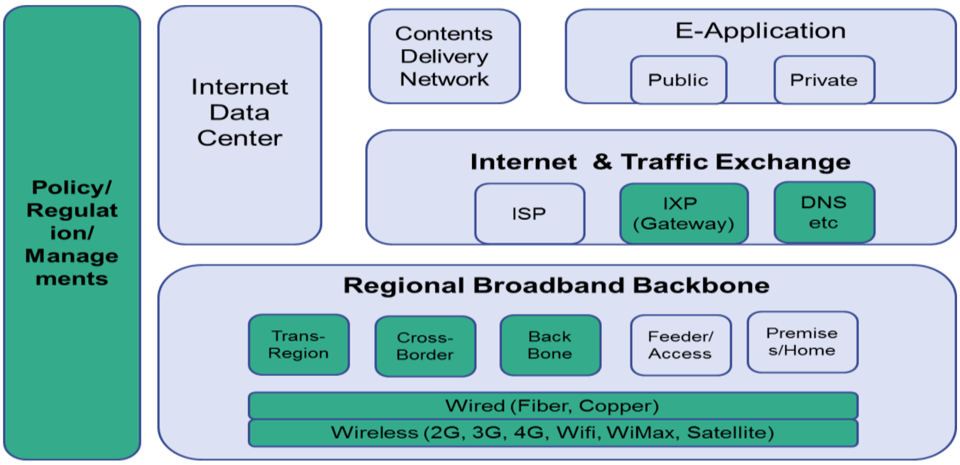
The Master Plan on ASEAN Connectivity of 2010 and ASEAN ICT Master Plan 2015 of 2011, the ASEAN mid-term evaluation in 2013 reveals that "most of infrastructure plans were accomplished, but ASEAN Internet exchange network is at risk." In ESCAP resolution 69/10 of May 2013, member states stated that it is required to "promote and strengthen regional cooperation, and collaborate with international and regional organizations." Many experts also expressed their opinion, stating "missing terrestrial links, submarine dependency, high price and gap, low penetration were observed' and that they "need to follow global norms such as single, uniform, nondiscriminatory, neutral, open access, competition, etc."

Based upon the evaluations made on the current status of ICT infrastructure in the region, the team came up with a strategy or direction named 'Pan-ASEAN ICT Connectivity and Exchange' or simply PACE, for AP-IS development. Some of the implications drawn from the *status quo* evaluations also guide the direction for AP-IS development, signifying that the PACE program should allow network operators and service providers from the very outset to be substantial and implementable in real world, be beneficial for both network operators and subscribers i.e. by ensuring low cost to operators and reasonable price to subscribers, and be enforced by the government of each member country.

1.3.2 Conceptualized Map of AP-IS

Breaking down the Broadband Internet service into components will make it easier to identify what should be done in the future. [Figure 1-3] shows the simplified network categorized into blocks. The physical network infrastructure is positioned at the most bottom layer, above which the Internet service infrastructure that support IP network, such as IXP, DNS (Domain Name Server) and IX supporting systems is positioned, all of which formulate the ecosystem of broadband service. It is necessary to select some of the main components as PACE and develop them in more detail.

[Figure 1-3] Broadband Internet Service Components



The interconnection between national backbone network to subscribers' home or mobile terminals can be largely explained in blocks as illustrated in [Fig 1-4].

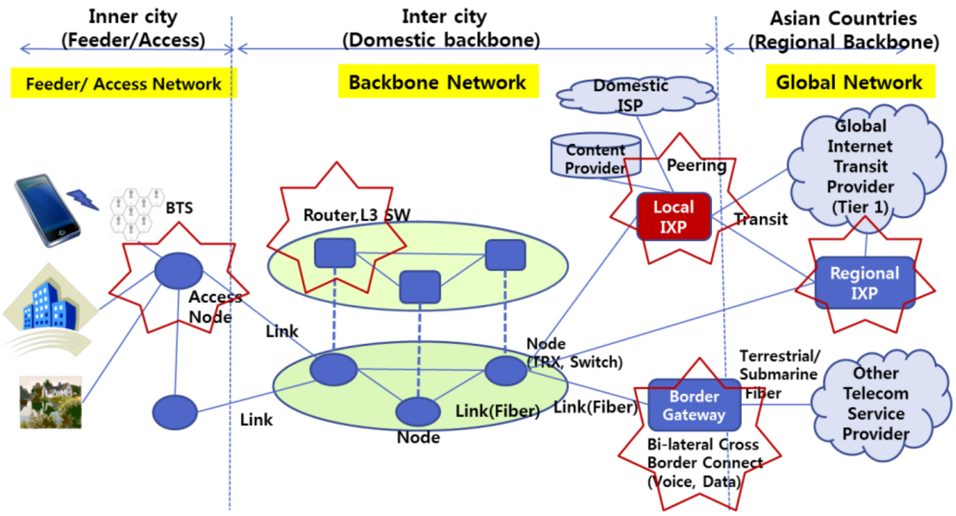
First, the cross-border communication between countries, networks are interconnected through the existing border gateway between countries, and the circuit network is also interconnected along with voice communication network of the past. The voice communication network mostly satisfies the global standard typically set by ITU-T standards and is directly interconnected between countries based upon inter-governmental consensus and standard interfaces.

Second, the IP traffic interconnection is not directly made between countries but rather achieved, either through a global transit provider or direct peering arrangement with neighboring service providers. For a country with low Internet penetration and lack of requirement for direct interconnection with neighboring countries, connectivity to the global Internet has been made through regional IXPs installed by global transit providers.

Third, as for the domestic backbone network, Internet traffic is also exchanged through the upper-level IP network through the existing fiber-based transmission network. Domestic ISPs are directly interconnected or through local IXPs. In some countries, where there is no direct peering among local ISPs, then Internet traffic sometimes tours around and comes back from other continents.

Fourth, the access or feeder network provides the delivery routes from the backbone to the subscriber network. Links among telecom nodes, even in local areas, are mostly made up of fiber-optic cables, and other variety of communication means to connect to the subscribers - FTTx, copper cable, HFC, wireless, or satellite.

[Figure 1-4] Horizontal Interconnectivity Map



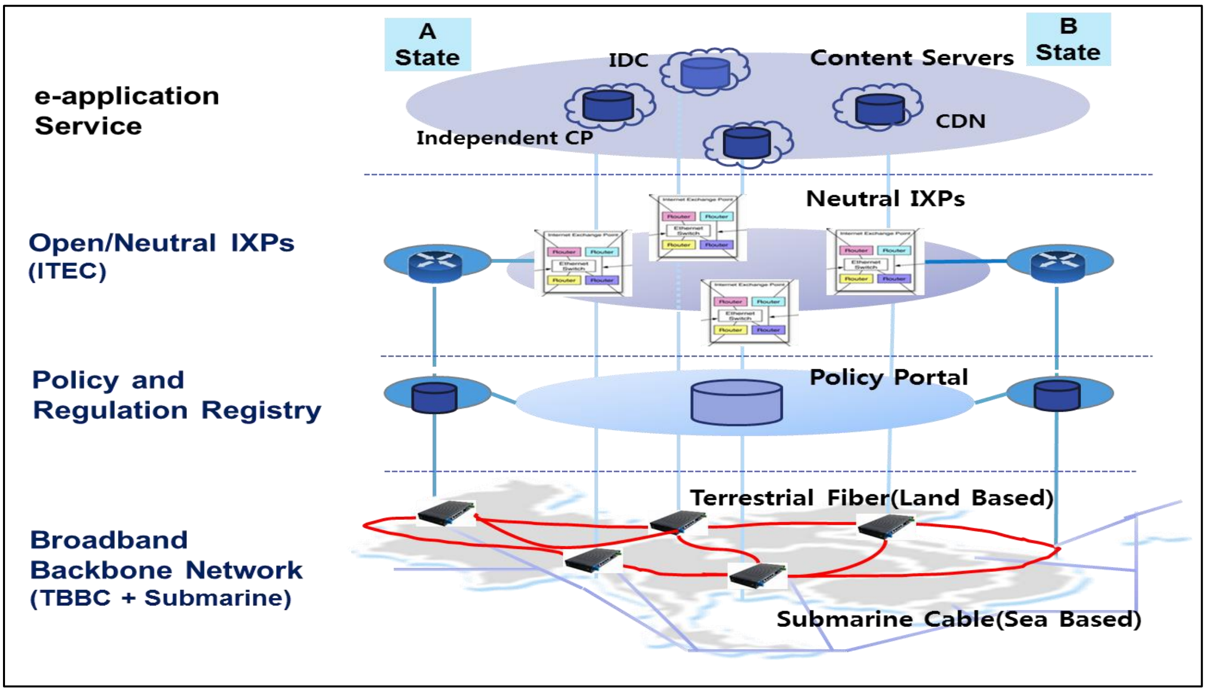
When we talk about network topology, a logical network of AP-IS needs to be considered on top of the geospatial network feature as illustrated in [Fig 1-5]. Even if the physical or geospatial network is interconnected by a link at some point in the border area through fiber, it lacks utility if there is no data flowing through the link. Therefore, AP-IS is fully achievable only when both physical network and logical interconnection are completed, and that each country builds networks to fulfill both requirements.

The team suggests AP-IS Map with the logical layers that make up Telecom Transport Network layer, Policy/Regulation/Governance layer, Internet layer, and e-application layer. The Telecom Transport Network layer at the bottom is made up of well-balanced and seamless submarine, terrestrial fiber networks which are owned by carriers. It should be designed to fill and interconnect missing links. For the Policy/Regulation/Governance layer, for example, special purpose vehicle (SPV) could coordinate IP routing and peering or transit, and collaborate with regulators in the region to set network neutrality and non-discriminatory rights of access to the backhaul. It may create and maintain the policy and regulation registry or database for securing policy universality that updates information and regulations.

The Internet layer, including open neutral IP exchange, ensures domestic neutral IP exchange, regional IP transit, and fiber connectivity between IXPs. The e-application layer serves as the Internet data center, independent contents providers, providing through the content delivery network. For example, the CDN service providers and CPs have very important role to the point that they can reduce cross-border Internet traffic by caching more contents in the local servers. They should be allowed to have direct peering through IXPs because some of them have their network and local Point of Presence (PoP) at the IXPs.

Based on this, AP-IS can be designed as seen in [Fig 1-5]. Main roles of each layer need to be defined in the future, and further discussions are required to achieve AP-IS through collaboration among member countries.

[Figure 1-5] High-level Map of AP-IS



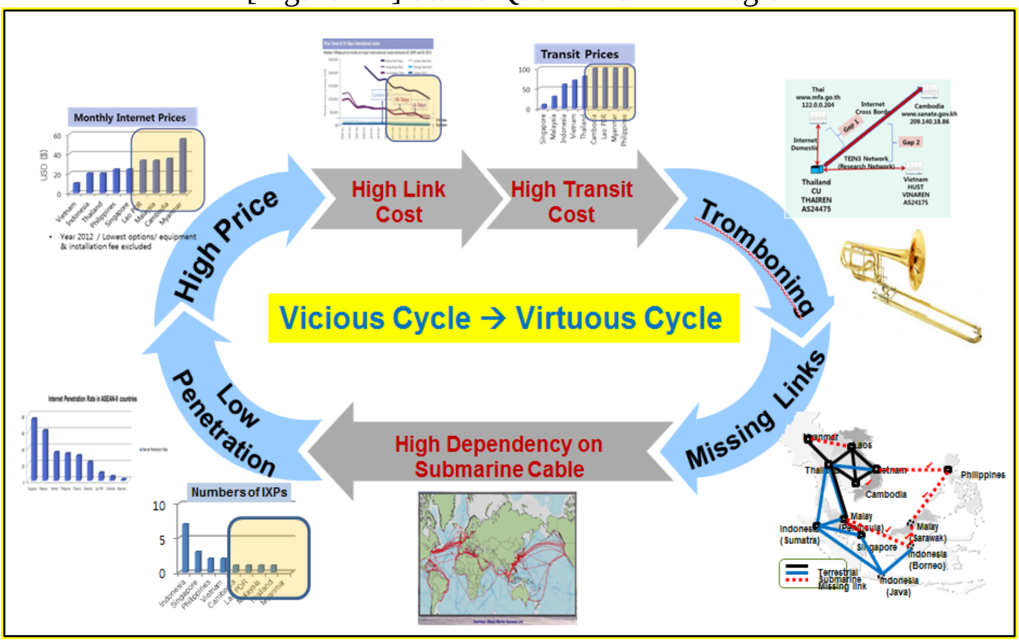
Meanwhile, for landlocked and the least developed countries, which have poor communication infrastructure and may find building a new fiber network is economically taxing. Therefore, using the existing roads, railroads, and dry ports can be an alternative to build a network at reasonable cost. It is generally agreed that the dominant constituent in fibre deployment costs is, by far, civil engineering works. A recent review of available literature shows that in general, close to 80% of the costs for deploying terrestrial fibre networks is associated with digging, trenching and laying down the conduits in which fibre is subsequently laid. Considering the cost of civil engineering work, using the existing dry ports can be a good alternative in terms of economic feasibility. In this case, locating facilities like IXP and IDC in the existing logistics hub can minimize investment into physical facilities. However, cooperation and cost sharing is additionally required with the existing operators of roads, railways, and the power grid.

2. Current Status Analysis and Internet Traffic Measurement

2.1 Overview of Broadband in ASEAN

A desk survey using existing reports and literature was conducted to collect and analyze data on the status quo of the broadband Internet connectivity in the ASEAN region. It was found that there is relatively weak land-based interconnectivity and a high cost or high price structure, which serve as the main hurdles to be overcome.. High price, high link cost, high transit cost, traffic tromboning, missing links, high dependency on submarine cable, and low penetration all influence each other in a cycle.   It means, therefore, improving one segment of the cycle will lead to betterment of the rest, thus turning the vicious cycle to a virtuous one. The [Fig 2-1] well illustrates the cost escalating cycle that is deeply rooted in the region.

[Figure 2-1] Status Quo in ASEAN Region



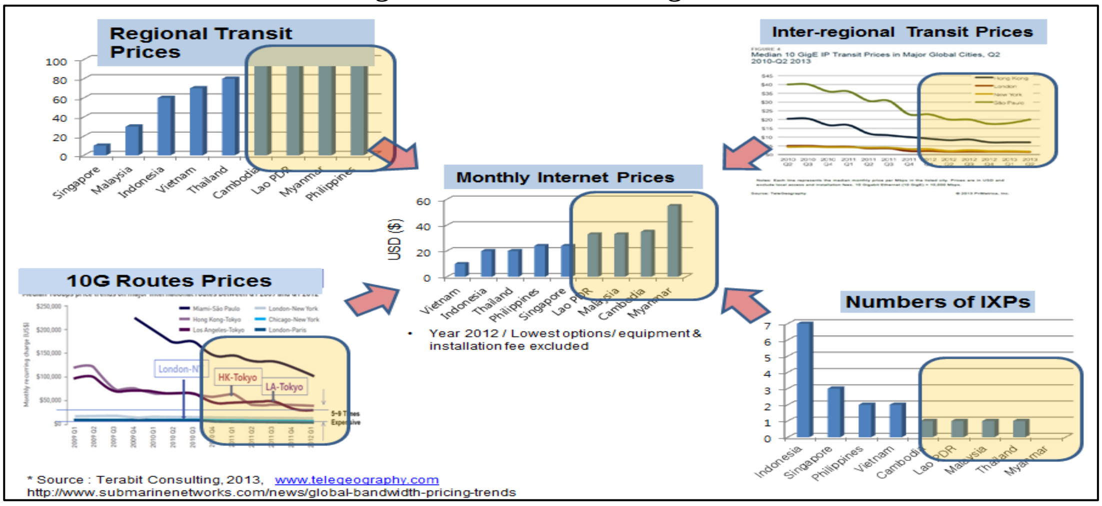
Comparing the price of international routes, 10Gbps prices on intra-Asia routes remain five times the price of comparable connections within the US and up to nine times the price of comparable connections on intra-European routes even though 10Gbps median monthly lease prices on the Los Angeles-Tokyo route fell 37% between Q1 2011 and Q1 2012 according to telegeography[2]. The price of a route connecting London and New York is also

2 Source : www.telegeography.com, http:/www.submarinenetworks.com/news/global-bandwidth-pricing-trends

far cheaper than the price of a route connecting Hong Kong and Tokyo or Los Angeles and Tokyo.

IP transit price in this region also appears to be so expensive that high transit prices may result in high Internet service prices, as shown in [Fig 2-2]. Moreover according to Terabit Consulting, the regional transit prices in some countries like Cambodia, Lao PDR, Myanmar, and the Philippines are ten times more expensive than that of Singapore. High transit prices, high transport cost, and a low level of regional traffic exchange may result in high service prices. This is the problem that the ASEAN region is facing right now.

[Figure 2-2] Structural High Cost

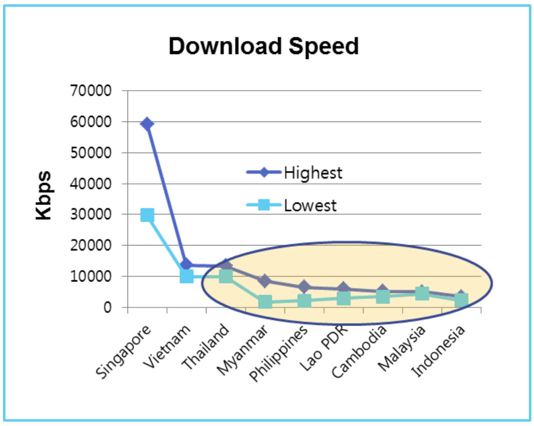


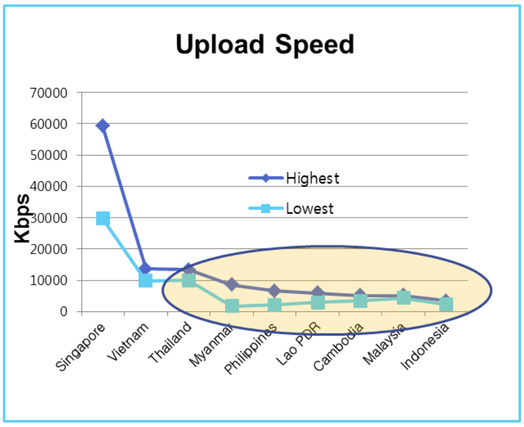
Lack of regional Internet traffic exchanges could result in long traveling distance and time to reach the destination. Especially in countries like Cambodia, Lao DPR, and Myanmar, more Internet exchange points appear to be needed to close the gap with the rest of the countries in the region. Consequently, the lack of Internet exchange points leads to high Internet service prices. In fact, the price gap between Viet Nam and Myanmar is five times.

Speed data from Ookla, a global internet diagnostics company, aggregated by users in their respective regions, are used as a reference when subscribers want to know local service quality in each country. Most of the subscribers in the ASEAN countries are observed to have relatively low-speed level, with big speed gap among the countries. Compared to the speed in Singapore, countries like Indonesia, Myanmar, and the Philippines show a significantly lower download and upload speed level. Average Internet speed in ASEAN as a whole falls below the world average except Singapore and Thailand.

[Figure 2-3] Internet Speed in ASEAN

		Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
Down laod	Highest	5125	3472	5987	5099	8503	6536	59279	13328	13615
	Lowest	3425	2238	2951	4417	1772	2085	29731	9948	9903
Up laod	Highest	5828	1891	6146	4027	6283	2265	43980	4209	11773
	Lowest	3690	974	2786	3428	1260	673	17297	2281	7382





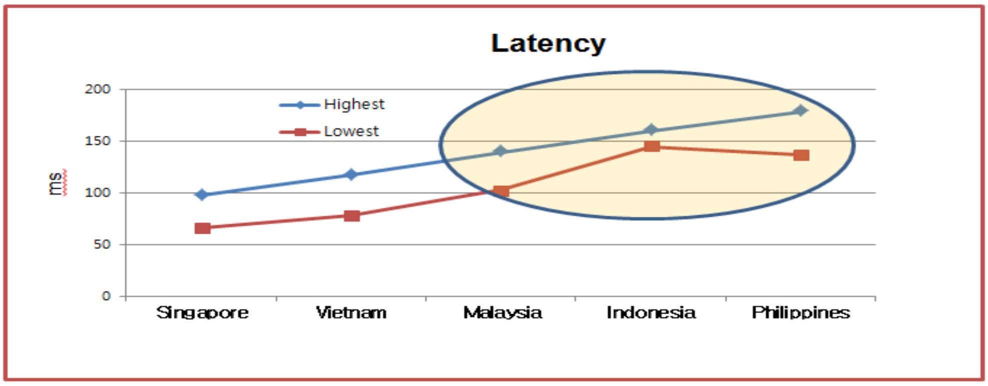
Source: Ookla http://www.speedtest.net/, Based on daily data for a year (2013. 01. 01 ~ 2013. 12.31)

According to the new trend, Internet serves all the telecommunication service including old voice service, the quality of Internet needs to be addressed in analyzing current status in the region too. Quality factors recognized in the industry are speed, latency, loss and routing distance or number of hops from source to destination. A relatively high level of domestic latency was also observed, as shown in Figure 2-4.

[Figure 2-4] Internet Latency

	Indonesia	Malaysia	Philippines	Singapore	Vietnam
Highest	160	139	178	98	117
Lowest	145	103	137	66	78

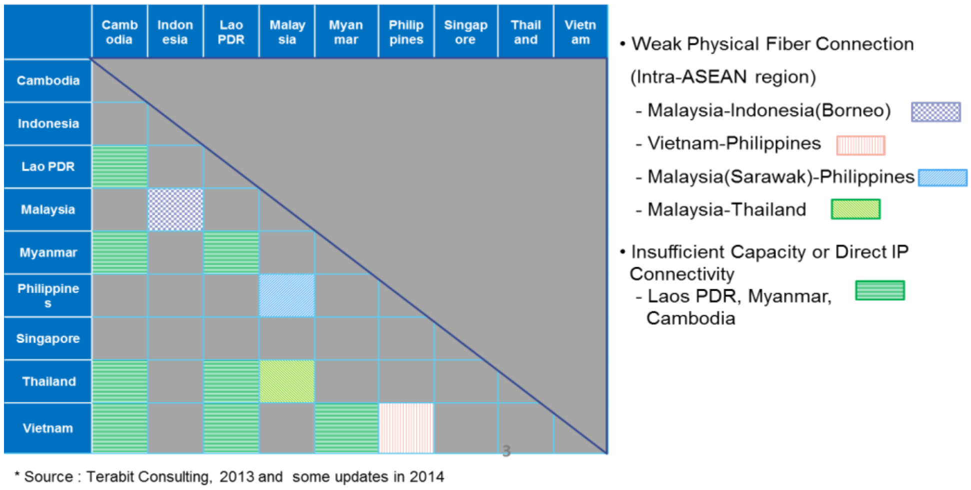
- Unit : ms / based on year 2013



- Source: Ookla http://www.speedtest.net/
- Based on daily data for a year (2013. 01. 01 ~ 2013. 12.31)

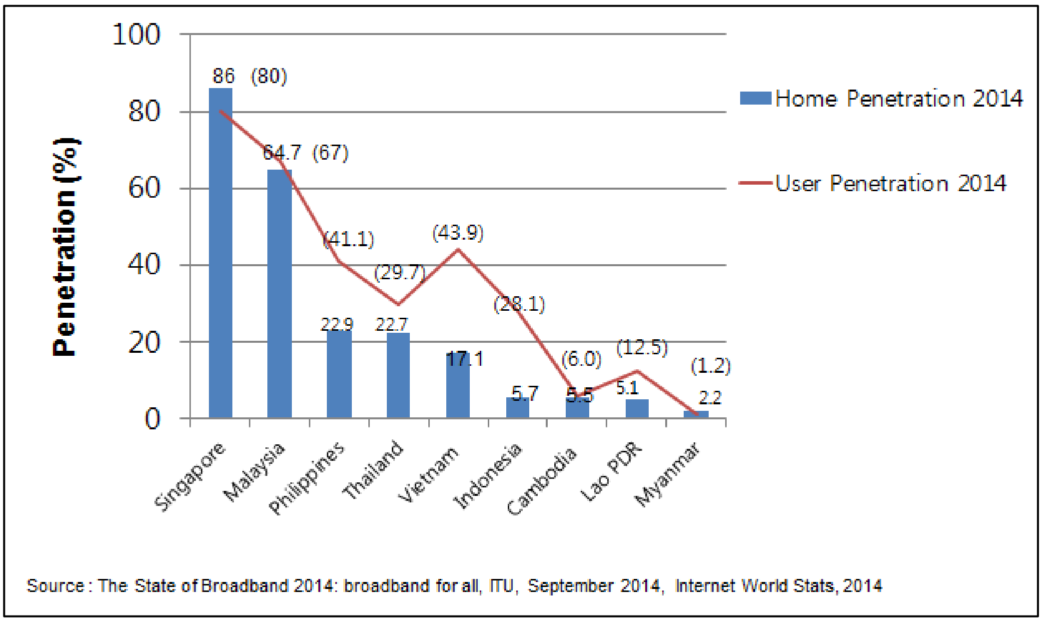
Though there are many regional connectivity programs being carried out, some missing fiber-optic links and insufficient capacity are identified in the ASEAN countries. With regard to the cross-border fiber links, the team have collected updates from each country and finally summarized missing links as seen in the [Fig 2-5].

[Figure 2-5] Missing Links



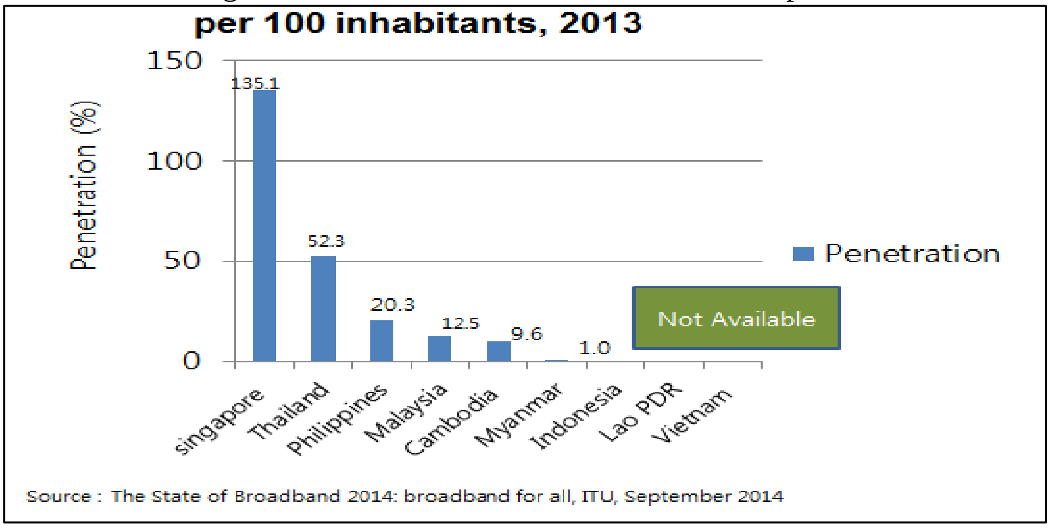
A big penetration gap exists inside the ASEAN region, and therefore, narrowing the gap should be one of the AP-IS's main objectives. In terms of the percentage of households with Internet subscriptions, Singapore has the highest penetration rate with of 86%, followed by Malaysia (64.7%), the Philippines (22.9%), Thailand (22.7%), and Viet Nam (17.1%). Countries like Indonesia, Cambodia, Lao PDR, and Myanmar all have rates below 10%. User penetration in 2014 also goes along with the curve of household penetration rate shown in [Fig 2-6], which demonstrates that the User Penetration is closely related to the household penetration rate.

[Figure 2-6] Percentage of Households with Internet



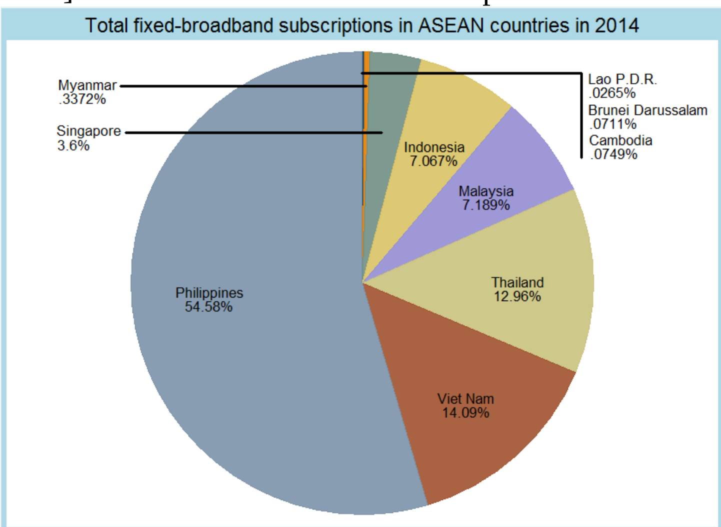
Active mobile broadband subscription rates also vary, to a great extent, throughout the ASEAN region. Singapore's subscription rate is more than 130% while the data is not even available for countries like Indonesia, Lao PDR, and Viet Nam.

[Figure 2-7] Active Mobile Broadband Subscriptions



According to the latest ESCAP analysis on the broadband connectivity among the ASEAN countries, the majority of the fixed broadband subscribers reside in the Philippines, Vietnam and Thailand.

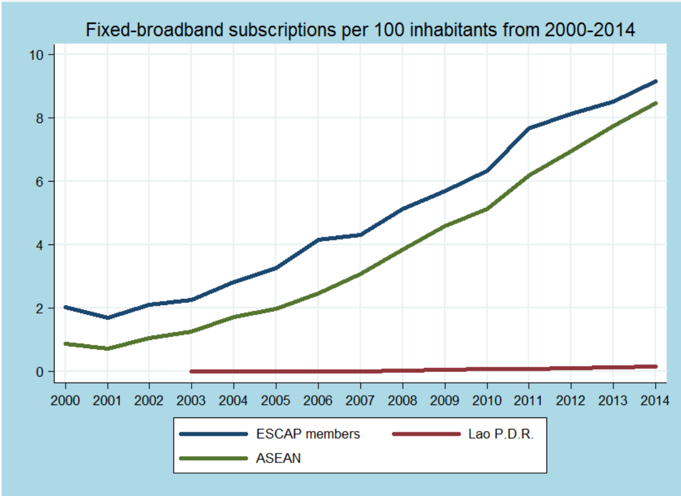
[Figure 2-7-1] Total Fixed Broadband Subscriptions in ASEAN countries



Source: ESCAP analysis based on the 2014 ITU ICT data

While some ASEAN member countries have experienced rapid growth, the disparities among the ASEAN countries have also been noticeable.

[Figure 2-7-2] Fixed Broadband Subscriptions per 100 Inhabitants



Source: ESCAP analysis based on the 2014 ITU ICT data

With regard to policy, many ICT plans, strategies and projects have been created and carried out by each ASEAN member state. The ASEAN ICT Master Plan after 2015 is being discussed in the ASEAN community. It seems, therefore, that AP-IS is not a simple project but one that would require collaboration and cooperation from many parties. A harmonized framework other than country level ICT Plan is another key factor for the successful establishment of AP-IS[3].

[Table 2-1] ICT Policies in ASEAN Countries[4]

Cambodia	· National Strategic Development Plan Draft ICT Policy · IT 21 · ITU National Broadband Policy	Philippines	· The Philippine Digital Strategy · Integrated Government Project, iGovPhil
Indonesia	· Indonesia ICT 2025 · Palapa Ring Project	Singapore	· iN2015 Master Plan · Next Generation National Broadband Network
Lao PDR	· Laos Vision 2020 · Nation ICT Policy · Laos e-Government project	Thailand	· iN2015 Master Plan · Next Generation National Broadband Network

[3] The recently published World Development report 2016 – “Digital Dividends” – includes a policy framework for the supply of internet service which provides a way forward for future policy strategies. The World Bank’s report highlights that policy actions should be based on the digital state of a particular country (emerging, transitioning or transforming) and be aimed at achieving Internet universality by ensuring affordable and accessible internet not only to urban areas but also to rural settings, small islands and fragile or conflict-afflicted states. While an exploration of all applicable regulatory issues is beyond the scope of this study, these need to be assessed in each member country of ASEAN towards the implementation of any successful broadband masterplan.

[4] Source : CONEX, www.kisa.or.kr

Malaysia	· MyICMS 886 Strategy · The 10th Malaysia Plan 2011~2015 · National Broadband Plan · National Broadband Initiative · National Creative Industry Policy · National IT Agenda · Spectrum management and reframing	Viet Nam	· Viet Nam's Posts and Telecommunication Development Strategy until 2010 and Orientation until 2020 · Public Telecommunications Service Program 2011~2015
Myanmar	· Myanmar ICT Master Plan · e-Government project		

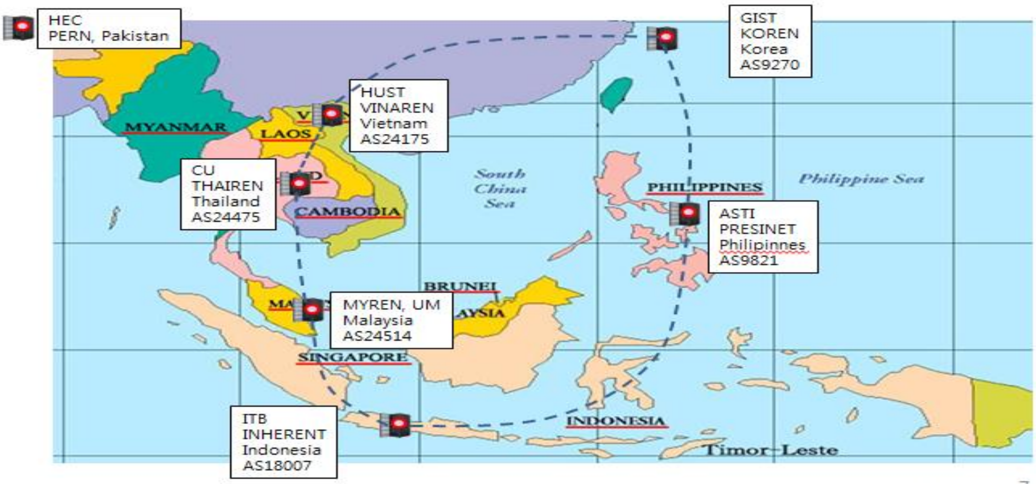
2.2 Internet Traffic Measurement

2.2.1 Traffic Measurement Environment and Method

Measuring the cross-border Internet traffic among nodes in the ASEAN member countries was not simple nor was it easy to get cooperation from countries. It also requires custom designed software installation in each node for real world traffic measurement.

Upon confirming that the requested countries had little offer to cooperate in the traffic measurement, the team decided through discussions with ESCAP not to install measurement tools in the nodes of telecom service providers in each country but instead use TEIN (Trans-Eurasia Information Network) nodes, a non-profit research network connecting Asia and Europe, for traffic measurement. Since most of the ASEAN countries are also connected to this network, it served as a useful medium for measuring international traffic.

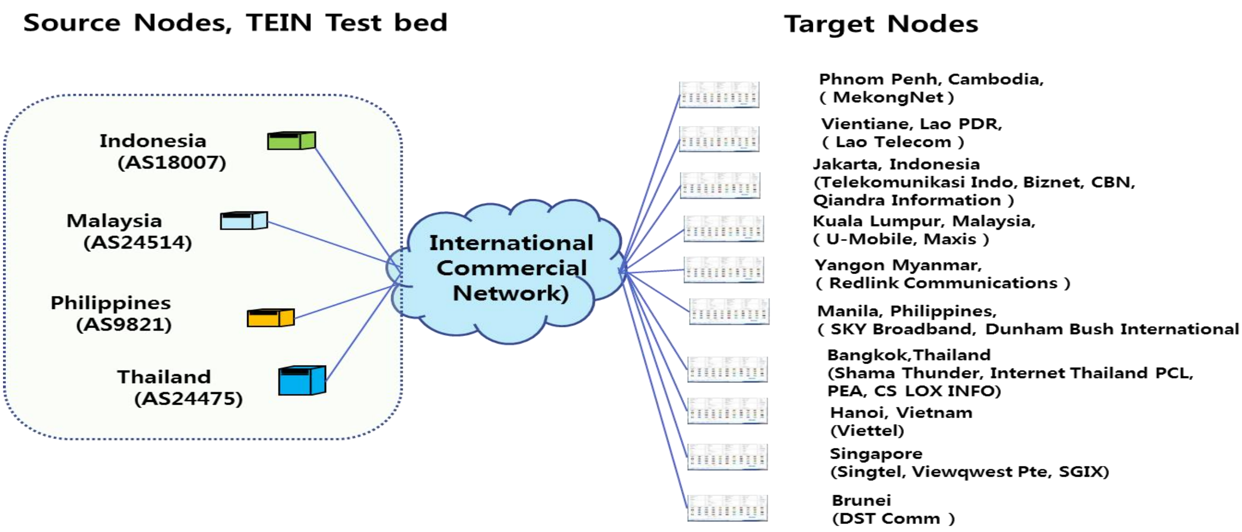
[Figure 2-8] Test System Locations on TEIN



ACMTECH Co., Ltd.

OF@TEIN system at each node was used as an alternative since it is already installed for the purpose of academic research and development. Network connectivity of OF@TEIN is as seen in [Figure 2-8]. Each country has the bandwidth of 622Mbps or higher only the Philippines have 100Mbps connectivity. But the problem of measurement on the TEIN network was that it is not enough to get fact data because TEIN is a closed network separated from the commercial network. And then, taking such limitations into consideration, the team decided to use commercial servers currently available in commercial ISPs as the target servers, which are open and operated by private businesses as seen in [Figure 2-9]. With assistance from TEIN node operators in each country, the team changed the routing path from inside the TEIN backbone to the commercial network reaching to target servers.

[Figure 2-9] Diagram on Testing from TEIN Nodes to Capital Cities



Virtual machines were created in OF@TEIN servers. Consultations with the local operators for each node were held to allow remote operation once servers are allocated and many following activities were carried out such as allocating an IP address to each server and setting network configuration for external connection. However, some nodes were found inaccessible due to technical problems, in particular, remote access to Viet Nam was impossible within a limited period Finally after endeavoring a long time, the team could set up a measurement system, consisting of four source nodes and ten target nodes in the respective capital cities in ASEAN countries.

As for the target servers, at least one server for each country was selected, and if there are multiple servers, all of them were included. ISPs that have target servers and their IP addresses of each country are listed in [Table 2-2].

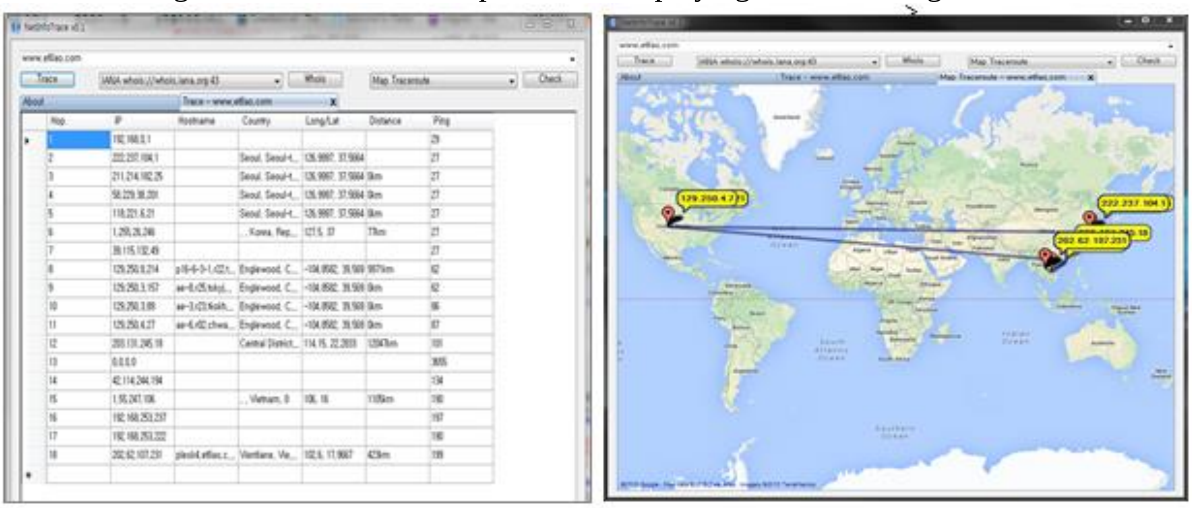
[Table 2-2] Target ISPs and Their IP Addresses

Country	Capital City	ISP	IP Address
Indonesia	Jakarta	**Telekomunikasi Indo**	**118.98.104.194**
		Biznet Networks	203.142.69.190
		CBN	202.158.8.14
		Qiandra Information	122.200.144.6
Malaysia	Kuala Lumpur	U Mobile	123.136.100.5
		Maxis	**121.123.132.194**
Viet Nam	Hanoi	Viettel	27.68.242.178
Thailand	Bangkok	Shama Thunder	27.55.63.2
		Internet Thailand PCL	203.150.212.26

		PEA	202.151.5.110
		CS LOXINFO	202.183.136.110
Cambodia	Phnom Penh	MekongNet ISP	116.212.136.134
Myanmar	Yangon	Redlink Communications	61.4.77.249
Laos	Vientiane	Lao Telecom	202.137.128.218
Philippines	Manila	**SKY Broadband**	**182.18.209.47**
		Dunham Bush International	202.57.42.2
Singapore	Singapore	New Media Express	202.150.221.172
		Viewqwest Pte. Ltd	**202.73.51.10**
		SGIX	202.3.78.3
		SingTel	165.21.71.68
Brunei	Brunei	DST Communications Sd	202.152.92.38

To measure speed and latency, target servers' IP addresses were used to identify the names of ISPs and their locations. Finally capital cities and ISPs of source and destination sites were selected from the map and sent test packets ten times for each target node. For finding trace routes, 'NetinfoTrace', open source software for tracing routes was used as a measuring tool to analyze the number of hops, IP addresses of nodes, locations, and routing distances.

[Figure 2-10] Text and Map Screens Displaying Trace Routing Result



Four indicators were used in the measurement – download speed, upload speed, latency, and tromboning index. The tromboning index here is the value obtained by dividing the entire routing distance by the shortest linear distance, and the longer the actual route between two points, the greater the tromboning index is.

2.2.2 Internet Traffic Analysis

2.2.2.1 Key Finding of Traffic Analysis

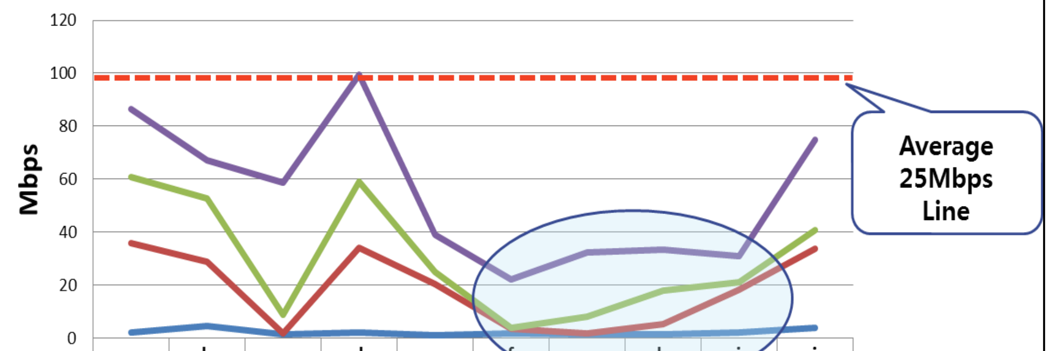
For the countries that have more than 2 target servers, the team selected a typical server in order to compare all the data from member countries that have single server. Telekomunikasi Indonesia from Indonesia, Maxis from Malaysia, SKY Broadband from Philippines, Viewquest Pte, Ltd from Singapore, Internet Thailand PCL from Thailand were selected for comparison among countries.

Details about data of other Internet Service Providers were explained in the Appendix. The measurement result is as follows;

(Speed Down Load/Up Load)

The team had sent test packet and gathered data from 4 sources to 10 target system in each country, and summarized in the graph as shown in [Figure 2-11]. Data in the graph means cumulative sum from 4 source nodes. As a result, big gap in Down Load Speed was observed among ASEAN countries, and average Down Load Speed was less than 25Mbps.

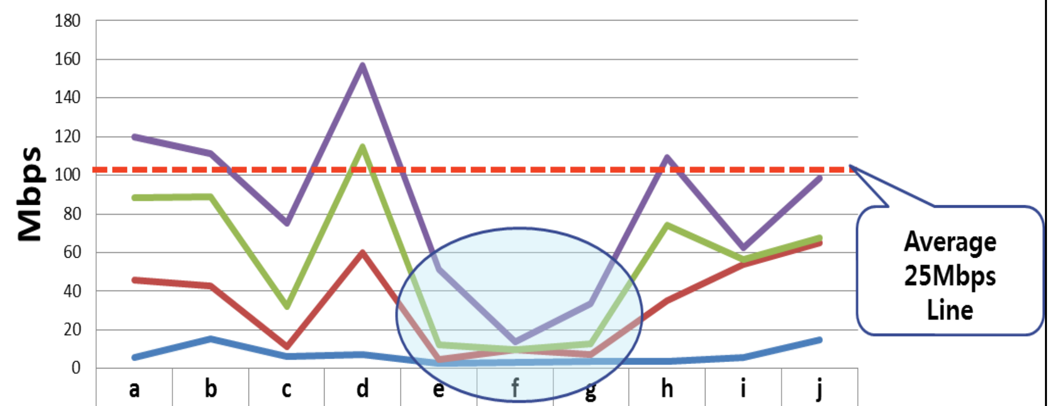
[Figure 2-11] Cumulative Speed- Down Load[5]



	a	b	c	d	e	f	g	h	i	j
TH	25.8	14.6	50.1	40.4	13.9	18.5	24	15.5	10	34.3
PH	24.8	23.7	7	24.7	4.5	0.15	6.5	12.5	2.7	6.9
MA	33.7	24.4	0.4	32.2	19.6	2	0.3	3.9	16	29.8
IN	2.2	4.6	1.4	2.1	1	1.7	1.5	1.5	2.3	4

5 In the graph [Figure 2-11] ,altitude of violet colored line means cumulative value of Speed test results from 4 source node countries to the ten target countries, then in order to be higher than 25 Mbps for each country, the violet colored value should be at least 100Mbps. On a similar vein, the green colored line represents the cumulative figures of Indonesia, Malaysia and the Philippines.

[Figure 2-12]　Cumulative Speed - Up Load

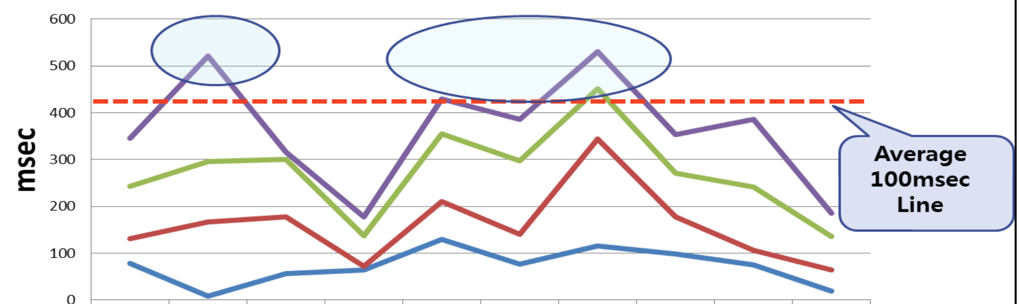


	a	b	c	d	e	f	g	h	i	j
TH	31.5	22	43.1	42.2	39.2	4.3	20.8	35.1	6.2	31
PH	42.9	46.6	20.8	55.1	7.6	0.02	5.4	39.1	2.6	2.4
MA	39.8	27.4	4.9	52.8	2.2	6.6	3.8	31.4	48.1	50.3
IN	5.9	15.1	6.3	7	2.6	3	3.6	3.6	5.8	14.9

(Latency)

Big Gap in Average Internet Latency was also observed, more than 100msec in 3 countries, less than 50msec in 2 countries

[Figure 2-13] Cumulative Latency

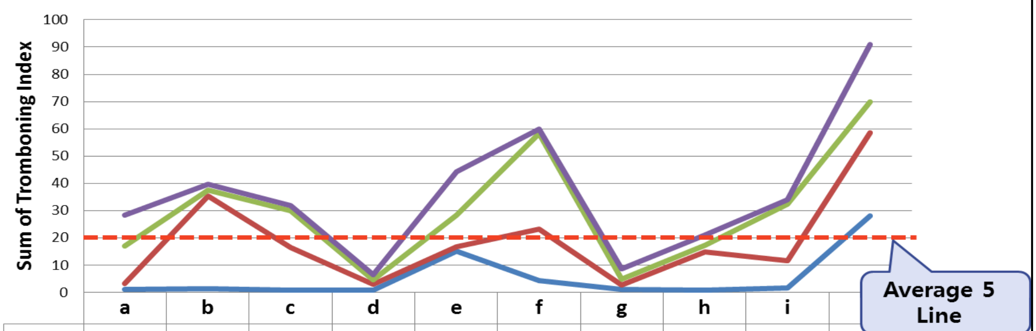


	a	b	c	d	e	f	g	h	i	j
TH	101.8	226.3	15.9	40.1	74.4	89.1	80	82.9	143.8	49.7
PH	112.1	129.6	123.5	66.8	145.1	156.6	106.7	93.5	136.1	71.3
MA	53.6	158.4	120.1	7.5	79.7	63.3	228.4	79.1	31	46.3
IN	77.5	7.6	56.9	63.6	130	77.1	116	98.6	74.4	18.4

(Relative Routing Distance)

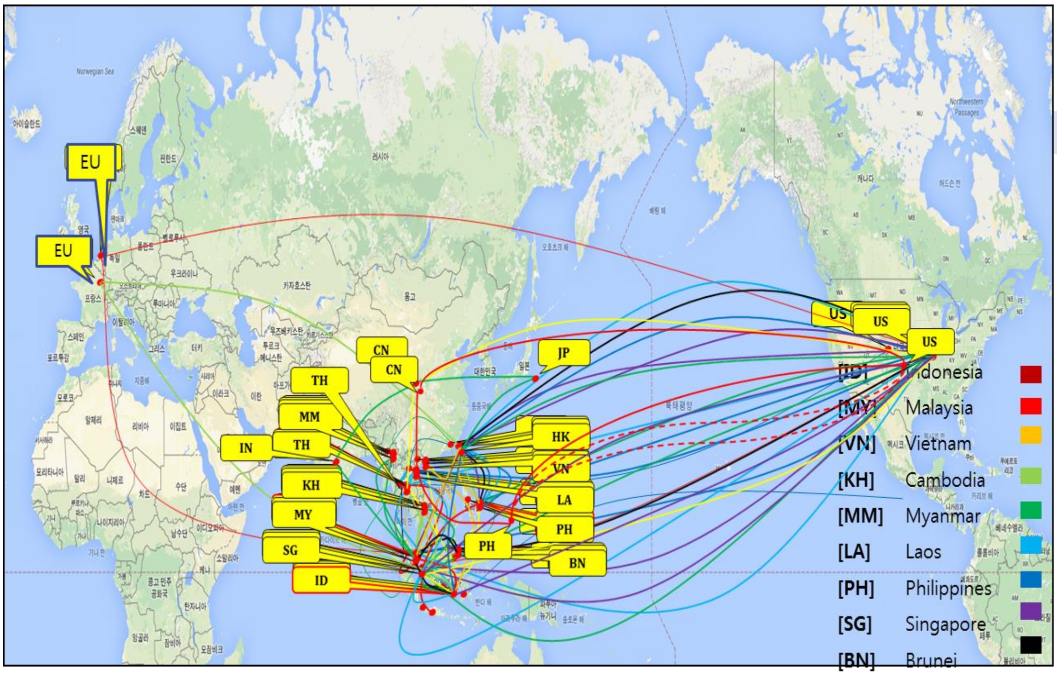
Higher than five times more distance than the straight line distance was observed in 7 of 10 countries. The actual traffic routes among ASEAN countries are unnecessarily long. In some countries, even domestic traffic has to travel a long way. Even though there are several regional cooperation efforts to enhance the ICT infrastructure in the ASEAN region, still, high link cost, high transit cost, traffic tromboning, high dependency on submarine cable, and low penetration all influence high price each other in a cycle.

[Figure 2-14] Cumulative Relative Routing Distance



	a	b	c	d	e	f	g	h	i	
TH	11.5	2.3	1.7	2	15.8	1.5	3.7	3.8	1.6	21
PH	13.6	2.1	13.6	1.5	11.8	35	2	2.4	20.9	11.1
MA	2.2	33.9	15.5	2.1	1.5	19	1.8	14	9.8	30.7
IN	1.2	1.5	1	1	15.2	4.3	1.1	1	1.8	28

[Figure 2-15] Cumulative Routing Routes



2.2.2.2 Summary of Test Results in each Source Node

Source Nodes	Speed, download	Speed upload	Latency	Routing distance
Indonesia	For most of the countries the speed was fairly even from 1Mbps to 4Mbps	Uniform around 3~8Mbps except Philippines at 2.6Mbps and Singapore at 15Mbps	Stable latency of below 100ms for most countries, except for Myanmar and Thailand	To Myanmar and Singapore 15 times longer than the straight-line distance
Malaysia	For Cambodia, Indonesia, and Singapore it was fairly high over 20Mbps, while for Lao PDR and Thailand it was very poor at below 2Mbps	Fairly reasonable speed for Brunei, Cambodia, Indonesia, Singapore and Viet Nam and low speed at below 10Mbps for Lao PDR, Myanmar, Thailand and the Philippines	High latency of over 100ms for Thailand, Indonesia, and Lao PDR; in particular, latency for Thailand was the highest at 228ms	More than 10 times longer than the shortest routes to Indonesia, Lao PDR, Philippines, Singapore and Viet Nam. However, Cambodia, Myanmar and Thailand had the shortest traffic routes from Malaysia
Philippines	For Cambodia, Indonesia and Malaysia it was over 20Mbps, however for Brunei and Myanmar it was below 5Mbps	Over 20Mbps for Cambodia, Indonesia, Malaysia, and Viet Nam while it was below 5Mbps for Brunei, Singapore	Over 100ms for Brunei, Cambodia, Indonesia, Lao PDR, Myanmar, and Thailand. Relatively good for Malaysia, Singapore and Viet Nam	More than 10 times for Brunei, Cambodia, Lao PDR and Singapore. However, 3 times longer than the shortest routes for Indonesia, Malaysia, Thailand and Viet Nam. Some Philippines' domestic traffic was exchanged out of the country
Thailand	Around 40Mbps for Lao PDR, Malaysia and Singapore. However, the speed from Brunei, Viet Nam, Indonesia, and Myanmar was relatively low	Low speed at below 10Mbps for Brunei and the Philippines	Over 100ms for Brunei, Cambodia and Indonesia; in particular, the latency of traffic between Thailand and Indonesia was even over 200ms	More than 10 times longer for Cambodia, Singapore, signifying that even the traffic between nearby countries had to make a detour around other countries

3. Gap Analysis – As-Is vs. To-Be

3.1 **Summary of Goal Setting**

To conduct a gap analysis, the team first set goals for infrastructure and service improvement and then price and quality improvement. Defining clear goals for what should be done in the future will also lead to the development of detailed implementation strategies; therefore, the team came up with some detailed and quantifiable goals. These goals may not suit the environment of each and every country, but in this report, they are applied to the ASEAN member countries as a whole. The indicators were selected based upon a comparison of the ASEAN countries and the world's top-level countries as well as on plans published by each of the ASEAN countries. For infrastructure and service improvement, the goals are again categorized into ICT connectivity, which consists of physical (fiber) connectivity and Internet interconnectivity, in other words ' TBBC and ITEC'. For price and quality improvement, the goals are set for four areas – monthly Internet transit cost, average speed, latency, and tromboning index.

With regard to physical or fiber connectivity, most countries in the region are already interconnected with fiber but there are some weak or insufficient capacity observed; this shall be improved to achieve full connectivity between neighboring countries. As for Internet interconnectivity, most countries are currently dependent on global transit providers or providers who have an infrastructure of their own. The level of direct peering is poor, and some countries lack interconnectivity even between domestic ISPs. This needs to be improved to achieve full and bilateral peering or transit among neighboring countries.

Broadband Internet penetration needs to be improved to the extent of well-developed countries; from the current 3% for fixed-line Internet and 30% for mobile to 25% for fixed-line and 90% for mobile, reaching the coverage of 90%. Internet penetration also shall be improved from the current 26% to 80%. However, Internet penetration is somewhat dependent on policy or strategy of each country or market competition, so the team decided to set aside it as a reference goal.

The monthly Internet transit cost should be brought down to less than 10 US dollars from the current 10~100 US dollars and eventually down to 2 US dollars, the level of lowest competition market price. The average speed of the Internet needs to be improved from 0.2~43 Mbps for download and 0.3~57 Mbps for upload to over 25 Mbps for both upload and download. Latency and Tromboning index should be also improved from 13~363 milliseconds and 1~34 to below 100 milliseconds and below 5 respectively. [Table 3-1] compares the goals to the current status (as-is).

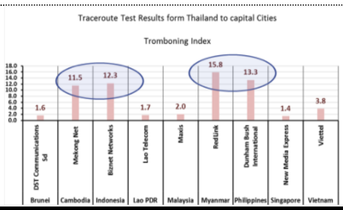
[Table 3-1] As-Is and To-Be

Category			As-Is	To-Be
Infrastructure & ICT Connectivity	TBBC		· Most countries are interconnected with fiber · Some weak or insufficient capacity observed	· At least one direct land based fiber link to each neighboring country · Regional Terrestrial Backbone Network, hybrid mesh and ring · Center Node establishment for low cost and reliable delivery of traffics
	ITEC		· Dependent on global transit providers · Poor direct peering · Some countries no peering among domestic ISPs	· Direct bilateral peering/transit between neighboring states · Intra/Inter Regional Transit Nodes · Domestic Traffic exchanged domestically
Transit Price and Quality	Monthly Internet Transit Cost (US$/Mbps)		· Min 10 US$ (2012) · Max 100 US$ (2012)	· < 2 US$ * re-adjustable year by year considering the fair market price; in 2015, Min < 2 US$ in US, Europe Market
	Average Speed	Down	· 0.2~43 Mbps	· > 25 Mbps
		Up	· 0.3~57 Mbps	· > 25 Mbps
	Latency (msec)		· 13~363 msec	· < 100 msec
	Tromboning Index		· 1~34	· < 5

In order to set up norms and principles for AP-IS implementation and measures commonly applicable to all countries in the region, it is very important to define categories and set goals for each category in the master and action plans. The goal relevance and the rationale is as shown in the [Table 3-2]

[Table 3-2] Goal Setting

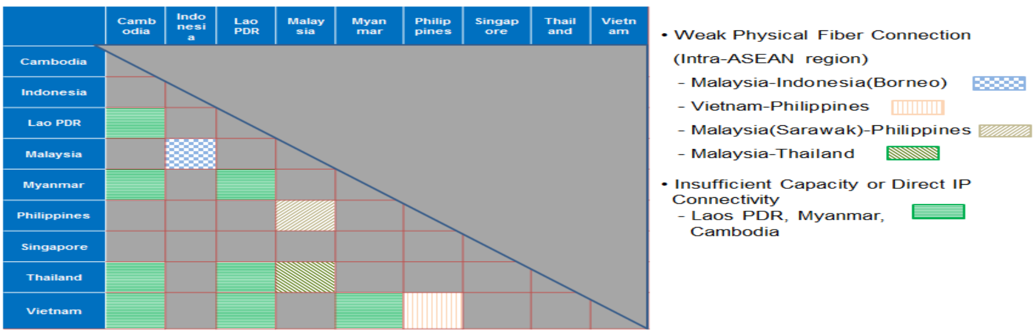
Category		Rationale of Goal-Setting
Infrastructure & ICT Connectivity	TBBC	· Most of the terrestrial networks are completed; fiber optic network construction using roads and railroads is not a requirement for cross-border interconnectivity. · Some sections between Indonesia, Borneo and Malaysia, need fiber optic network construction.
	ITEC	·  · The goal is to achieve direct Internet interconnection through IXP between neighboring countries and diversification of interconnectivity regions.

Transit Price and Quality	Monthly Internet Transit Cost (US$/Mbps)		The goal is set to below 2 US$, currently the world's lowest level (considering US and Europe competition market price of 2 US$ and Singapore's capacity pricing of 10 US$ in 2012).
	Average Speed	Down	· The goal is set to achieve the speed of 25Mbps or higher considering the plans of US FCC (25M), Indonesia (20M), Philippines (20M), Malaysia (10M), Singapore (100M) and Thailand (100M).
		Up	· Same as above
	Latency (msec)		· The goal is set to reduce round trip (PING) latency to or below 100msec considering the Class 0 IP transfer delay as specified in the ITU standard.
	Trombonning Index		·  · The goal is set to reduce the traveling distance of traffic from source to destination to less than five times the straight-line distance.

3.2 Goal-setting for Terrestrial Broadband Backbone Connectivity

Thanks to the Greater Mekong Sub-region Information Superhighway (GMS[6]) project or new deployment of the submarine cable network, many missing links for the optical communications network have been rapidly connected within the region. However, additional inspection needs to be carried out for direct connection of island countries and between Borneo and its neighboring countries. According to TRPC's recent data, most of the optical cable network among Cambodia, Lao PDR, Viet Nam, Myanmar, and Thailand has been connected through the GMS project. However, there is still a lack of terrestrial network connection between Malaysia and Thailand, Borneo of Indonesia, Malaysia, and finally to the Philippines and its vicinities such as Viet Nam and Malaysia. Further review should be conducted on whether there is any plans for this, and if any, how far it has progressed. Therefore, once a direct connection is achieved among the countries within the ASEAN region, alternate routing through the terrestrial network can be considered as achieved in most part.

[Figure 3-1] Physical Fiber Connection of ASEAN countries

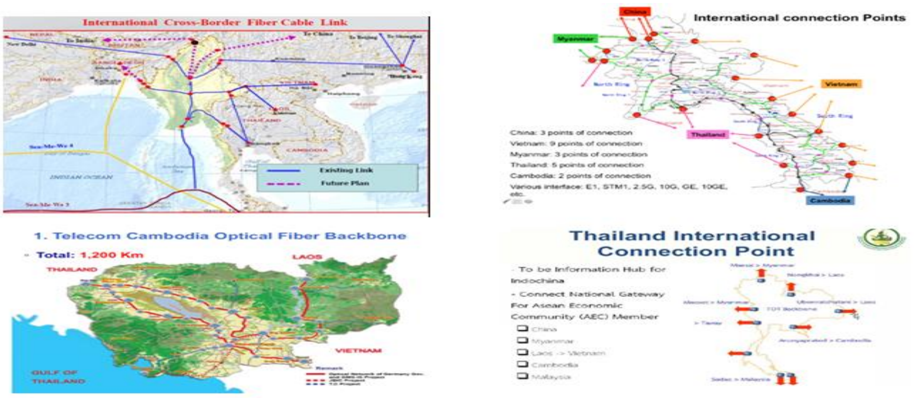


* Source : Terabit Consulting, 2013 and some updates in 2014

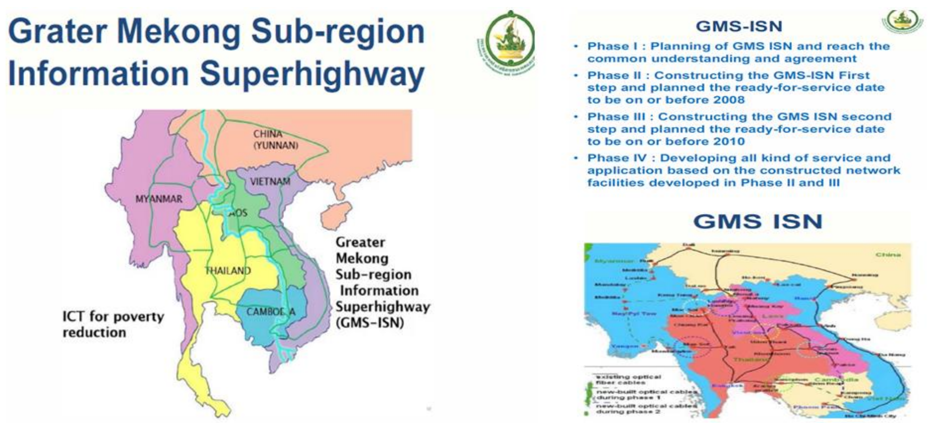
6 GMS: Greater Mekong Sub-region Super Highway currently under construction (Myanmar, Laos, Thailand, Cambodia, Viet Nam, China)

As for the optical network connecting Myanmar, Lao PDR, Viet Nam, Cambodia, and Thailand, which seemed to be the countries lacking terrestrial network within the ASEAN region, it has almost reached full connectivity. As for the backbone network, each country has established its plan for improving national ICT infrastructure, and the need to make recommendations through this study is decreasing; except further improvement on the efficiency of national backbone network construction, minimization of redundant investment, parallel construction of communication facilities when building main roads as part of reducing cost, and parallel construction of optical communication network when building SOCs like railroads or dry ports is still recommended, along with intensive implementation of strategy for significantly increasing user affordability through mutual cooperation between organizations supervising the works.

[Figure 3-2] Examples of Cross-border Fiber Connectivity



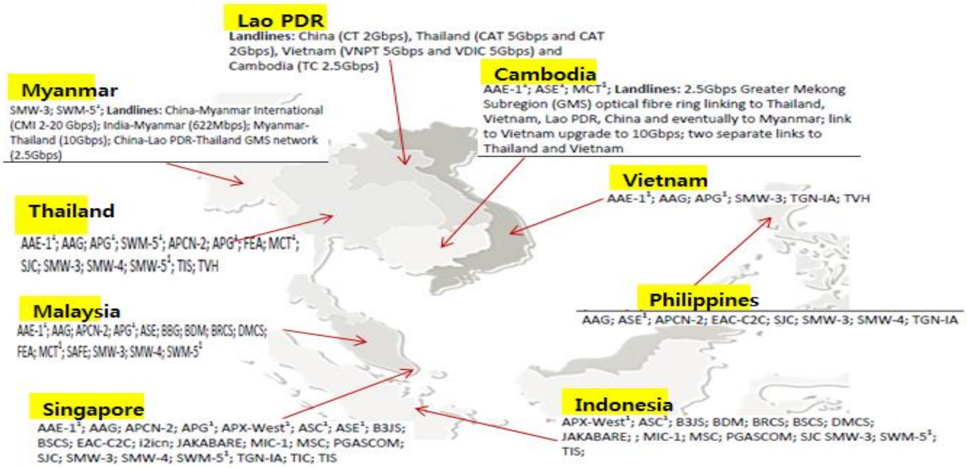
Source : ESCAP Bhutan Expert Group Meeting 2014.10



The GMS project, which started from the mid-2000s, contributed to the near completion of physical connection of regional terrestrial backbones. Internet-based data communication has been largely dependent on traffic through global Internet Service portal, contents providers and Social Networking Service providers, like Google, Amazon, and Facebook rather than the traffic with neighboring countries. This means most of the traffic exchanges have been made through global transit providers. However, as there are many efforts being made for e-government initiatives, along with e-commerce facilitation in private-sector businesses and rapid localization of major contents, it is necessary to make more traffic localized or flowing within the ASEAN region.

The submarine cable network in the ASEAN region is significantly expanded through private consortia based upon demand forecast from home and abroad, through which provisioning of submarine capacity within the region is expected to be satisfied with the demand and even be surpassing the demand. There are many projects being carried out to build new networks and most of them are driven by decisions from the business point of view; therefore, there are limitations or no need even, for international organizations like ESCAP to take part or intervene. The framework for international monitoring on the choke points needs to be reinforced to prepare for natural disasters like earthquakes, floods etc.. It is prudent to have further discussions focusing on securing alternate routing through a terrestrial network in a time of disasters. Since most of the international traffic is for data communication, it is essential to find measures to secure alternate routing paths between ISPs and stabilize the network as soon as possible.

[Figure 3-3] Physical Fiber Network Connecting Each Country



Source : TRPC Research, Note : (1) Planned or Under Construction (2) Landlines

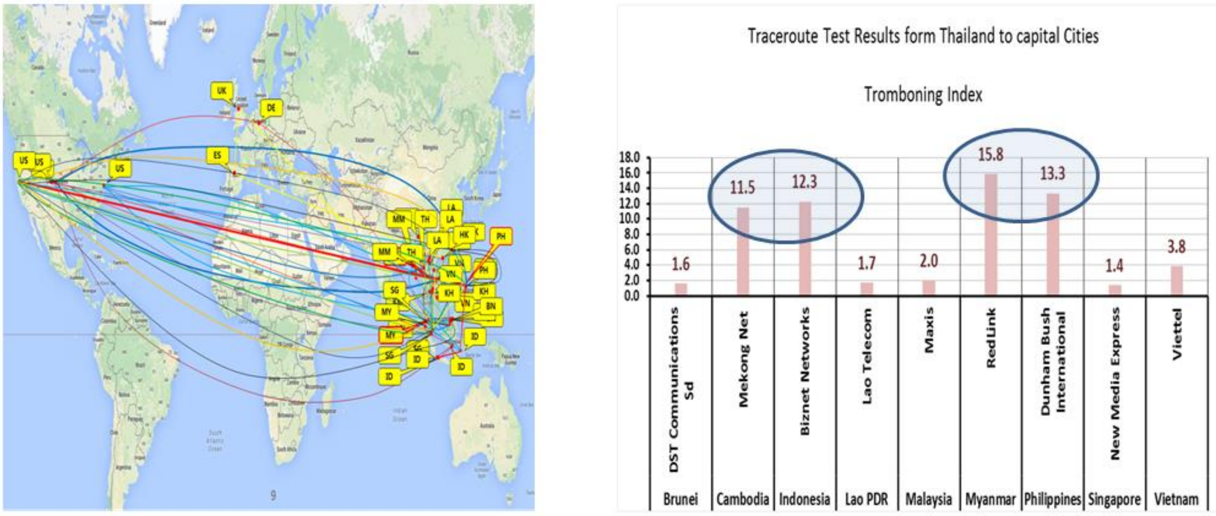
For now, submarine cables have been built to a sufficient level, and there are even more to be built, meaning there will not be a lot of difficulties in achieving connectivity between countries in the region. Overall, the missing links have been already filled or are being rapidly filled in terms of physical infrastructure. The problem is that these countries need to create actual traffic to expand physical infrastructure and facilitate connectivity as well as gain financial benefits. When communication networks are integrated to focus on the Internet and when data traffic takes up most of the traffic, direct connectivity of the Internet, between neighboring countries will be raised as an important issue.

3.3 Goal-setting for Internet Traffic Exchange Connectivity and Tromboning Index

Measuring traffic between countries found that even though there is a direct physical connection between neighboring countries, most of the Internet traffic is being carried through long detour routes. This study identified the traffic routes between countries and found that there is a ‘spaghetti bowl phenomenon’. Therefore, it is necessary to check whether the actual Internet traffic is being carried through the routes of such physical connection. This is why we need to consider the flow of IP packet over direct physical connection when establishing a strategy for achieving connectivity between countries in this region.

There is a significant amount of traffic that goes out from ASEAN countries and comes by way of US and Europe as shown in [Figure 3-4]. For instance, in some ISPs, analyzing the routes from Thailand to each ASEAN country found that the tromboning index is over 10 for Cambodia, Indonesia, Myanmar, and the Philippines. In particular, the routes are unnecessarily long even though Myanmar and Cambodia are neighboring countries to Thailand. Such spaghetti bowl phenomenon can be not only a problem in terms of the transit price, since the traffic goes back and forth international submarine cables, but also a potential risk that might cause Internet blackout in the entire region if there are submarine cable failures.

[Figure 3-4] Internet Traffic Routes from Thailand to Capital Cities



Though there are multiple IXPs in some countries in the ASEAN region, it is difficult to find out detailed information on interconnectivity between ISPs. This needs further in-depth study and field interviews in the future. Based on what has been found so far, an interconnection between ISPs is mostly established through competition and cooperation between ISPs in the market. Therefore, when the number of Internet users is small in the early market stage, and when most of the traffic goes out overseas, external connection was mostly made through global transit providers (Tier 1 ISPs) rather than through direct connection with regional or domestic ISPs. However, it is time to establish direct bilateral peering between neighboring countries within the region in order to prepare for rapid increase of Internet users, facilitate of e-government and e-applications, increased data created within each country, and data center localization by global platform providers like Google and Facebook.

In summary, most of the countries have direct fiber connectivity with neighboring countries but in order to solve the issue of Internet traffic coming back from other continents through tier 1 providers, it would be necessary to establish more regional IXPs with full peering or transit arrangement. For more specific location and number of IXPs, quantified traffic analysis should be conducted before investment. IXPs must be configured so as to find alternate routes in time of submarine cable failures. In establishing additional IXPs, the case study of Kenya and Nigeria would be good reference knowing that IX experts from ISOC had been engaged in whole process of IXP installation, peering and operation as seen in the [Box 3-1].

[Table 3-3] IXPs in the ASEAN Region

Name	Description	City	Country
NAPSINDO-IIX	NAPSINDO International Internet Exchange	Jakarta	ID
MCIX	Matrix Cable Internet eXchange	Jakarta	ID
NICE	National Inter Connection Exchange	Jakarta	ID
IIX	Indonesia Internet Exchange	Jakarta	ID
BIX	Biznet Internet Exchange	Jakarta	ID
CBN NETWORKS	PT Cyberindo Aditama	Jakarta	ID
IndonesiaEP	IndonesiaEP	Jakarta	ID
MyIX	Malaysia Internet Exchange	Kuala Lumpur	MY
PhOpenIX	Philippine Open Internet Exchange	Manila	PH
Manila IX	Manila Internet Exchange	Manila	PH
PHOpenIX	Philippine Open Internet Exchange	Metro manila	PH
BAYANTEL	Bayan Telecommunication Internet and Gaming Exchange	Quezon city	PH
SOX	Singapore Open Exchange	Singapore	SG
Equinix Singapore	Equinix Singapore Exchange	Singapore	SG
CAT-THIX	CAT National Internet Exchange	Bangkok	TH
Viettel	Viettel ISP/IXP	Hanoi	VN
VNIX	Viet Nam Internet Exchange	Hanoi	VN
VNIX-Ho Chi Minh	Viet Nam Internet Exchange	Ho Chi Minh City	VN

[Box 3-1] Internet Exchange Points – Empirical Study of Kenya and Nigeria[7]

The establishment of an IXP in the country enables local ISPs to connect directly together and exchange domestic traffic, typically with settlement-free peering, thereby reducing or eliminating tromboning and saving cost on international transit while reducing latency (by avoiding local traffic to be carried internationally). To the extent that the IXP begins to build critical mass, involving most or all of the ISPs, it will also begin to attract content providers, along with business, academic, and government users, and thereby become the center of a vibrant Internet ecosystem in the country. Further, the IXP can also begin to attract international content and connectivity providers, becoming a regional hub for Internet traffic.

The benefits of localizing Internet interconnection are increasing, due to consumers' growing demand for services with increasing bandwidth (such as video) and lower tolerance for latency (such as Voice over IP). In developed countries, IXPs have played a key role in advancing the Internet ecosystem over the past 15 years. Today, IXPs are also progressively growing in Africa, despite a more challenging economic and telecommunications environment.

Here, the benefits that IXPs are generating have been quantified for two African countries: Kenya and Nigeria. In each of these countries, the IXPs are booming and contributing to the growth of the surrounding Internet ecosystem in a number of ways: In Kenya, the Kenya Internet Exchange Point (KIXP) currently localizes more than 1Gbit/s of peak traffic, dramatically reducing latency (from 200-600ms to 2-10ms on average), while allowing ISPs to save almost $1.5 million per year on international connectivity. The IXP also increases mobile data revenues by an estimated $6 million for operators having generated at least an additional traffic of 100Mbit/s per year; helps the localization of content in the country including from Google; is critical to raising government tax revenues, and increasingly acts as a regional hub for traffic from neighboring countries.

In Nigeria, the Internet Exchange Point of Nigeria (IXPN) currently localizes 300Mbit/s of peak traffic with corresponding reductions in latency, and allows national operators to save over $1 million per year on international connectivity. The presence of the IXP induced Google to place a cache in Nigeria as the first step in plans to build out Google infrastructure to Lagos, and is at the center of a partnership to improve communications between universities. The IXP also helped repatriate previously externalized financial platforms for online banking services.

Overall, the IXPs have had the direct effect of lowering the operating costs for local ISPs, while increasing the traffic, and where relevant corresponding revenues, of ISPs, with further benefits for those sectors that have incorporated the IXP in their delivery of services, notably the revenue authority in Kenya, and educational and banking sectors in Nigeria. Finally, it can be expected that over time, together with the decrease of international bandwidth costs, the IXPs will help reduce Internet access tariffs and result in increased Internet penetration and usage.

[7] Report for the Internet Society, Assessment of the impact of Internet Exchange Points – empirical study of Kenya and Nigeria, *April 2012* Michael Kende, Charles Hurpy, 2012 Analysys Mason Limited and The Internet Society (ISOC)

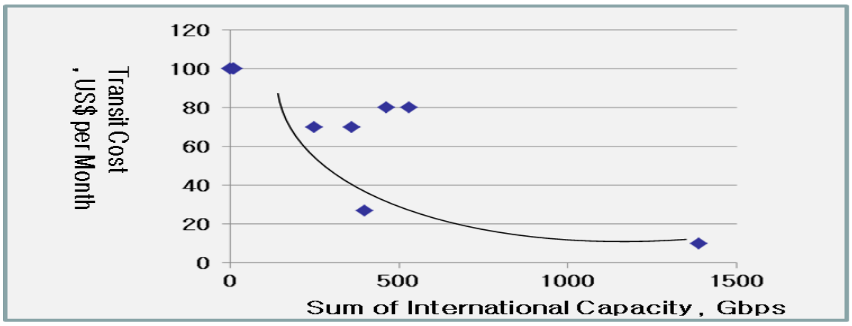
Examples of more advanced IXPs should encourage stakeholders in Africa to increase their usage of IXPs, in order to lower their costs and improve the quality of their services. Furthermore, policy makers should help to promote the establishment and development of IXPs by adopting sector reforms when necessary and offering targeted support when possible, as advanced IXPs ultimately benefit the entire ecosystem.

Note: this study was commissioned by the Internet Society (ISOC), a non-profit organization that provides leadership in Internet-related standards, education and policy, and a key independent source on these issues.

3.4 Goal-setting for Monthly Internet Transit Cost

The transit cost of international links varies depending upon the environmental elements like geographic location of the country, accessibility to submarine cables, competition intensity, etc. The analysis have shown that larger the international capacity, lower the transit cost. Based on such analysis, the cost is likely to continue to come down along with the increase in the number of Internet subscribers and speed, reaching the level below Singapore. Since international transit cost directly affects the user subscription price, further ISPs' joint response to Tier 1 providers to lower transit price and regional cooperation is necessary.

[Figure 3-5] International Capacity vs Transit Cost



Some countries in the region have abnormally high cost for international capacity or IP transit due to complex factors including weak geographical (landlocked) conditions or lack of competitive environment, low capacity demand, or small number of subscribers. However, recent analysis has shown that these countries seem to be taking measures to overcome such challenges. In particular, countries that have been categorized by Terabit Consulting as having 'very expensive' cost are making efforts to reduce international transit cost per unit through actions like diversifying international links or expanding the capacity. Also they are creating or expanding connection with neighboring countries to minimize dependency on submarine cables as well as improve stability and survivability of the network. With these efforts made, the monthly Internet transit cost is expected to reach in the mid and long terms 10 US dollars, which is the price level of Singapore in 2012. In the year 2014, in competitive market in Europe and US, transit price per Mbps has shown less than 2 US dollars. Despite all this, the transit cost in Asia is still higher than that of the United States or Europe because it is estimated that the unit cost of the global ISPs is higher in Asia than in other continents due to long distances from Asia to other continents. The price needs to be adjusted down to the same level with that of US or Europe in the long term, so this study sets the target price as less than 2 US dollars.

[Table 3-4] Monthly Cost of Internet Transit Traffic[8]

Country	Cost per Month (USD)	Country	Cost per Month (USD)
Cambodia	$100 per Mbps	Philippines	$80 per Mbps
Indonesia	From >$100 to $60/70 per Mbps	Singapore	<$10 per Mbps bought in volume
Lao PDR	$100 per Mbps	Thailand	$80 per Mbps
Malaysia	$25~30 per Mbps bought in volume	Viet Nam	$70 per Mbps
Myanmar	>$100 per Mbps		

[Box 3-2] Example of International Transit Pricing[9]

Singapore took measures to open its international and domestic telecommunications markets by 1997. This brought down prices and stimulated outgoing international traffic growth. By comparison, Cambodia has no submarine cable landing stations, landlocked Lao PDR is dependent upon low-capacity landlines, and Myanmar has connection to just one aging and low-capacity cable. As an OECD report notes, if "the market for backhaul and co-location is dominated by an incumbent telecommunications carrier, which does not allow independent co-location facilities to emerging, there is a significant obstacle to the development of the Internet in that country" and "control over landing stations has been a source of monopoly power." On the contrary, as the report also notes, sharing the costs of landing station and backhaul equipment with multiple carriers in a co-location data centre is a sensible way to improve the economics of running an international gateway and lowering the costs of the Internet.

Equally important for countries wanting to attract foreign companies to locate and invest, as well as making their businesses more competitive in international markets, are the options available in the operation of backhaul, from the international cable landing station to the international gateway, and on to points-of-presence (POPs) created by foreign carriers wanting to serve corporate clients. In more open and competitive markets carrier, wholesale prices tend to be lower, and competition accelerates as the monopoly power of the incumbent declines.

For instance, in three bi-annual studies for the Asia Pacific Carriers Coalition (APCC) over the years 2009-2012, TRPC research shows that "it is a reasonable assumption that where the local market is characterized by competition local access prices are likely to be lower" but also cautions that "the determinants of local access prices are far from transparent."

3.5 Goal-setting for Quality Aspects

The table below shows international standards for L3 layer network quality classes. Various QoS classes should be determined to the IP network design and technology adaption. Since the broadband requires a certain level of the quality, Class 0 – level QoS and IP packet transfer delay (IPTD) of 100ms or less as because Internet delivers triple play services; data, voice and video. L3 layer quality classes are as seen in the [Table 3-5].

[Table 3-5] International Standards for L3 Layer Network Quality Classes[10]

QoS Class	Service/ Application	Network Performance Parameters			
		IPTD	IPDV	IPLR	IPER
Class 0	Voice over IP (VoIP) Video Teleconference (VTC) Note 1: PSTN Voice quality	≤100 ms	≤50 ms	≤10–3	≤1 × 10 -4

[8] ESCAP and Terabit consulting, An In-Depth Study of Broadband Infrastructure in the ASEAN Region, 2013

[9] The Future of Broadband in South-East Asia, A Report from the Economist Intelligence Unit, 2014

[10] ITUT- Rec.Y.1541 Network performance objectives for IP-based services; IPTD : IP Packet Transfer Delay, IPDV : IP Packet Delay Variation; IPLR : IP Packet Loss Ratio, IPER : IP Packet Error Ratio

Class 1	Voice over IP (VoIP) Video Teleconference (VTC) Note 2: Satellite Voice quality	≤400 ms	≤50 ms	≤10–3	
Class 2	Transaction data Note 3: Highly Interactive data (Signaling)	≤100 ms	U	≤10–3	
Class 3	Transaction data Note 4: Interactive data (Business data)	≤400 ms	U	≤10–3	
Class 4	Video streaming	≤1 s	U	≤10–3	
Class 5	Traditional applications of Default IP networks	U	U	U	U

The Internet speed among the ASEAN countries is far behind that of the global standard of 25 Mbps, signifying the need for infrastructure development through direct interconnection between countries or expansion of alternate routing paths. When it comes to quality of Broadband Internet, we need to set target speed or bandwidth when packet crosses the borders in the region. Discussions need to be held on how fast speed can be defined as broadband. Currently, it has been agreed that broadband that offers the speed of around 25 Mbps for a fixed-line network. It is not only easy to define broadband for mobile network, but also yet commonly applicable worldwide. There is a little common acknowledgment on the speed of mobile broadband. In some countries, 3G of 4G LTE network as "broadband" but their actual speed per subscribers is often a few Mbps because the speed for each terminal is varied depending upon the number of subscribers accommodated by each station. Therefore based on the optimal speed of international recognition, this report sets broadband as 25 Mbps or greater for fixed-line home subscribers, 4G LTE level of speed for mobile subscribers.

[Box 3-3] Definition of Broadband

Akamai : Akamai collects its data through its "globally-deployed Intelligent Platform" and defines broadband Internet as **4 megabits per second** (Mbps) or greater and "high broadband" as 10 Mbps or greater.

ITU : The "Defining Broadband" section details recent and upcoming innovations in broadband technology. It defines broadband as **256 kilobits per second** (or 0.256 Mbps)

OECD : The report defines broadband services in a broad manner, and like the ITU report, it counts speeds that are as low as 0.25 Mbps as broadband, though it does include speeds up to 45 Mbps as well. the **"high-speed" threshold of 25 Mbps** has been proposed in various contexts around the globe

FCC : FCC defined Broadband Internet as **25 Mbps** on the press release in 2014

Broadband services can be offered only when there is infrastructure ready, so it is very important to build the infrastructure before service provisioning. When a user makes a subscription, preparations have to be made up with the access network ready to the subscriber's home within a certain period which is called broadband coverage. Achieving broadband coverage with a speed higher than 25 Mbps can be a more urgent goal.

[Box 3-4] Speed of Broadband Services in ASEAN Countries[11]

Singapore
Regional and a global leader in making high-speed broadband widely available and encouraging its adoption. Today, a 100Mbps connection is about SGD 29/month with a 1Gbps connection at SGD 49.99/month. Singapore now has over 95% household coverage with an adoption rate of 46%.

Malaysia
Slightly different approach to broadband implementation. In case of Malaysia, the broadband targets are based on speeds of 256Kbps with the aim to provide 10Mbps or greater to high economic impact areas Malaysia set a target to increase the broadband penetration rate to 75% of households by 2015. Sacrificing speed for greater availability.

Indonesia
Indonesia initiated the National Broadband Network Expansion of Indonesia Economic Development 2011-2025, commonly referred to as MP3EI.21 Under the plan, the wired access target for a 20Mbps connection is set to increase from 21% in 2010 to 75% in 2015.

Thailand
Thailand cabinet approved the government's National Broadband Policy, which built on the ICT2020 Masterplan of 2008, in November 2010 with the aim of extending basic broadband services to 80% of the population by 2015 and 95% by 2020. Other targets are to provide 100Mbps fiber-optic services to key cities and regional areas of commerce by 2020.

Philippines
Digital Strategy 2011–16 aims to lower average prices for broadband access by 5% a year and to provide services of at least 20Mbps to all central business districts by 2016 while providing at least 2Mbps service to 80% of households by 2016 and 100% of villages by 2020

[11] ASEAN Project Information Sheet MPAC PP/ A3/01 11 IDA Fact Sheet (November 2013): Mid-Term Review of the ASEAN ICT Masterplan 2015 (AIM2015), http:// iif.un.org/content/broadband-commissiondigital-development

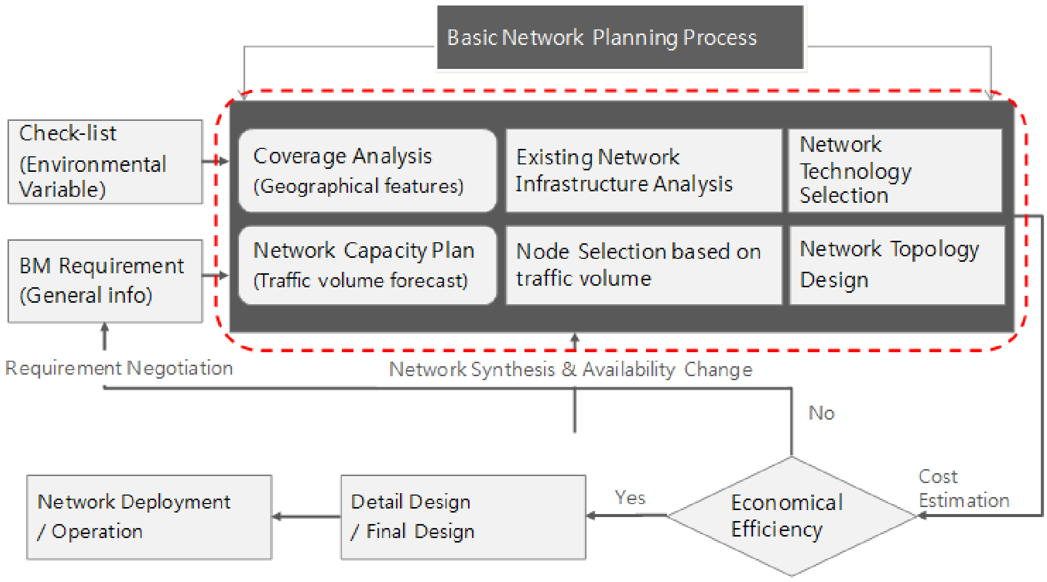
4. Network Topology and IXP

4.1 Network Topology

Designing a backbone network in the ASEAN region requires a lot of information including existing network infrastructure, traffic demand, and traffic flows in and out of the region. This chapter mainly focuses on the process of network topology design and applicable topologies for AP-IS.

As illustrated in [Figure 4-1] , we need composites of steps in designing a network, once the service types and traffic volume have been defined and identified. A checklist is first made, considering the environmental variables, along with a BM requirement that contains general information. Then, the actual basic network planning process starts- coverage analysis including geographical features, existing network infrastructure analysis, network technology selection, network capacity plan including traffic volume forecast, node selection based on the traffic volume and flows, and finally network topology design. When the network design process is finished, cost estimates and economic efficiency analysis are followed for more actionable planning. There may be some options to meet optimal efficiency and requirement negotiation based upon the result of efficiency analysis.

[Figure 4-1] Network Design Process



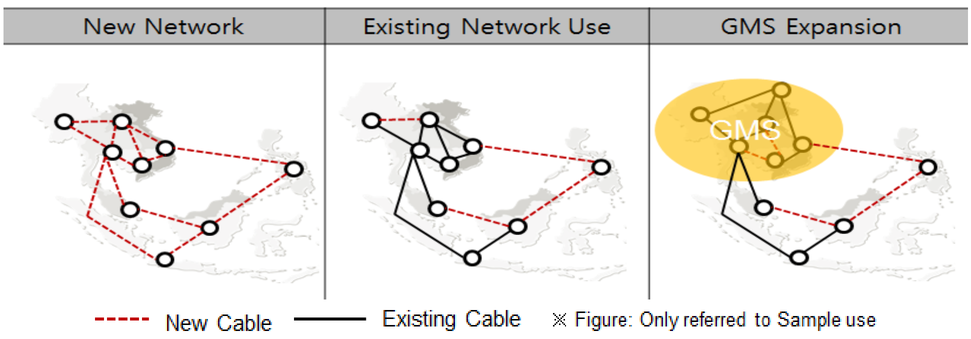
In designing AP-IS Network, and depending upon utilization of existing infrastructure, there are three options – new network build-up, GMS expansion, and existing telecom network use – and the necessary information and pros & cons for each option are as follows:

The First Option is to build a new backbone network along with existing infrastructure such as road, railway and power line. For the feasibility study and investment planning, information on road and railway routes of each country, current construction status, and future plans would be needed.. This option has both pros and cons. Building a new network will be the best choice for we can draw network optimization through link capacity estimation and guarantee sufficient capacity. However, it requires expensive deployment cost, long construction period, and high maintenance cost. This option is somewhat unrealistic in the ASEAN region, given that in most of the countries, basic telecommunication infrastructure and fiber backbone network was built recently.

The Second Option is to expand the Greater Mekong Sub-region Information Super-highway (GMS – currently under construction connecting Myanmar, Laos, Thailand, Cambodia, Viet Nam, and China). Some information on GMS such as physical connectivity status including capacity, routes, usage, involved ISPs of each country, GMS operation center, node information; current status and future plans, transmission topology, capacity, and equipment status, and international connectivity point and capacity should be provided for more feasible network design. Expanding GMS to build AP-IS can be rapid and realistic solution for ASEAN connectivity since this option is more ISP friendly, easy to fund for network deployment. However, in order to get optimal topology, it needs long negotiation with incumbent carriers for the amendment of existing GMS settlement, open access to each other's network and cooperation.

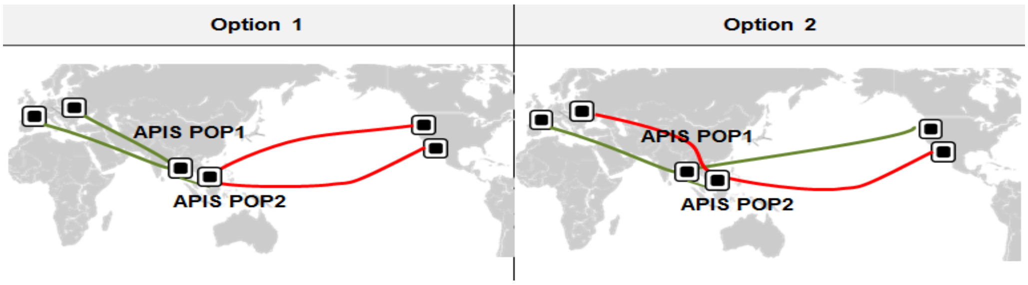
The Third option is to use the existing network and then selectively fill the missing links and nodes. Information on submarine and terrestrial cable status such as (a) the capacity, routes, and stakeholder of each country, (b) submarine and terrestrial cable usage status of each country, and (c) transmission topology, capacity, and equipment status are needed. For capacity planning, international traffic status of each country, traffic ratio toward each continent, and domestic and international long-term traffic forecast data are required. For node positioning, existing IXP locations in each country, top 3 cities in terms of traffic volume, and city disaster occurrence data of each country are needed. Using the existing networks for building AP-IS is the most effective option for saving CAPEX and shortening the construction period. On the other hand, there is an uncertainty of link and node availability and difficulties in negotiating with existing network providers.

[Figure 4-2] Options for Network Design



For external connectivity to Europe and America, two POPs (point of presence) and links would be required as shown in [Figure 4-3]. There are two options.

[Figure 4-3] Options for External Connectivity

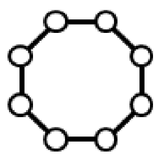
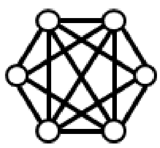
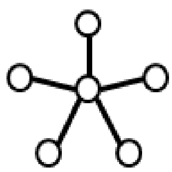
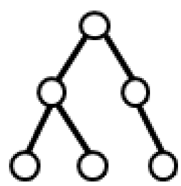


Option 1: The first option has two geospatially separated routes to Europe through POP1 and two separated routes to North America through POP2. Here, POP1 is connected through Trans-Eurasian Information Super Highway (TASIM) and POP2 is connected through the road project conducted as part of the South Asia Sub-regional Economic Cooperation (SASEC). This option can minimize the physical latency but does not guarantee secure external connectivity in case of failure in one of the POPs.

Option 2: The second option, POP1 has one route to Europe and the other route to North America and POP2 also has two routes same as POP1. Routes to Europe are geospatially separated, for example, POP1 is connected through TASIM and POP2 through SASEC respectively. Even if there is a failure in one of the AP-IS POPs, the second option will still ensure external connectivity but it needs sophisticated network management compared to the first option. As for the external connectivity, globally well-known locations of POPs are in San Jose, LA and Seattle in North America, Amsterdam, London, and Frankfurt in Europe. Connecting to one POP from both POP1 and POP2 should be avoided.

Network topology means specific physical (real) or logical (virtual) arrangements of the network elements. Two networks have the same topology if the connection configuration is the same, although the networks may differ in physical interconnections, distances between nodes, transmission capacity, and/or signal types. The topologies often used in communication network design are ring, mesh, star, and tree as shown in [Table 4-1]. For network design, one type can be selected or more than one can be selected and mixed for their different advantages in a hybrid type. Therefore, the best option should be selected for AP-IS of the ASEAN region considering pros and cons of topologies introduced.

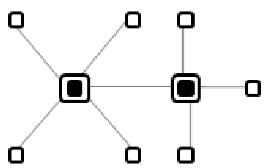
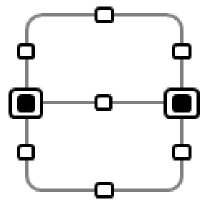
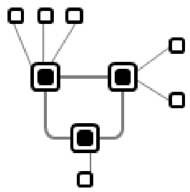
[Table 4-1] General Topology Options for AP-IS

Topology Options	Ring	Mesh	Star	Tree
Shape				
Management	Hard	Hard	Easy (Centralization)	Easy (Hierarchical structure)

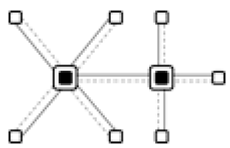
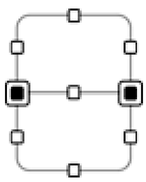
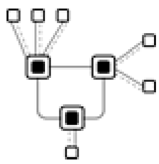
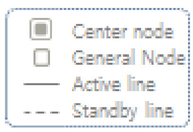
Stability	Medium	High	Low (Single point of failure)	Low (Single point of failure)
Connectivity	Medium	High	High	Low
Construction cost	Low	High (Longest total cable length)	Low	Low (Shortest total cable length)
Traffic centralization	Low	Low	High	High

As explained in the conceptualization part of this report, each layer can have different Topology-type. Therefore, the optimal topology design should be considered reflecting network requirement and current & future demand of each layer. CAPEX, management, stability, and scalability need to be considered before selecting topology and pros and cons of each option should be analyzed in a comprehensive manner before selection of the optimal model. Detailed topology options for the fiber backbone network, transmission network, and IP network are shown in [Table 4-2], [Table 4-3], and [Table 4-4].

[Table 4-2] Physical Connectivity Modeling

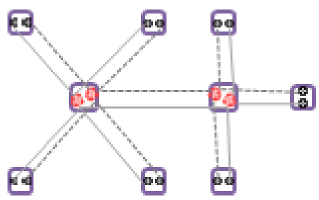
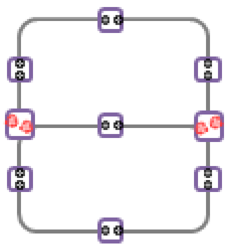
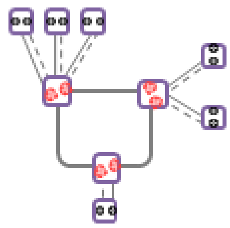
Options	Star	Ring	Hybrid (Ring+Star)
Topology			
	Dual Center Center to Edge: Star	Dual Center Center to Edge: Ring	Three Center: Ring Center to Edge: Star
CAPEX	Medium	High	Low
Management	Easy	Hard	Medium
Stability	Low	High	Medium
Scalability	Easy	Hard	Easy

[Table 4-3] Transmission Topology Modeling

Options	Star	Ring	Hybrid (Ring+Star)	Remark (reference)
Topology				

Description	• Dual center • Center to Node: PTP -Fiber route diversity	• Dual center • Dual ring	• Three center • Center to Center: Ring • Node to Center: PTP – Fiber route diversity	• Consideration (Center) – Traffic demands – External connectivity
CAPEX	• Fiber: High • System: High	• Fiber: Low • System: Low	• Fiber: High • System: Medium	• Fiber: Depends on – fiber length – # of route • System: # of degree
Management	• Easy	• Medium	• Hard	
Stability	• High	• High	• Medium	• Depends on fiber route diversity
Scalability	• Easy	• Easy	• Medium	

[Table 4-4] IP Topology Modeling

Options	**Star**	**Ring**	**Hybrid (Ring+Star)**
Topology			
			
Description	• Dual Center • Center to Edge: Star	• Dual Center • Center to Edge: Ring	• Three Center: Ring • Center to Edge: Star
CAPEX	• Medium	• High	• Low
Management	• Easy	• Hard	• Medium
Stability	• No single point of failure	• No single point of failure	• No single point of failure
Scalability	• Easy	• Hard	• Easy

As for the fiber optic international backbone in ASEAN, there is little information about terrestrial cables in public media while submarine cables are more open to the public. Therefore, this report finds out the key criteria required for terrestrial network design based on the limited amount of data available. Based on the current conditions the ASEAN region is in, AP-IS can be designed to the following criteria:

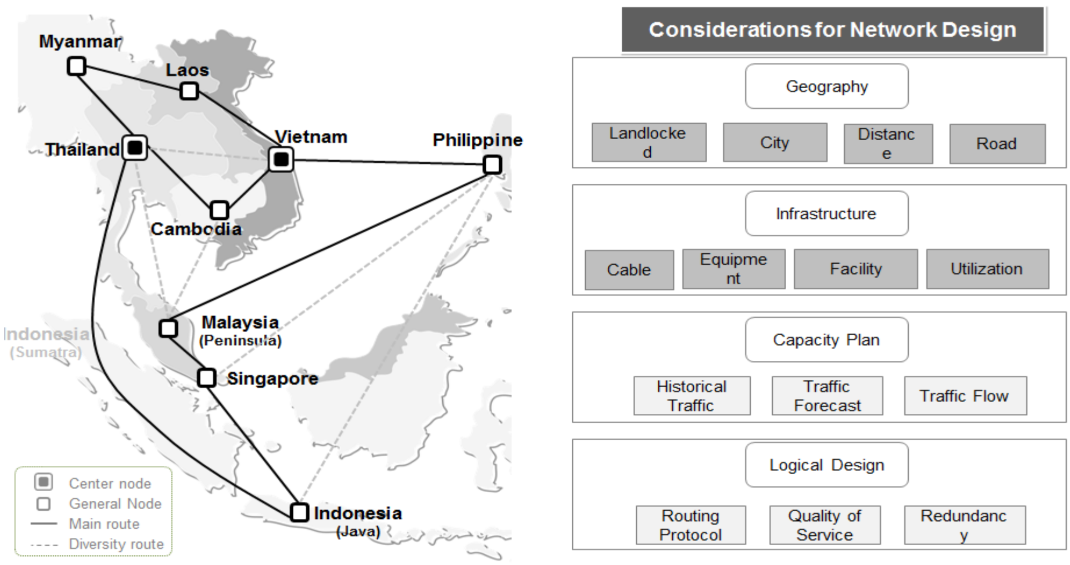
(Fiber Backbone Network)
The hybrid-type topology between large cities across borders and an adequate level of backup capacity with differentiated routes for resilience are recommended. But there might be constraints or challenges to be tackled such as ongoing monopoly power over gateways or the local access networks; linking available capacity to IXP, restrictive regulation such as gateways to international facilities, the use of alternative networks and dark fiber or competitive backhaul from satellite and submarine cable landing stations. Competitive backhaul or capacity along the railway, roads, and electric power line should be provided to the new players or competing service providers

(Network Capacity)
Total Network capacity can be calculated based on 200~500 Kbps for each subscriber, accordingly the number of fibers for the backbone links can be calculated reflecting maximum capacity of a single fiber, currently 6.4 Tbps (50 Gbps x 160) when DWDM applied. Transmission equipment with capacity of 1~10Gbps and switching systems with Ethernet suite of standards can be applied. Annual Internet traffic growth rate in ASEAN is up to 50 % while the rate in OECD countries is 20~40% year on year.

(Traffic Exchange)
Local traffic is exchanged locally, and direct traffic exchange is made with neighboring countries. Submarine cable dependency should be decreased to the degree of well-balanced with a terrestrial network, for example, 50% of traffic goes to the Terrestrial, other 50% to Submarine. Capacity swaps on each other's networks should be arranged by using IRU (Indefeasible Rights of Use) or fiber swaps for inter-city or inter-border network at the IXP.

In parallel with the above criteria, AP-IS network can be physically and logically designed in terms of network topology, nodes and links as shown in [Figure 4-4]. This figure portrays the overview of the entire network, and its configuration, capacity, and technologies need to be developed into a detailed illustration with major considerations applied as required in network design.

[Figure 4-4] AP-IS Network Feature and Considerations



4.2 Internet Exchange Points[12]

An Internet eXchange Point (IXPs) is the most critical part of the Internet's Infrastructure. The networks they control are grouped by Autonomous Systems (or AS) by the IETF Standard RFC1930.

Otherwise, an Internet Exchange Point (IXP) is a physical location where different IP networks meet to exchange traffic (switch, routers, cabling, and ports) with each other to keep local traffic local. In order to have connectivity to the "global Internet", an AS of an ISP must be connected to an AS of at least one other ISP that already has "global Internet" connectivity. This is called "buying transit," as the process usually involves an economic transaction. Autonomous Systems are interconnected via the BGP protocol RFC4271. Internet service providers usually buy transit, with the exception of a small number of very large ISPs (called "Tier 1" ISPs), who get global Internet connectivity simply by being interconnected with each other. In this model, all Internet traffic flowing between smaller ISPs (also called "Tier 2" ISPs) has to pass through their upstream providers' networks.

Some of the Tier 2 ISPs decide to interconnect their AS directly, in order to reduce the amount of different networks (the number of 'hops') the traffic has to traverse, and at the same time save some transit costs. This practice is called "peering“. Peering reduces upstream costs, providing a physical connection between two ISP's networks. Internet Exchange Points (IXPs) provide a solution to this.

An IXP is a single physical network infrastructure to which many ISPs can connect. Any ISP that is connected to the IXP can exchange traffic with any of the other ISPs connected to the IXP, using a single physical connection to the IXP, thus overcoming the scalability problem of individual interconnections. Such peering practice is called "public peering" (as opposed to "private peering", where two ISPs have a direct physical interconnection as described above), and IXPs are often referred to as "peering points" or "public peering points". By enabling traffic to take a shorter path to many ISP networks, an IXP can improve the efficiency of the Internet, resulting in a better service for the end user. IXPs are not, typically, involved in the peering agreements between connected ISPs; IXPs do however have requirements that an ISP must meet to connect to the IXP, Since the physical network infrastructure is shared by all the connected ISPs, and activities of one ISP can potentially affect the other connected ISPs, all IXPs have rules for proper use of the IXP.

Benefits of an Internet Exchange Point (IXP) are that it:

- Keeps local Internet traffic within a local infrastructure, and reduces costs associated with traffic exchange between networks;
- Builds local Internet community and develops human technical capacity – better net management skills and routing;
- Improves the quality of Internet services and drive demand in by reducing delay and improving end-user experience;
- Convenient hub for attracting hosting key Internet infrastructures within countries.

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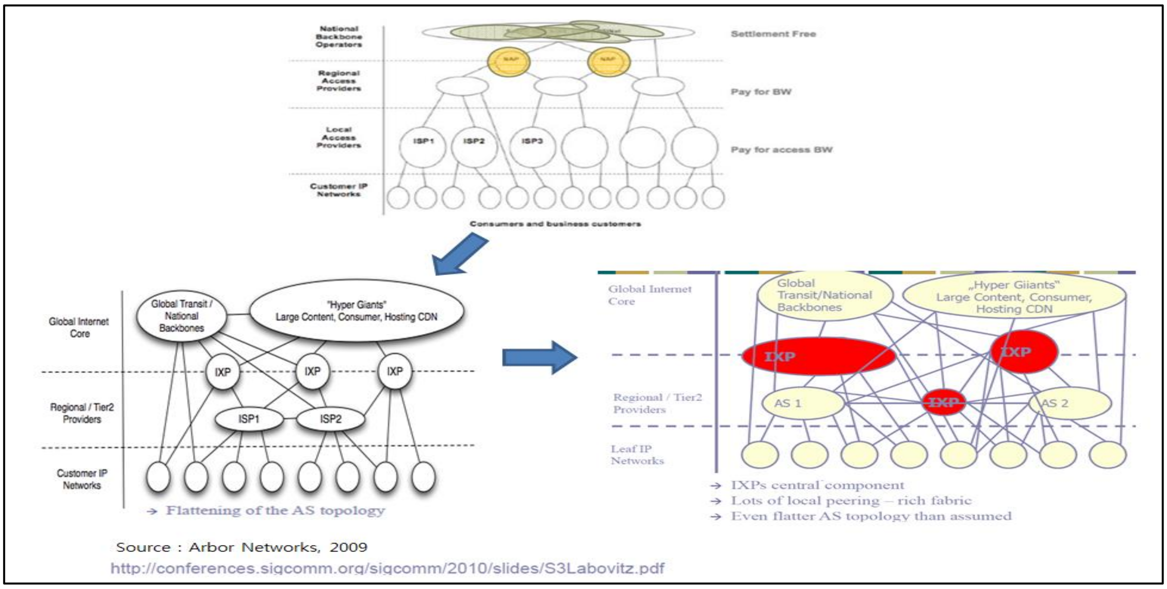
12 " IXP", Gaurab Raj Upadhaya, RIPE NCC Regional Meeting, 15 Nov.2006
"ISOC: Internet Exchange Point-Global Development Work", Jane Coffin and Christian O'Flaherty, July 2014

[Figure 4-5] Recent IXP Model Evolution

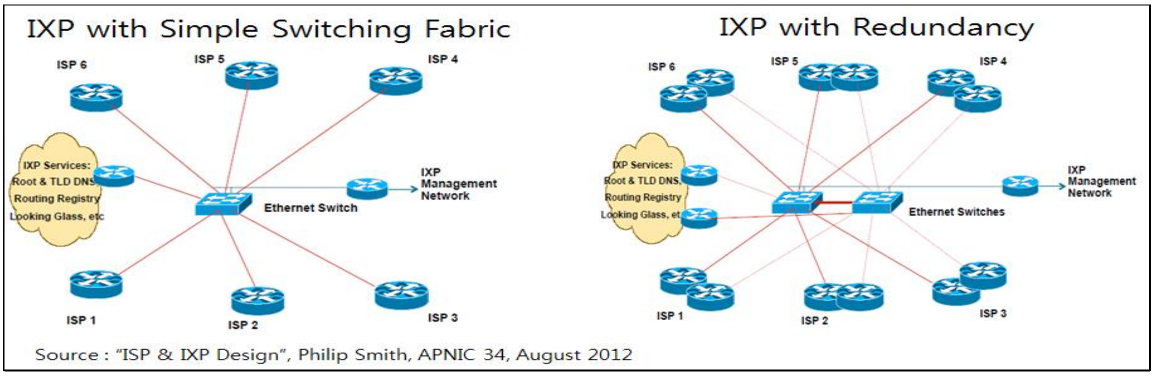


The initial stage of interconnectivity model between ISPs was mostly in a vertical as seen in the [Figure 4-5], hierarchical structure where interconnection was made through NAP (network access point) based on a telecom provider that operates the nationwide backbone network. However, as there emerged an increasing number of global transit providers and stakeholders who produce, consume, and provide massive-scaled contents, the structure evolved into a flatter one. Recently, as the efficiency of interconnectivity and economic feasibility has become the key issues, the hierarchical structure is changing toward an IXP-based flat topology structure that facilitates multilateral interconnection.

The core job of an ISP is essential to forward Internet traffic. Physically, this is done with devices called "routers," who work at the "network" layer (also called "layer 3") of the OSI and TCP/IP models. There has to be a connection between all participating ISP routers. This has been done in the past by physically connecting (i.e., at the so-called "layer 1") the routers (for example, with a 10BASE2 cable); however, most IXPs currently connect routers at the data link layer ("layer 2") by cabling them to Ethernet devices and letting them share a Local Area Network, called "Peering LAN".[13]

[13] "ISP & IXP Design", Philip Smith, APNIC 34, August 2012

[Figure 4-6] IXP Design



Since an IXP's stability and survivability is very important, it usually has dual switches and routers along with DNS, Routing Registry, and Looking Glass, all of which help interconnection among the accommodated ISPs and their management. According to "ISP & IXP Design" by Philip Smith, IXP design requires the following considerations:

- Two switches are required for redundancy
- ISPs use dual routers for redundancy or load sharing
- IXPs must offer services for the 'common good' – Internet portals and search engines; DNS Root & TLD[14], NTP[15] servers; and routing registry and looking glass
- IXP management should be neutral – usually funded equally by IXP participants; and 24x7 cover, support, value added services
- Location must be secure and neutral
- Configuration – IPv4/24 and IPv6 /64 for IXP LAN; ISPs require AS, basic IXP does not
- Network Security Considerations – LAN switch needs to be securely configured; Management routers require TACACS+[16] authentication, vty[17] security; and IXP services must be behind router(s) with strong filters

The fact that needs to be taken into account when preparing for peering is that each participant needs to run BGP with own AS number, public ASN, not private ASN. Each participant configures external BGP directly with the other participants in the IXP whether peering is done with all participants or a subset of participants. There are a few options in peering. First, in mandatory multi-lateral peering (MMLP), each participant is required to peer with every other participant as part of their IXP membership. Second, in multi-lateral peering (MLP), each participant peers with every other participant (usually aided by a Route Server). Third, in bilateral peering, participants set up peering with each other according to their requirements and business relationships, and this is the most common situation at IXPs today.

In terms of services, the services offered should not compete with member ISPs (basic IXP); for instance, web hosting at an IXP is a bad idea unless all members agree to it. IXP operations should make performance and throughput statistics available to members. In this case, tools such as MRTG/Cacti can be used to produce IX throughput graphs for member (or public) information. Routing Registry is used to register the routing policy of the IXP

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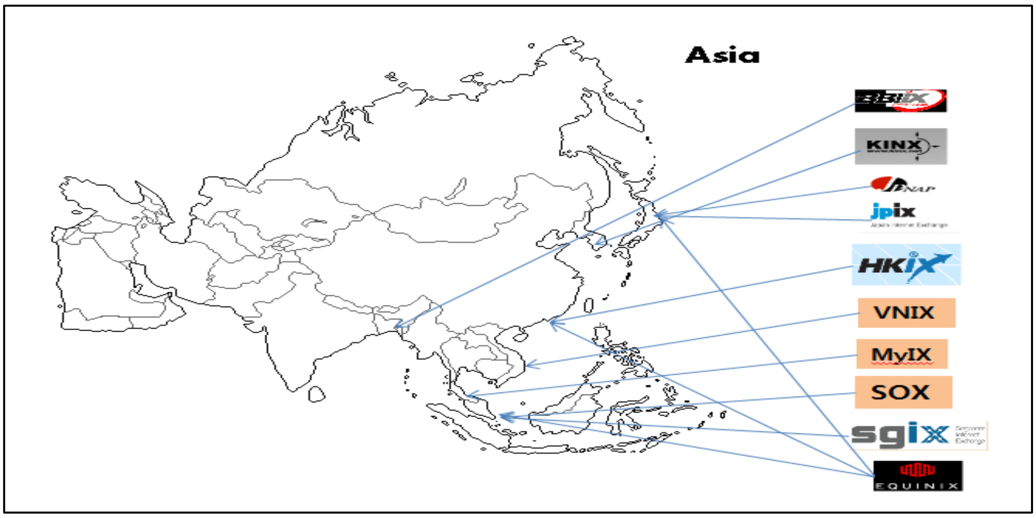
14 TLD: Top Level Domain
15 NTP: Network Time Protocol
16 Terminal Access Controller Access-Control System Plus, is a protocol developed by CISCO and handles authentication, authorization, and accounting (AAA) services
17 Virtual TeletYpe

membership. The country IXP could host the country's top level DNS and optionally host backup of other country's ccTLD DNS. There could be a Route Collector, which shows the reachability information available at the exchange. One way of making the Route Collector routes available for a global view is Looking Glass (www.traceroute.org), where only public or members can access[18].

In the Asia-Pacific region, APIX is the association of internet exchange points (IXPs) since 2010. It serves as a forum for IXP personnel to share information and experiences. APIX members meet twice a year, at APNIC and APRICOT conferences. The 14 IXPs who join APIX as active members include: BDIX of Bangladesh (Dhaka), HKIX of Hong Kong, JPNAP, JPIX, BBIX, and Dix-ie of Japan, KINX of Korea (Seoul), NIXI of Indonesia, MyIX of Malaysia, NP-IX of Nepal (Katmandu), SGIX and SOX of Singapore, VNIX of Viet Nam (Hanoi and Ho Chi Minh City), and Equinix of AP (Hong Kong, Singapore, and Tokyo).

[Figure 4-7] Asia-Pacific Internet Exchange Point (APIX)



There are also indications in some countries that there may be insufficient competition in backhaul markets where the majority of the most accessed websites, designated under their country code top level domain, are hosted at a foreign location. This requires ISPs in these countries to purchase more international links or access, which reduces the resilience of networks and weakens the effectiveness of IXPs in their country. Just establishing IXPs in the region is not sufficient to decrease cost and increase performance, still there exist entry barriers in the market of links (or backhaul) to the IXPs for the new players. In many countries around the world, insufficient competition is the cause of the lack of affordable backhaul.

The availability of submarine fiber technology has brought prices down in coastal countries where competitive operators can bring this capacity to the market. The challenges can be greater for landlocked countries without co-operative neighbors for access to landing stations and other necessary infrastructure. Countries could greatly improve the functioning of their markets by removing specific licenses for specific functions in the backhaul market, such as regional, national and international licenses and licenses for landing stations.

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18 "ISP & IXP Design", Philip Smith, APNIC 34, August 2012

5. Implementation Models

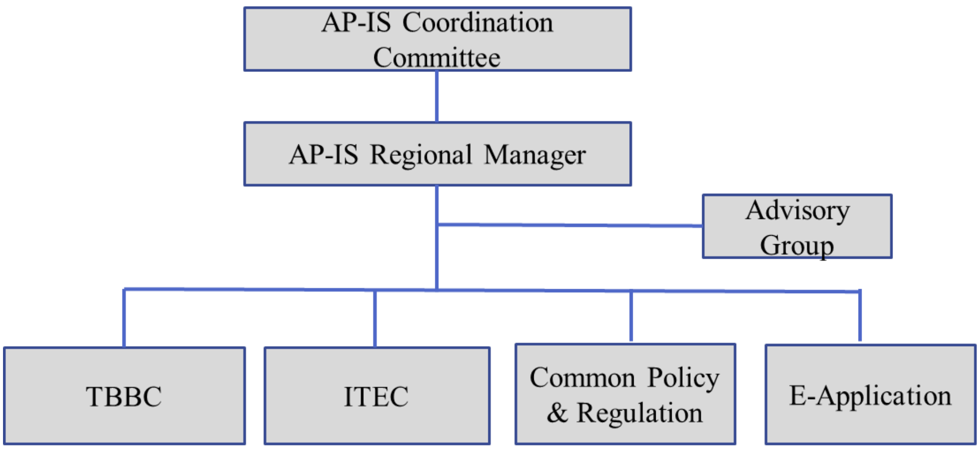
5-1 Organization for AP-IS

In order to improve ICT infrastructure in the region and interconnectivity between the ASEAN countries, it is necessary to establish an organization, which consists of sub-committees (or sub-working groups) for the discussion of the entire process including identification of domestic or international issues and problems, setting goals, making plans, and reviewing the result. Furthermore, it is required to design an organization that has the authority actually to take actions beyond individual countries to the entire ASEAN region to put out effective resolution; designing well-balanced land/sea based regional networks, negotiating affordable transit price, solutions to inequalities and gap in broadband coverage and service quality, and affordable subscriber price, etc.

So far, the focus has been on improving the domestic infrastructure of each country, with efforts for international interconnectivity being made only in a form of declarations[19].

However, international collaboration will be essential in the future to reduce dependency on the submarine cable networks, to improve network sustainability, and to deploy broadband infra more reasonable costs. Establishing SPVs, as pointed out by many experts, is ultimately required, yet since it has high potential of making complex situations with different viewpoints between countries, as well as other problems regarding funding, cooperation, competition between countries or providers, it would be more realistic to first operate the organization in form of a committee and then gradually drilling it down to details.

[Figure 5-1] Organizational Structure



At the first part of this report the team suggested AP-IS conceptualization that has 4 layer structure, so the organizational structure consists of four sub-committees or study groups for each layer; TBBC, ITEC, common policy and regulation, and e-application development.

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[19] Bilateral agreement at Government level is very rare at this moment, so I selected "declaration" reflecting the ICT Masterplan of ASEAN community level.

Here professionals with expertise in the field need to be consulted for practical discussions. Because each layer has distinct features of its own, with different expertise and experiences from other layers, the study groups should be operated independently. Instead, one or two persons from each group can join the coordination committee to express their interests, identify action items for cooperation, and further coordinate or integrate them for more efficient operation. Roles and Responsibilities of sub-groups are given in [Table 5-1]

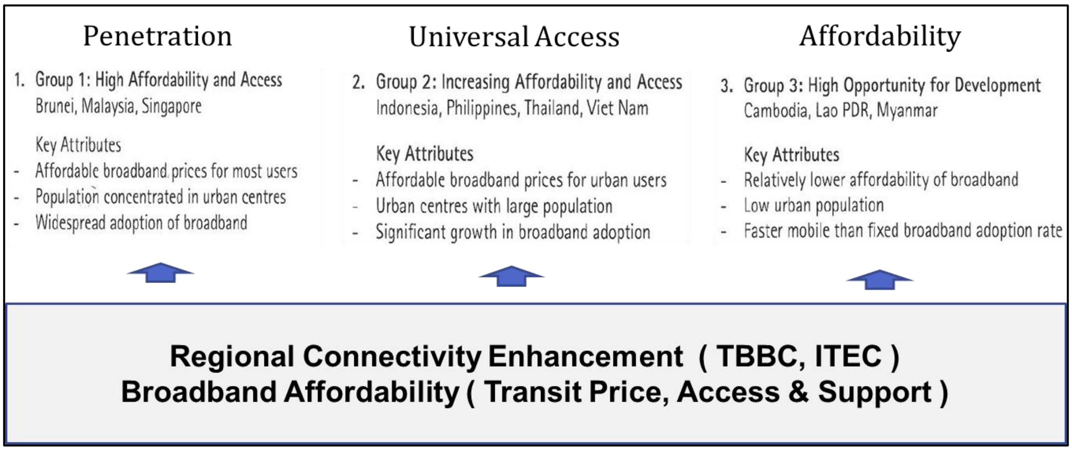
[Table 5-1] R&R of Sub-groups

Sub-group/Study group	Roles and Responsibilities
TBBC Study Group	• identify & fill in missing fiber links between countries within the region or with other continents. • identify and build capacity for direct international connection. • review and standardize the interconnectivity specifications and technological methodologies between countries. • review yearly progress and submitting reports, etc.
ITEC Study Group	• conduct surveys on the current status, price, and contract conditions of regional and extra-regional peering transit. • conduct research on the current status of regional and extra-regional traffic, traffic conditions for each service type, and routing route information. • conduct research and making policies to the most optimal Internet exchange model. • develop plans for local IXPs, main IXPs of each country, and IXPs for interconnection between countries. • conduct research on IXP operational policies. • find out measures to minimize the amount of traffic to North America or Europe.
Common Policy & Regulations Study Group	• conduct research to find solutions on issues of provider license, frequency regulations, interconnectivity regulations, network neutrality, open access or other inequalities and discrimination between providers. • develop measures for each country to improve infrastructure. • support remote areas or disadvantaged groups. • develop policy issues on the government and public institutions' infrastructure improvement, projects for cooperation. • build and manages comprehensive databases on national plans for building, promoting, regulating the ICT infrastructure and introduces case studies.
E-application Study Group	• conduct research on the current status of public sector e.g. e-government • resolve issues and develop projects for cooperation. • develop and produce contents in local languages. • find measures to internalize high-capacity contents to minimize external traffic and improve service quality. • explore possibilities to invite global providers or data centers in the region.

5-2 Project Development and Implementation

The ASEAN ICT Master Plan 2015 and the supporting ASEAN Broadband Corridor Project recommends implementation based on groups that are classified according to the maturity level of countries in terms of ICT development. Each group is given different goals and tasks to focus. In most cases, the focus is on increasing broadband access and affordability within the country. Therefore, it is recommended to find out issues that can apply to the entire region and focus on cross-border collaboration while maintaining existing ASEAN plans and strategies that have been already made for each country.

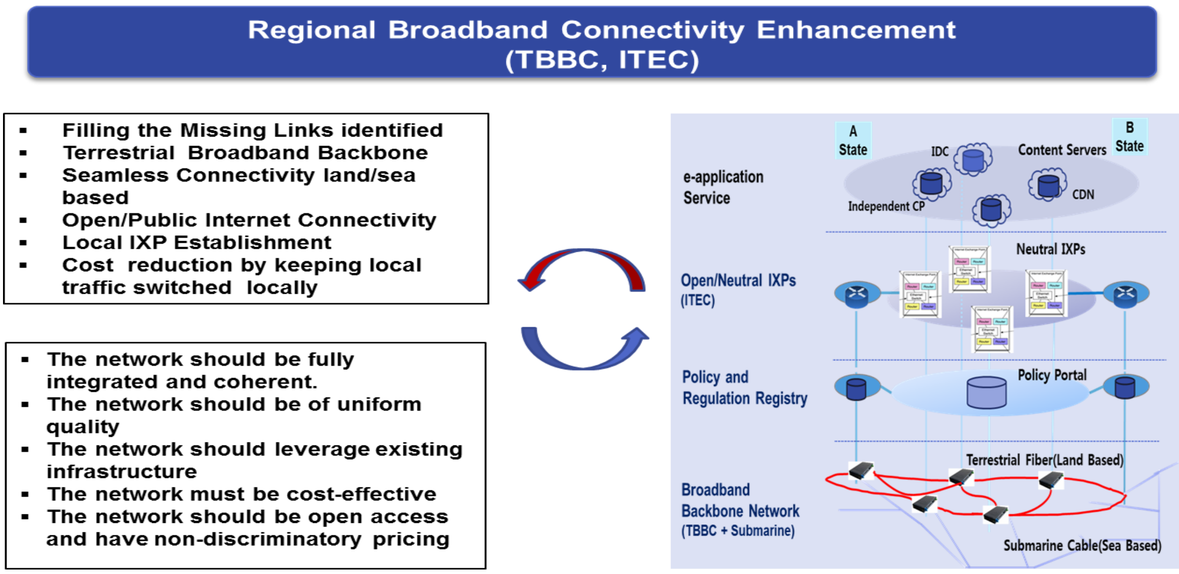
[Figure 5-2] ASEAN collaboration



AP-IS construction for the ASEAN region needs to be carried out in two different projects – one for achieving regional connectivity enhancement and the other, for broadband affordability.

Each of these projects needs to be carried out through international cooperation along with urgent discussions on what type of implementation framework is the best. Since there are a lot of projects currently being carried out or scheduled, the issue of submarine cable network investment as part of response to the demand is likely to be in large part resolved through cooperation with telecom providers. It is recommended to streamline the communication channels with these consortia and share information for AP-IS, rather than having a separate project. However ensuring the terrestrial broadband connectivity and direct traffic exchange among member countries is another important issue to be solved by a certain level of Governmental intervention and regional collaboration.

[Figure 5-3] Collaboration for Regional Connectivity

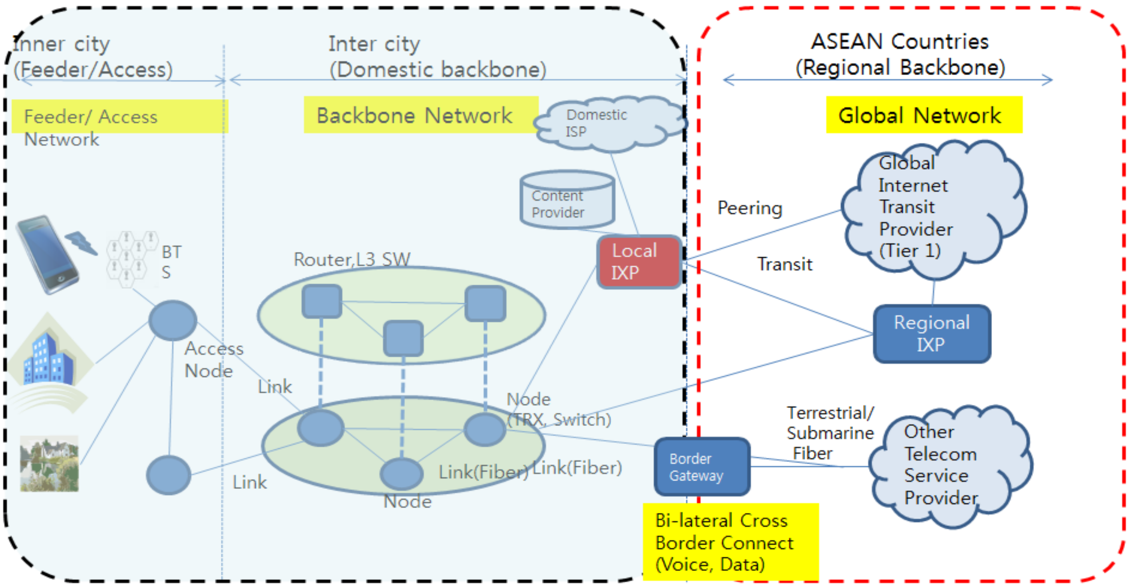


In order to achieve broadband affordability, if the monthly price of broadband is set to be less than 5% of GDP (or for example US$ 10), efforts should be made in terms of increased government investment, increased use of the existing infrastructure such as the railroads and roads, and cost reduction. Above all, reducing the 'cost of connectivity' to a great extent is very important, which can be achieved not only from efforts of each government but also from cooperation among countries within the region. Since the share of external data traffic is larger than domestic, reducing the cost of Internet transit can lead to overall cost reduction to a certain level.

5.3 Network Topology & Traffic Exchange

The network can be largely divided into three – inner city network, inter-city domestic backbone network, and cross border network. Since there are already many strategies for the domestic network being developed and implemented by each member country for advancement, this chapter focuses on cross-border interconnection, which is illustrated in [Fig 5-4]. In particular, a direct interconnection of a cross-border network by way of potential center nodes, and IXP construction, Internet peering or transit should be focused. So, international connectivity needs to be considered in terms of fiber optic cables, transmission, and IP peering or transit.

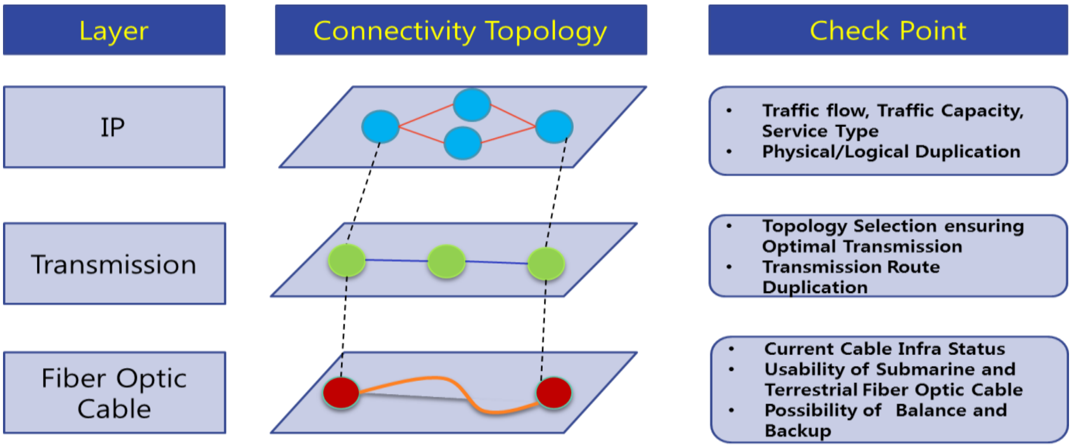
[Figure 5-4] Scope in Interconnectivity Map



For international connectivity on traditional telephone and leased line telecommunication systems, in general, there are well-established technical standards and revenue sharing models for international connectivity. The governing body, ITU, sometimes mediates involved parties based on consensus between telecom operators and governments of neighboring countries. However, in the Internet market, even though there are well established standards by IETF (Internet Engineers Task Force), interconnectivity contracts have been established by private-sector ISPs with the manner case by case and has so far been lagged behind in ASEAN region in terms of fair market competition. On the other hand, as the communication network is gradually shifting from telephone network-based to the Internet-based, and as most of the existing services now can be accommodated via the

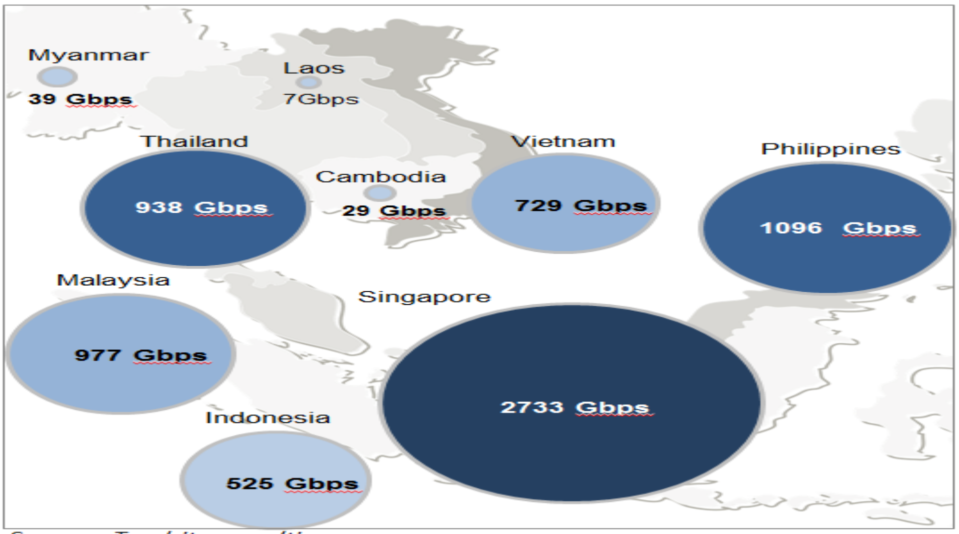
Internet by using new technology like VoIP and IPTV, it is necessary at least that each country takes a look at the reality and, if it is publically beneficial and needed, intervenes market and takes measures to amend existing policies and regulations that can be applied to all the parties in the Internet connectivity market.

[Figure 5-5] Network Connectivity Check Points



Based on data from ASEAN Country Traffic Volume (2014), it is necessary to select the regional hubs or center nodes for optimal traffic exchange and networking efficiency. In terms of operation, center nodes are important because no matter what topology we may design, having center nodes makes the system more efficient and robust. Especially for a star- and hybrid-type topology, it is essential to have center nodes to have a connection within the entire ASEAN region. From the external connectivity view, having center nodes is much more efficient compared to having it in every country because, by traffic aggregation, it has both strong bargaining power in the negotiation with tier 1 ISPs and more efficiency by making local traffic exchanged locally.

[Figure 5-6] Traffic Volume in each country



Source: *Terabit consulting*

When selecting center nodes for AP-IS, factors like geographic location, domestic infrastructure, intra-ASEAN connectivity, and international connectivity should be considered and evaluated as important factors;

- Geographic location should be such that each country can be easily connected in the shortest distance possible
- Domestic infrastructure of each country - ICT, transportation, and electricity infrastructure,
- intra-ASEAN connectivity should be also considered as it is directly related to the CAPEX and OPEX of the network, and
- International connectivity is important factor as it is related to connections to TASIM, SASEC, North America and Europe.

Resilience to the impact of disasters would also be a key factor for center node selection. If possible, disaster-free areas from the earthquake and other natural disasters would be preferred. The countries that have high traffic volume production and consumption would be also preferred.

[Table 5-2] Center Node Selection Criteria

Country	Geographic location	Domestic Infrastructure	International connectivity	Intra-ASEAN connectivity
Cambodia	◔	◑	◔	●
Indonesia	◔	◑	◔	◑
Lao P.D.R.	◔	◔	◔	◑
Malaysia	◑	◕	●	◑
Myanmar	◔	◔	◔	◔
Philippines	◔	◕	●	◑
Singapore	◑	●	●	◕
Thailand	●	◕	◕	●
Vietnam	●	◑	◕	●

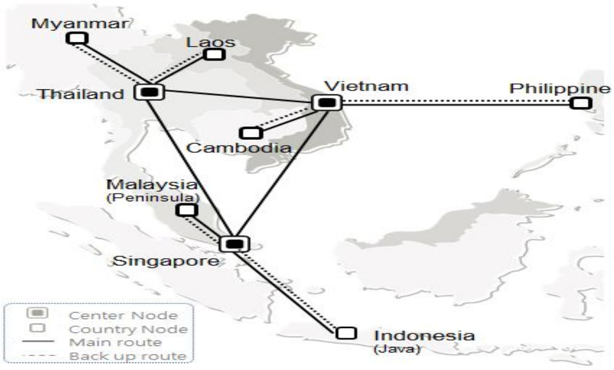
Best score ● ←→ ○ Least score

Once candidates of center nodes are selected, then topology design should be followed. If conditions allow, the hybrid-type is the optimal one because it requires less amount of resources as compared to the ring-type topology and interconnection through center nodes ensures stable and faster traffic flow as discussed in the previous chapter. In a hybrid topology, the entire AP-IS can be interconnected within a few hops only, with better physical latency compared to the ring-type topology.

However, the hybrid topology requires complex configuration. Any type of disability in a center node may cause critical impact on AP-IS interconnection so it is required to put intensive amount of efforts in the operation of the center nodes, with well-trained operating engineers for the entire system.

When the types of physical routes and geographical topology are selected, next is selecting the best models for the upper layers. As for the transmission topology, hybrid-type is also recommended. As shown in Figure 5-7, three center nodes – Thailand, Viet Nam, and Singapore – can be connected in a ring-type topology, with Point-to-Point (PTP) connection to neighboring countries. Fiber routes will have diversity, with the main route extending out directly and backup routes going through via neighboring countries for instance.

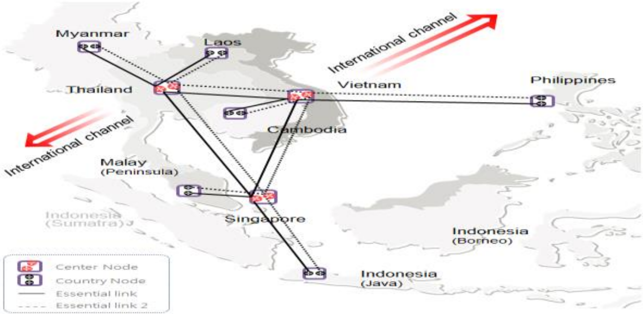
[Figure 5-7] Physical and Transmission Topology - Hybrid



The hybrid-type topology ensures whole stability network and is relatively simple with two dimensions – center and other nodes, yet offers path diversity for IP traffic. However, if fiber route diversity is not guaranteed, there may be a single point of failure issue. Moreover, it has some possibility of high CAPEX; fiber path/length increase and number of systems increase.

As for the IP topology, a hybrid type of redundancy is recommended to connecting three neutral IXP centers in a dual ring, where each center aggregates its sub-region (south, east, and west) countries. Direct international points of transit and peering or dedicated links are connected to international transit points on the outside of the region. For this type of IP topology, it is recommended to set up a governing organization for Internet exchange operation and long-term cooperation.

[Figure 5-8] IP Topology - Hybrid



The hybrid-type IP topology ensures more reliable operation with equipment and center backup. Having traffic of each country assorted to the center, making operators to timely increase or decrease switching capacity and easier traffic management. However, this type of IP topology increases CAPEX by establishing three center nodes for operation and needs high-performance equipment in centers because of traffic centralization, more careful process that reinforce stability and efficiency.

On the other hand, selecting the best IXP operational model is one of the key issues to be determined, mixed Euro and US model can be considered as a model of ASEAN IXP. Harmonization with the existing IXPs in the ASEAN region should also be considered. It is important to review pros and cons for each factor in the US model and Euro Model, based on which the most optimized choice should be made for the ASEAN region. The best operating models recommended and the reason are summarized in [Table 5-2].

When it comes to connectivity outside of the ASEAN region, for fault tolerant interconnectivity to Europe and America, it needs to have two POPs (point of presence) and links. International links from these POPs must be configured to ensure mutual backup. Physical links that have L3 traffic interconnection for the required capacity should be secured from the existing international fiber cables; whether to buy the existing global transit service as a whole or to buy links reaching POPs of America and Europe. In the long run, hosting POPs of a global tier 1 service provider at the ASEAN IXPs and bilateral L2 peering between operating body of AP-IS and tier 1 service providers are recommended. Eventually best efforts and continuous negotiation to narrow the price gap and keep international transit price down to that of London, New York should be done.

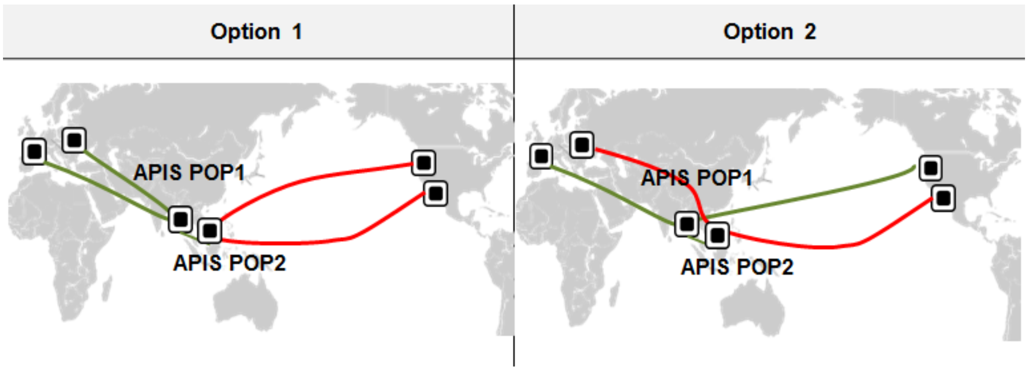
[Table 5-3] IXP Operational Model

Factors for IXP Model		Recommendation	Comments	Similarity
Neutrality	Carrier	Neutral	Open Competition by Equal Access to the Network	Euro Model
	ISP	Neutral	Fair market competition	Euro Model
	Colocation	Optional	Utilize the Major Carriers or Public Organization that has Existing Network Infra	Mixed
Organization		Not for profit	Best for new comers	Euro Model
Pricing		Cost based	Not for profit means cost based pricing	Euro Model
Pricing flexibility		Fixed and equal	Lower the entrance barrier to the ISP who want to peer	Euro Model
Contract		One contract for all Colocation and Peering	Simple and easy to peer	USA Model
Peering Fabric distribution	Domestic	Connected with Fiber	One contract in Domestic peering	Mixed
	Cross Border	Optional	Utilize the Major Carriers or Public Organization that has Existing Network Infra	Mixed

Peering Model	Public	Equal condition of connect for new players	Euro Model
Information Shared	Openly	All the information shared	Euro Model
Cross Connects	Colocation operate Cross Connect Fabric	Reduce duplication of Connect Fabric	USA Model

As mentioned in prior chapters, for external connectivity to Europe and America, it needs to have two POPs (point of presence) and links as shown in [Figure 5-9].

[Figure 5-9] External Connectivity Topology Options



The best recommendation is the option 2, here POP1 connects one route to Europe and one route to North America and POP2 also connects two routes that each extends to Europe and North America. POP1 is connected to TASIM and POP2 to SASEC. Even if there is a failure in one of the AP-IS POPs, the second option will still ensure external connectivity but the physical latency could be worse as compared to the first option. Physical latency, network redundancy, and connectivity must be taken into account for external connectivity. As for the external connectivity, POPs are in San Jose, Los Angeles and Seattle in North America, and Amsterdam, London, and Frankfurt in Europe, so duplicated connecting to one global POP from both POP1 and POP2 should be avoided.

5.4 Technology Selection

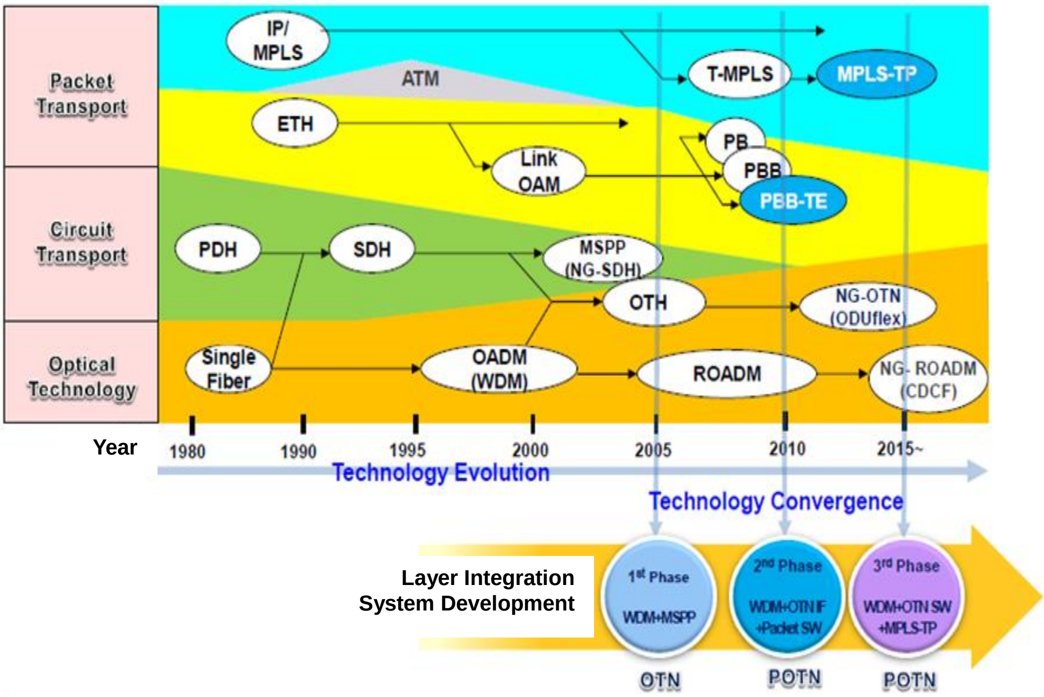
In general, technologies that make up long-distance transmission network between countries can be categorized into three layers as seen in [Fig 5-10]. As for the first optical layer at the most bottom, WDM-based OADM (Optical Add Drop Multiplexer) had been in the spotlight as a new technology since the early 2000s, recently the new optical switching technology, while ROADM (Reconfigurable Optical Add-Drop Multiplexer) has emerged.
This is achieved through the use of a wavelength selective switching module. This allows individual or multiple wavelengths carrying data channels to be added and/or dropped from a transport fiber without the need to convert the signals on all of the WDM channels to electronic signals and back again to optical signals. ROADM functionality originally appeared in long-haul dense wavelength division multiplexing (DWDM) equipment, but by

2005, it began to appear in metro optical systems because of the need to build out major metropolitan networks in order to deal with the traffic driven by the increasing demand for packet-based services. Designing international backbone network and the domestic long-haul network requires a process of setting the required capacity for the mid and long term operation, and then the most optimal technologies are selected in order.

The second layer consists of circuit transport technologies. In the 1980s and 1990s, these technologies were mostly based on PDH (Plesiochronous Digital Hierarchy) and SDH (Synchronous Digital Hierarchy). PDH is a technology used in telecommunications networks to transport large quantities of data over digital transport equipment such as fiber optic and microwave radio systems. However in the 2000s, as triple play (voice, data and video) service became widespread through the Internet and MSPP (Multi-Service Provisioning Platform) was widely adapted and installed in the real network system, which combined different communication networks to make transmission more convenient and simplified. Following the 2000s, the explosive growth of data and widespread of fiber-optic technologies, OTH (Optical Transport Hierarchy) and NG-OTN (Next Generation- Optical Transport Network) according to ITU-T Recommendation G.709 Standard, are emerging as new technologies. As the IP-based network accommodates transmission of voice and video traffics today, circuit transport technologies are slowly becoming extinct; instead network structures are being simplified so as to allow Ethernet packet transmission directly upon optical networks

The third layer consists of packet transport technologies. From the early stages until now, IP transport technology over Ethernet switches has been applied in general. In the meanwhile, MPLS-TP and PBB-TE are drawing attention, which enable a larger amount of transport per fiber core at a lower cost. Here, Multi-protocol Label Switching (MPLS) is a mechanism in high-performance telecommunications networks that directs data from one network node to the next based on short path labels. Multiprotocol Label Switching - Transport Profile (MPLS-TP) is a variant of the MPLS protocol that is used in packet switched data networks, a standard of joint Internet Engineering Task Force (IETF) / International Telecommunication Union Telecommunication Standardization Sector (ITU-T). Provider Backbone Bridge (PBB; known as "mac-in-mac") is a set of architecture and protocols for routing over a provider's network allowing interconnection of multiple Provider Bridge Networks without losing each customer's individually defined VLAN (Virtual Local Area Network). Provider Backbone Bridge Traffic Engineering (PBB-TE) is an approved telecommunications networking standard, IEEE 802.1Qay-2009. PBB-TE adapts Ethernet technology to carrier-class transport networks. The evolution of transport technologies is illustrated in [Figure 5-10].

[Figure 5-10] Evolution of Backbone Network Technologies



* Layer 3 (Packet Transport) : IP, MPLS(router/switch)-based packet switch technology

* Layer 2 (Circuit Transport) : TDM(PDH/SDH)-based (WDCS/MSPP) circuit switch multiplexing technology

* Layer 1 (Optical Technology) : High-capacity transport technology based on application of WDM(Layer 0), optic switching technology(OADM/OXC)

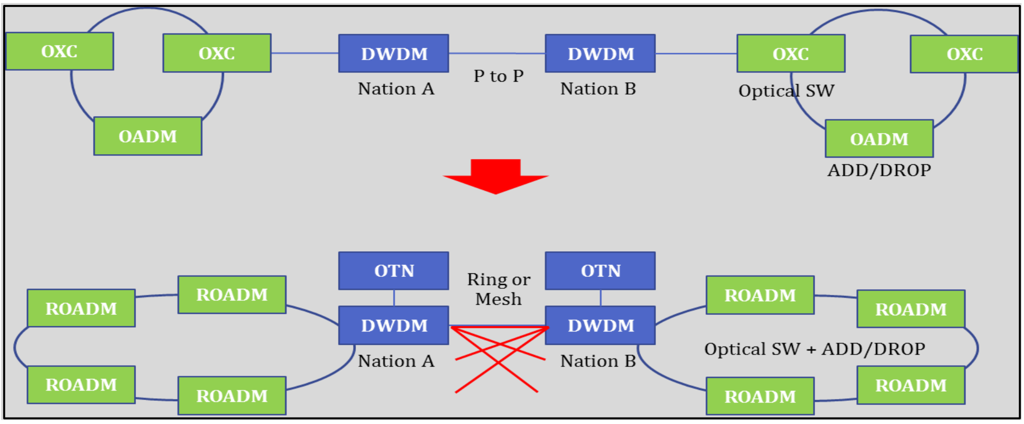
It is recommended to build an international connection based on DWDM-based fiber-optic communication in the short term and shift to OTN+DWDM after taking into account the traffic amount. In this case, only changing the equipment and utilizing existing fiber-optic cables will save investment cost. Moreover, a same mechanism to reinforce the stability and survivability of the network should be introduced. In addition, network configuration within each country should also be changed from OXC and OADM-focused to the ROADM environment as shown in [Figure 5-11].

[Table 5-4] Fiber-optic Transport and Switching Technology (International Core)

Technology	Functions	Topology	Capacity	Transport Distance
LH-DWDM	Long-distance and high-capacity optical transmission	Point-to-Point	400~800G	200~2000km
OADM	Optical signal ADD/DROP	Ring		
OXC	Optical signal switching	Mesh, Ring		
LH-ROADM	Optical signal switching and Add/Drop		400G	400km~600km

OTN Switch	Addition of optical switching function to WDM	Mesh, Ring		

[Figure 5-11] Simple Figure of Fiber-optic Transport and Switching



In designing and selecting technologies, accommodation of existing services and backward compatibility issues should be taken into account, for instance the existing telephone, mobile communications networks as well as the broadband Internet are merged and inter-operable in the new network. In most cases, telephone, dedicated communications, and broadcasting networks are accommodated through DCS (Telephone Data-Carrier System) + MSPP, which are then integrated into OADM of the core network. Since the existing wired and wireless data networks require IP packet switching, they are integrated into OADM through the core router.

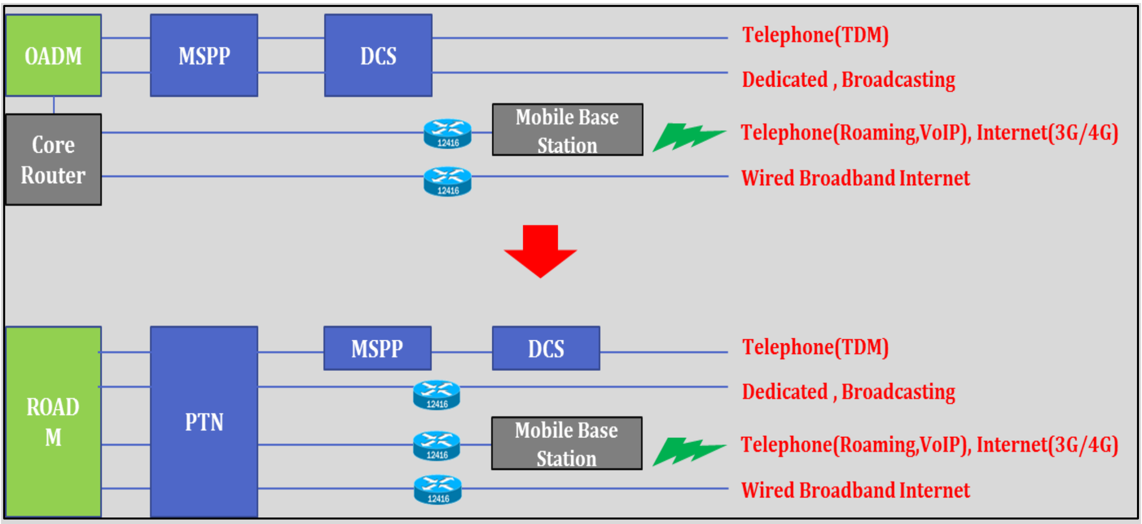
In the mid and long term, they are expected to be integrated into PTN (Packet Transport Network), which can accommodate packet data that have a different amount of capacities. Then, they are integrated back into ROADM in the core network and delivered through the long-distance transport network. As PTN has the entire data based on the packet, it minimizes wasting of the bandwidth. The rapid increase of traffic sourced from the broadband and burst styles of media services are compelling the shift from legacy networks to packet transport networks (PTN) and MPLS. PTN is a multi-core system that can carry any services over either SDH or IP/Ethernet infrastructures at the same time, since traditional leased line and 2G mobile businesses still constitute a significant portion of Carrier and ISPs' revenues. Therefore, the next-generation networks are required to be compatible with existing service models and are required to inherit TDM features.

The amount of data in the ASEAN region is rapidly increasing and along with the emergence of various e-applications, it is needed to prepare suitable network in advance by replacing the legacy telecommunication system with new system and new technologies. [Figure 5-12] shows an outline of the network configuration that can accommodate the backbone network and various existing telecommunication systems and subscribers.

[Table 5-5] Multiplexing Technologies for Circuit/ Packet

Technology	Function	Interface	Switching Capacity	Remark
DCS	PDH signal multiplexing	Nx64k, E1, DS3		
MSPP	SDH signal multiplexing Ethernet signal routing	E1, DS3, STM-n, FE/GE, ATM	60~80G	Ethernet signals need to be converted to TDM
PTN	Packet signal multiplexing (MPLS-TP, PBB-TE)	E1, DS3, STM-n, FE/GE/10GE, ATM	100G	No waste of bandwidth (packet processing)

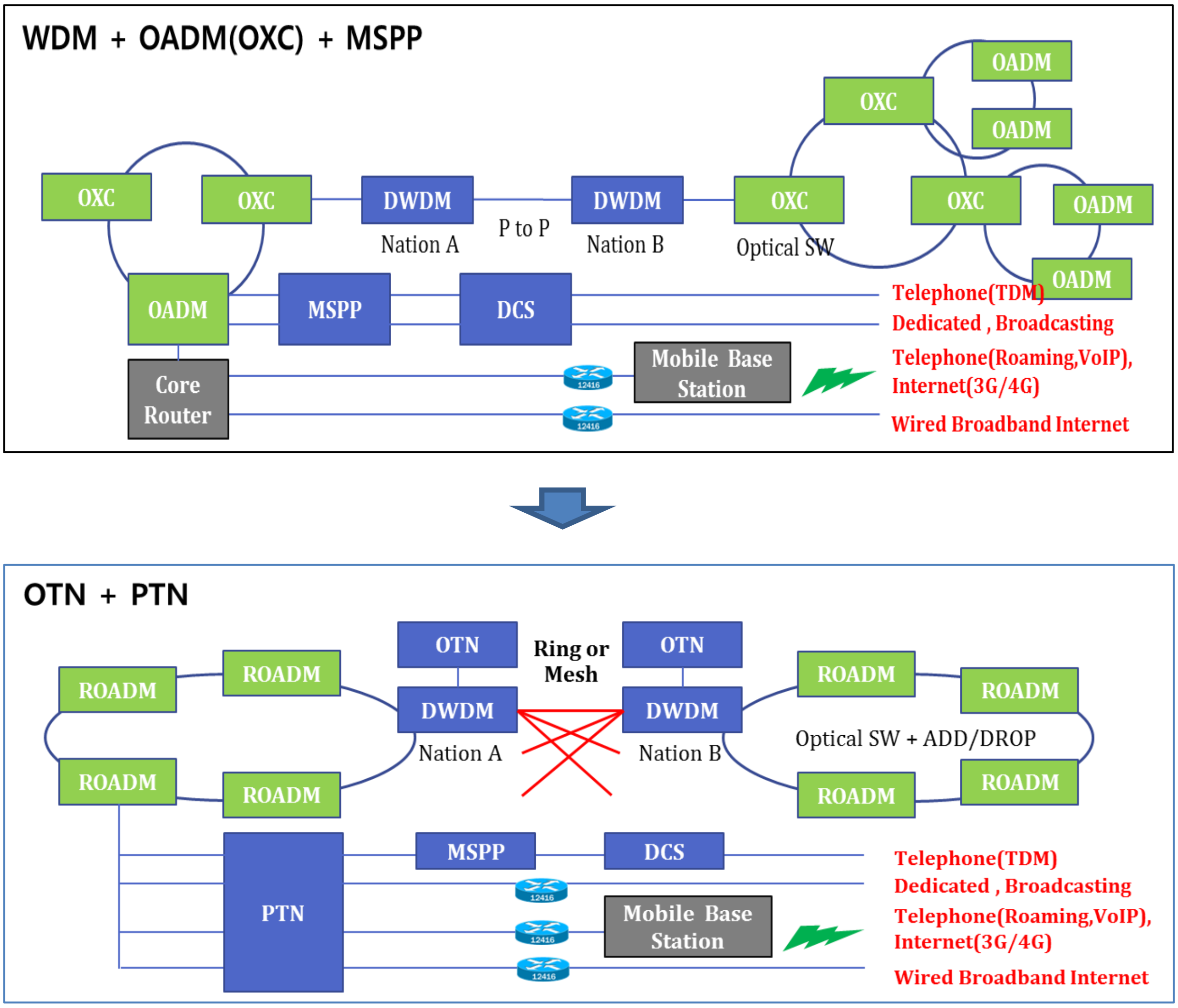
[Figure 5-12] Simple Figure of Multiplexing



While it is difficult to conduct an accurate analysis on the internal traffic or demand in the ASEAN sub-region, it would be necessary to select the most optimal equipment after considering the current technology maturity level, and build a network easily expandable in response to rapid increase of demands in the region.

For the mid-term, it is recommended to build the AP-IS backbone network in a form of a core network (OTN) between countries and metro core network (MSPP) between cities. The capacity of backbone network shall be ranging from 300G to 500G depending on the traffic volume coming from each country. Considerations will have to be made for maximizing backbone network stability of the ASEAN countries and ensuring automatic recovery through an OTN switch, since there are high possibilities of international backbone cable cut. In the long term, a core network (OTN) between countries and metro core network (PTN) between cities are recommended. The backbone network capacity would be ranging from 800G to 1200G depending on traffic volume too. Considerations will have to be made on establishing an all-IP based AP-IS backbone network for ASEAN countries, introducing PTN-based technologies to meet the rapidly increasing capacity demand from 4G or 5G mobile networks. Overall figures of future network stages are as shown in the [Fig 5-13]

[Figure 5-13] Overall Figures of Network Technologies By Stage

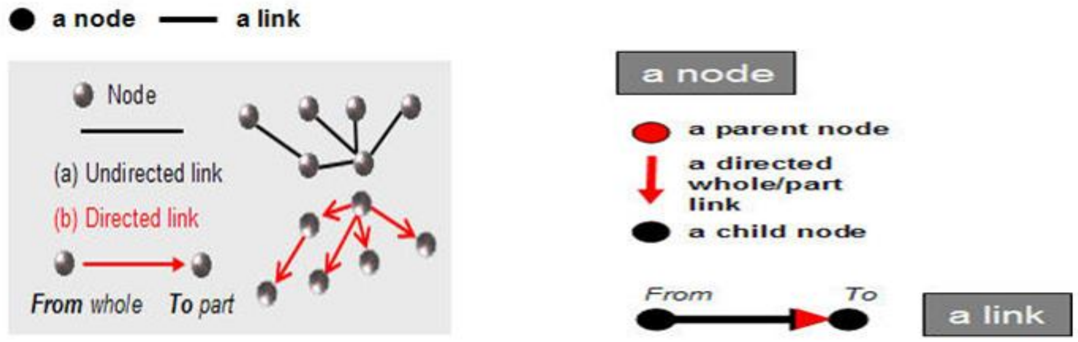


APPENDIX

Network Components and Hierarchy

Nodes and links are the elements needed to model our complex networked world of people, places, and IT systems networks are made up of nodes and links. Real-world nodes in organization networks cannot stand alone. Parent/child nodes commonly are found in most IT systems. In communication networks, the definition of a node depends on the network and protocol referred to the network. A physical network node is an electronic device that is attached to a network, and is capable of sending, receiving, or forwarding information over a communications channel.

[Figure 6-1] Network Components

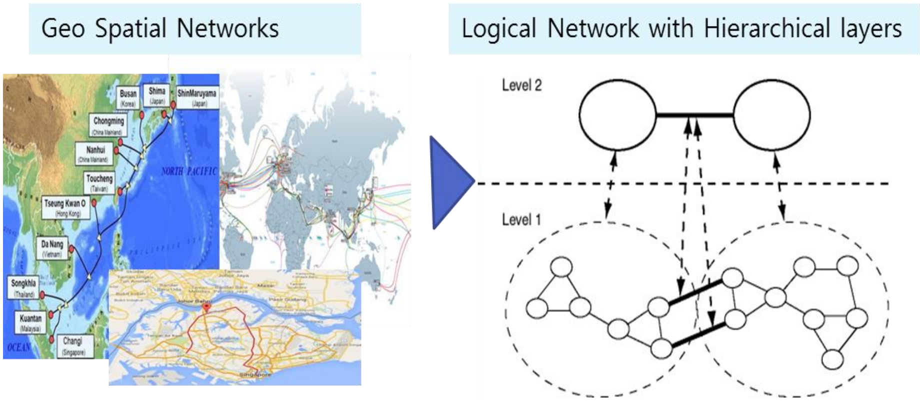


Links and nodes that make up the ICT infrastructure can be compared to roads and highway interchanges that make up our transport infrastructure as shown in [Figure 6-2].

[Figure 6-2] ICT infrastructure vs. Transport infrastructure

To understand the structure of ICT infrastructure, it is necessary first to understand some of the terms related to network and network hierarchy. A path is an alternating sequence of nodes and links, beginning and ending with nodes. There are often several paths between any two given nodes, and network operators may want to find the path with the minimum cost. A network is a set of nodes and links. A logical network contains connectivity information but no geometric information. A spatial network contains both connectivity information and geometric information.

[Figure 6-3] Network and Network Hierarchy



A network hierarchy represents a network with multiple levels of abstraction by assigning a hierarchy level to each node. The lowest level in the hierarchy is level 1, and successive higher levels are numbered 2, 3, and so on. Each node on the top level is the parent node of several nodes in the bottom level as seen in [Fig 6-3]. The link between the nodes in the top level is the parent link of two links between nodes in the bottom level.

The links between nodes in the bottom level are shown with dark connecting lines. These links can be two or more geo-spatially separated that makes a single logical link between the top level nodes in the hierarchy. The parent-child relationships between each parent node and link and its child nodes and links are shown with dashed lines with arrowheads at both ends. Links can cross hierarchy levels. For example, a link could be defined between a node in the top level and any node in the bottom level.

[Box 6-1] Network Examples

- Road Network
  In a typical road network, the intersections of roads are nodes and the road segments between two intersections are links. The spatial representation of a road is not inherently related to the nodes and links in the network. For example, a shape point in the spatial representation of a road (reflecting a sharp turn in the road) is not a node in the network if that shape point is not associated with an intersection; and a single spatial object may make up several links in a network (such as a straight segment intersected by three crossing roads). An important operation with a road network is to find the path from a start point to an end point, minimizing either the travel time or distance. There may be additional constraints on the path computation, such as having the path go through a particular landmark or avoid a particular intersection.

- Train (Subway) Network
  The subway network of any major city is probably best modeled as a logical network, assuming that precise spatial representation of the stops and track lines is unimportant. In such a network, all stops on the system constitute the nodes of the network, and a link is the connection between two stops if a train travels directly between these two stops. Important operations with a train network include finding all stations that can be reached from a specified station, finding the number of stops between two specified stations, and finding the travel time between two stations.

- Utility Network
  Utility networks, such as power line or cable networks, must often be configured to minimize the cost. An important operation with a utility network is to determine the connections among nodes, using minimum cost spanning tree algorithms, to provide the required quality of service at the minimum cost. Another important operation is reachability analysis, so that, for example, if a station in a water network is shut down, you know which areas will be affected.

Traffic Measurement Method and Results

- Background and Progress

Measuring of the Internet traffic among the ASEAN countries was not simple or easy to get cooperative assistance from countries. On October 22nd of 2014, UN ESCAP sent out a letter titled *Request for Collaboration on a Pre-feasibility Study on the Asia-Pacific Information Superhighway in ASEAN Region* to member countries. On November 18th, NIA also sent out letters requesting for cooperation to Myanmar, Lao PDR, Cambodia, and Thailand. Starting from November 2014 to January 2015, consultations were made on traffic measurement of governments and service providers along with explanations on the purpose and goals of the measurement and how they can cooperate but it was not easy to make practical preparations for measuring traffic under collaboration of these countries. As for Cambodia, Lao PDR, and Myanmar, visits were made from 26 January 2015 to 3 February, where discussions were made on the measuring system, technology, and how each country could collaborate and NIA distributed survey papers and requested for answers.

Many ASEAN countries, upon receiving official request from international organizations, are likely to take more time than expected if the requested ministry or department is not the actual working ministry or department. Especially for the AP-IS project, which requires collaboration of telecom providers, it takes even more time. Among the three countries, Lao PDR and Cambodia responded that they would cooperate as much as possible; however, they also showed concerns about the project influencing their own network. Since the working-level officials have limited authority on decision-making in ASEAN countries, it would be necessary to contact higher-level officials, deliver additional explanations on the project, and minimize the delay as much as possible through additional measures.

As the project requires international collaboration, it is in slow progress, requiring patience for responding to upcoming situations. In particular, the Republic of Korea already has experiences that will help with the AP-IS project and using such experiences will provide practical and effective support for the ASEAN countries. Should there be any similar projects in the future, communication channels and experiences made through this project will likely help increase efficiency.

Upon confirming that the requested countries had little progress to cooperate in the traffic measurement, the team decided through discussions with ESCAP to exempt measurement with governments or telecom providers but instead use TEIN (Trans-Eurasia Information Network) for traffic measurement.

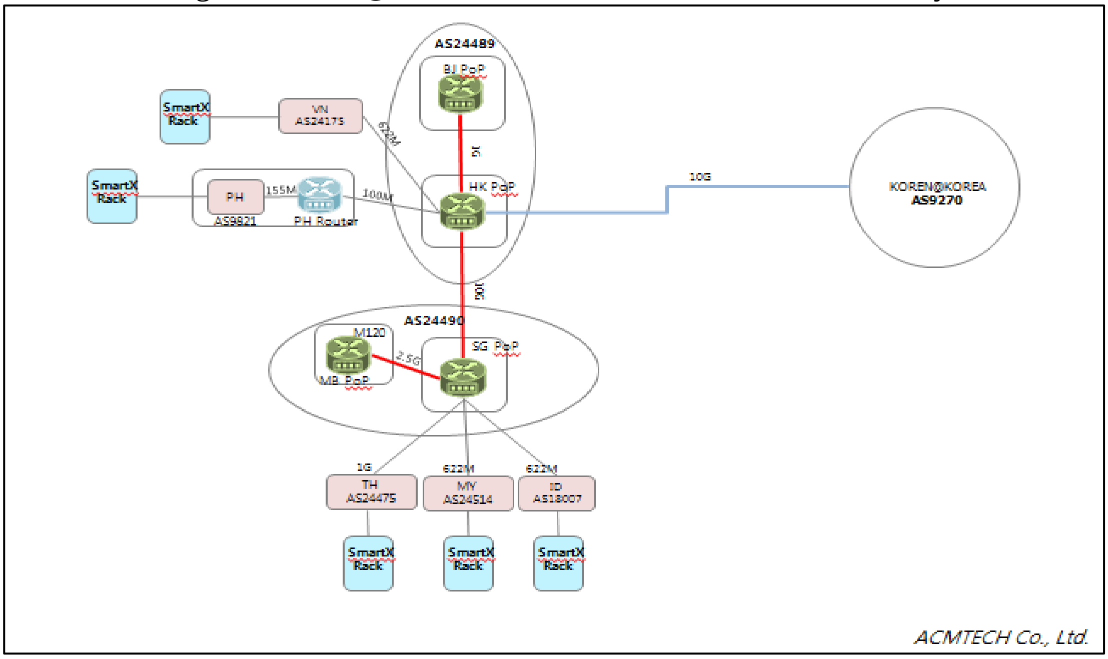
- Measurement Environment

TEIN is a non-profit research network connecting Asia and Europe through which a lot of tests are being carried out. Since most of the ASEAN countries are also connected to this network, it served as a useful medium for measuring international traffic. Some attempts were made to each country to discuss traffic measurement using the commercial network only to find out it was impossible to finish measuring the limited amount of time. Instead, the team decided to use TEIN to measure the speed, latency, the number of hops, and routing traces of traffic between countries.

OF@TEIN system was used for measuring at each node since it is already installed to serve the purpose of research and development. The network connectivity of OF@TEIN is as Figure. Node connections are achieved based on Hong Kong and Singapore, and each country has the bandwidth of 100Mbps or higher. All countries except the Philippines are connected at the speed higher than 622Mbps, which is a capacity large enough for traffic measurement. Using TEIN for traffic measurement would also be unlikely to influence end-to-end traffic quality.

As most of the OF@TEIN nodes are equipped with servers for the purpose of research and development, they are installed in universities or research institutions. They are interconnected with the closed network called TEIN backbone, which makes it difficult to measure traffic of the commercial network. Therefore, to accurately measure the international traffic, the team had to change the routing path to the commercial network instead of TEIN backbone.

[Figure 6-4] OF@TEIN Infrastructure: Network Connectivity



The measurement excluded traffic between TEIN nodes since it is a closed network and it does not help our measurement of the commercial network, traffic between countries. Of course the quality of traffic between TEIN nodes is definitely higher than that of the commercial network and it offers the best quality as test-bed for researchers; however, its closed features make it irrelevant to improvement of international connectivity between commercial networks, which is the main focus of AP-IS. Taking such limitations into consideration, the team used measurement servers that are already installed on nodes of commercial ISPs, which are open and operated by private businesses, instead of the TEIN servers.

Virtual machines like Windows, Client, Linux Server, etc. were created in OF@TEIN servers. Consultations with the local operators for each node were made to allow remote operation once servers are allocated and many following activities were carried out such as giving an IP address to each server and setting network for external connection. However, some nodes were found inaccessible due to local conditions or technical problems. In particular, remote access to Viet Nam was impossible within a limited amount of time; so the traffic measurement was made using the servers of the rest of the countries, excluding Viet Nam. The result is like the Table below:

[Table 6-1] Remote Server IP Addresses for ASEAN 5

Location	VM1 (Linux Server)	VM2 (Window Client)	Comment
Philippines	202.90.150.12	202.90.150.17	
Indonesia	167.205.51.42	167.205.51.47	Frequent disconnection
Malaysia	203.80.21.22	203.80.21.27	Frequent disconnection
Vietnam	203.191.48.232	203.191.48.237	Blocked network – remote access impossible
Thailand	161.200.25.112	161.200.25.117	

Virtual machine image files with NIA windows7 and Ubuntu were created remotely using smart X servers on the OF@TEIN. Specifications of the machines are as below:

[Table 6-2] Specifications of Ubuntu and Windows7

VM1 (Ubuntu 14.04 LTS)	VM2 (Windows7)
vCPU =4(2.3 GHz) Mem =4GB Disk =20GB (18 GB Free Space) vNIC =xenbr0 (Management) IP Address = 103.22.221.42 Username = tein/root Password = netmedia Access = SSH	vCPU =2(2.3 GHz) Mem =4GB Disk =20GB (7 GB Free Space) vNIC =xenbr0 (Management) IP Address = 103.22.221.47 Username = tein Password = netmedia Access = RDP (Remote Desktop)

- Measurement Method

Private systems were used as targets for traffic measurement, as they are already installed and open to the public in each country of the ASEAN region. The team decided to use the private measurement servers installed in the capital cities of the countries, checked the IP address, and set the addresses of the measurement servers as the target for traffic measurement. At least one server for each country was selected, and if there are multiple servers, all of them were included. ISPs that have target servers and their IP addresses of each country are listed in Table.

[Table 6-3] Country ISPs and Their IP Addresses

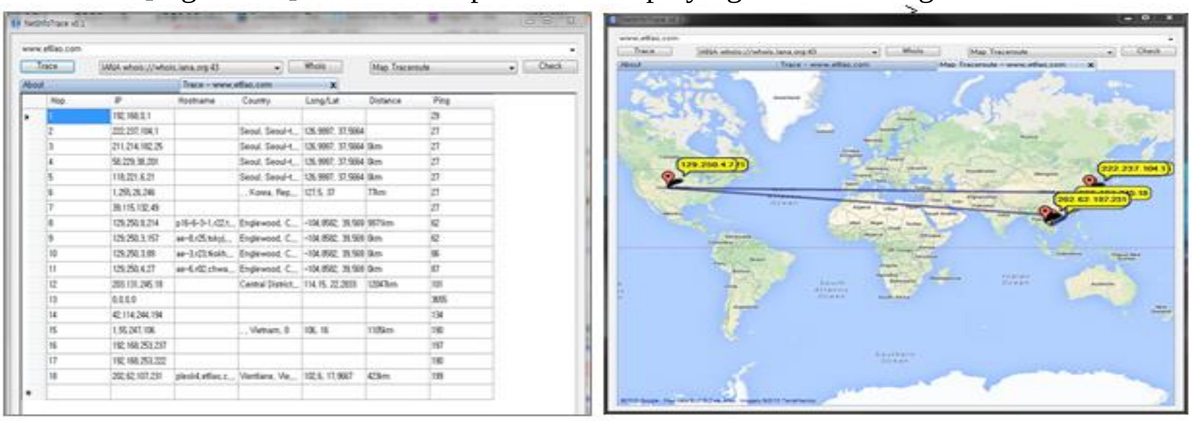
Country	Capital City	ISP	IP Address

Indonesia	Jakarta	Telekomunikasi Indo	118.98.104.194
		Biznet Networks	203.142.69.190
		CBN	202.158.8.14
		Qiandra Information	122.200.144.6
Malaysia	Kuala Lumpur	U Mobile	123.136.100.5
		Maxis	121.123.132.194
Vietnam	Hanoi	Viettel	27.68.242.178
Thailand	Bangkok	Shama Thunder	27.55.63.2
		Internet Thailand PCL	203.150.212.26
		PEA	202.151.5.110
		CS LOXINFO	202.183.136.110
Cambodia	Phnom Penh	MekongNet ISP	116.212.136.134
Myanmar	Yangon	Redlink Communications	61.4.77.249
Laos	Vientiane	Lao Telecom	202.137.128.218
Philippines	Manila	SKY Broadband	182.18.209.47
		Dunham Bush International	202.57.42.2
Singapore	Singapore	New Media Express	202.150.221.172
		Viewqwest Pte. Ltd	202.73.51.10
		SGIX	202.3.78.3
		SingTel	165.21.71.68
Brunei	Brunei	DST Communications Sd	202.152.92.38

For measuring speed and latency, target servers' IP addresses were used to identify ISPs and locations. Capital cities and ISPs of source and destination sites were selected from the map and the speed was tested for 10 times each. For domestic traffic measurement, the ISP and servers were selected from the map and the speed was tested for 10 times each.

For finding trace routes, 'NetinfoTrace', open source software for tracing routes, was used as a measuring tool for analyzing the number of hops, IP addresses of hops, locations, and distances.

[Figure 6-5] Text and Map Screens Displaying Trace Routing Result



[Table 6-4] Role of Measurement Servers of Each Country

No	Country	Measurement Method	Measurement Category	Comment
1	Indonesia	A separate virtual machine was created at each node and used as the starting point	International speed Domestic speed Latency Domestic trace route International trace route	Complete
2	Philippines			Complete
3	Thailand			Complete
4	Malaysia			Complete
5	Vietnam			Fail (Remote access impossible)
6	Brunei	Private servers installed in capital cities were used as targets for measuring international traffic; using these servers as the starting points was impossible.		Complete
7	Singapore			
8	Cambodia			
9	Lao PDR			
10	Myanmar			

Four indicators were used in the measurement – download speed, upload speed, latency, and tromboning index. The tromboning index here is the value obtained by dividing the entire routing distance by the shortest linear distance, and the longer the actual traffic between two points, the greater the tromboning index is.

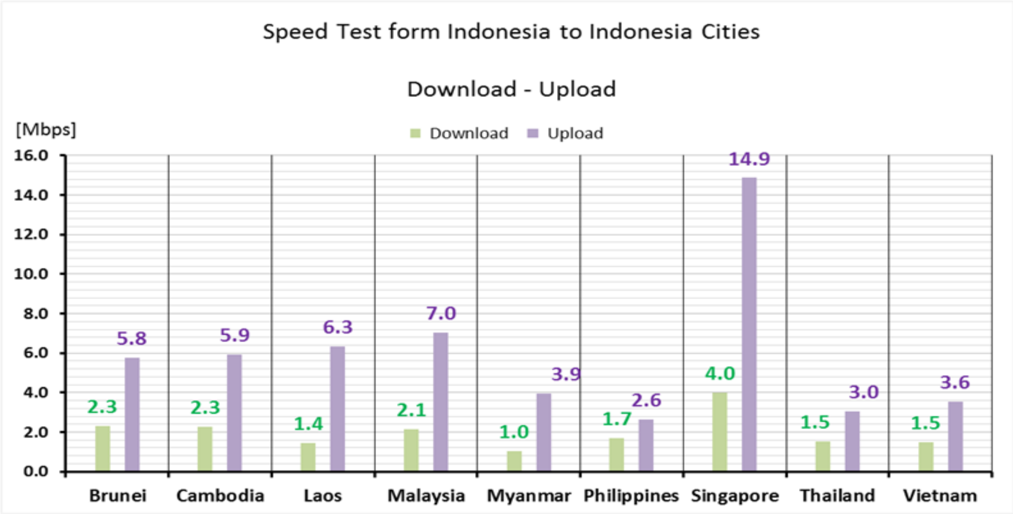
< Indonesia >

[Table 6-5] Test Results From Indonesia to Capital Cities[20]

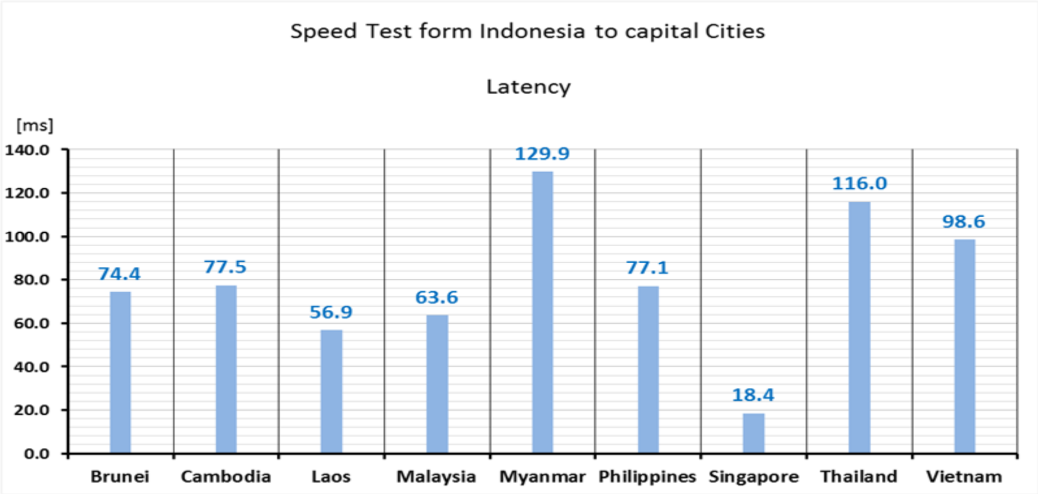
Destinations		Speed (Mbps)		Latency (msec)	No. of Hops	Trace Route		
To (Target)	ISP (Target)	Down	Up			Tromboning Index(B/A)	Geo. Distance (km) -A	Routing Distance (km)-B
Cambodia	Mekong Net	2.265	5.909	77.5	12(0)	1.2	2092.1	2483
Indonesia (Domestic)	Telekomunikasi Indo	4.613	15.108	7.6	8(0)	1.5	80.5	119
	Biznet Networks	4.694	15.499	5.5	8(0)	6.5	80.5	519
	CBN	4.374	14.473	6.2	8(0)	1.5	80.5	119
	Qiandra Information	4.806	13.238	6.2	8(0)	1.5	80.5	119
Lao PDR	Lao Telecom	1.427	6.329	56.9	7(1)	1.0	2816.4	2864
Malaysia	U Mobile	1.492	3.796	98.3	8(24)	1.1	900.51	1013
	Maxis	**2.139**	**7.022**	**63.6**	**7(3)**	**1.0**	**1287.5**	**1348**
Myanmar	RedLink	1.018	3.938	129.9	15(16)	15.2	2896.8	43904
Philippines	**SKY Broadband**	**1.683**	**2.639**	**77.1**	**11(1)**	**4.3**	**2816.4**	**12041**
	Dunham Bush International	2.057	2.08	75.3	10(1)	1.3	2816.4	3619
Thailand	Shama Thunder	2.883	8.533	49.3	12(2)	1.1	2414.0	2745
	Internet Thailand PCL	**1.514**	**3.03**	**116**	**11(1)**	**1.1**	**2414.0**	**2745**
	PEA	2.326	7.611	47.7	13(5)	1.1	2414.0	2745
	CS LOXINFO							
Vietnam	**Viettel**	**1.476**	**3.556**	**98.6**	**6(3)**	**1.0**	**3042.94**	**3142**
Brunei	DST Communications Sd	2.29	5.76	74.4	9(22)	1.8	1528.9	2811
Singapore	New Media Express	3.77	14.67	17.1	6(1)	1.0	1046.1	1013
	Viewqwest Pte. Ltd	**4.01**	**14.87**	**18.4**	**6(2)**	**28.0**	**1046.1**	**29341**
	SGIX	3.63	4.56	23.8	7(24)	1.0	1046.1	1013
	SingTel							

20 Figures in ( ) are estimates due to lack of accurate data on routing such as IP, country, long/lat, etc.
Data in blue shows test results on domestic traffic.
Unidentified data due to server change are shown in black.

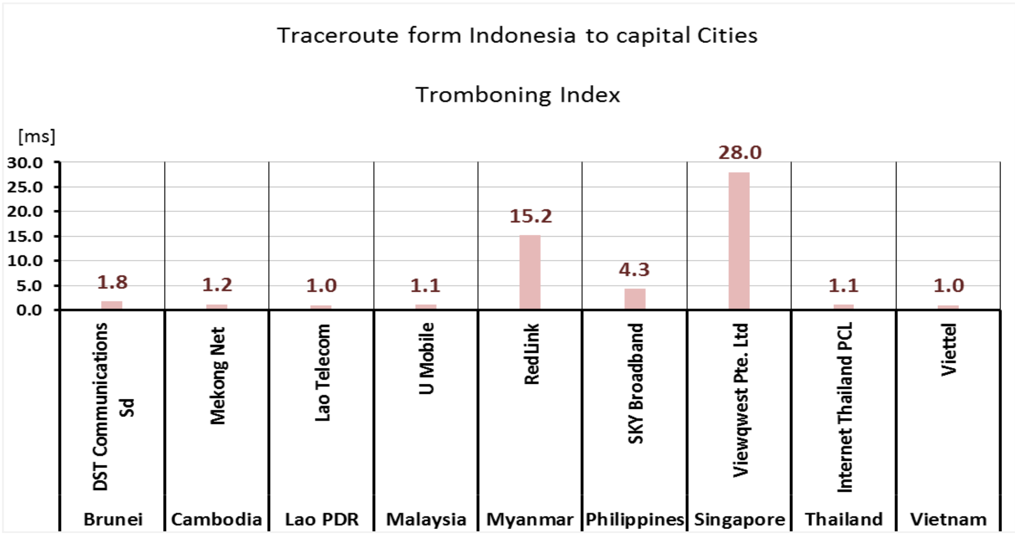
[Figure 6-7] Test Result for Indonesia - Download and Upload Speed



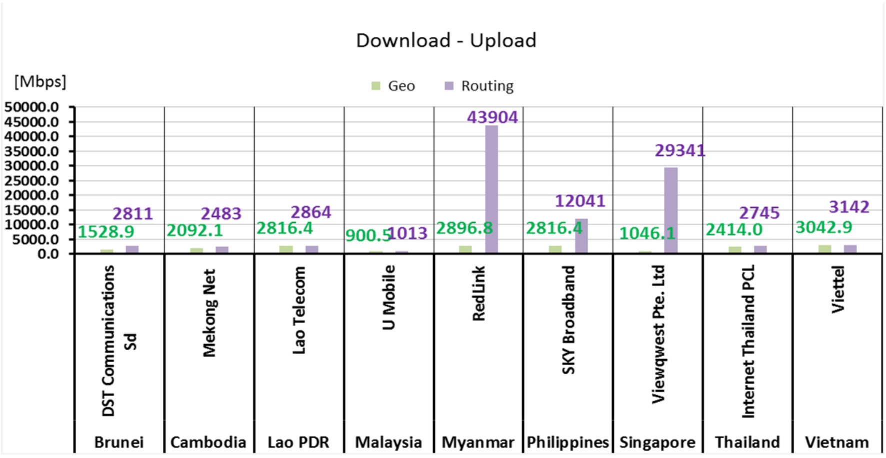
[Figure 6-8] Test Result for Indonesia – Latency



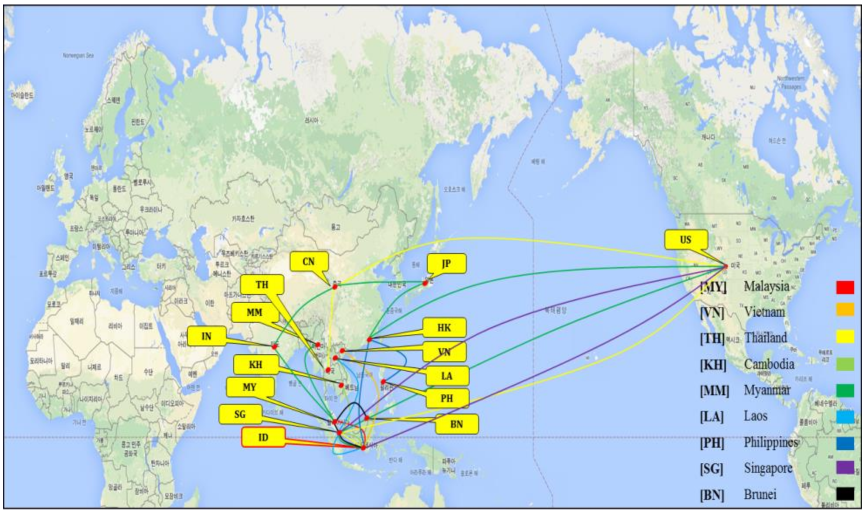
[Figure 6-9] Test Result for Indonesia - Tromboning Index



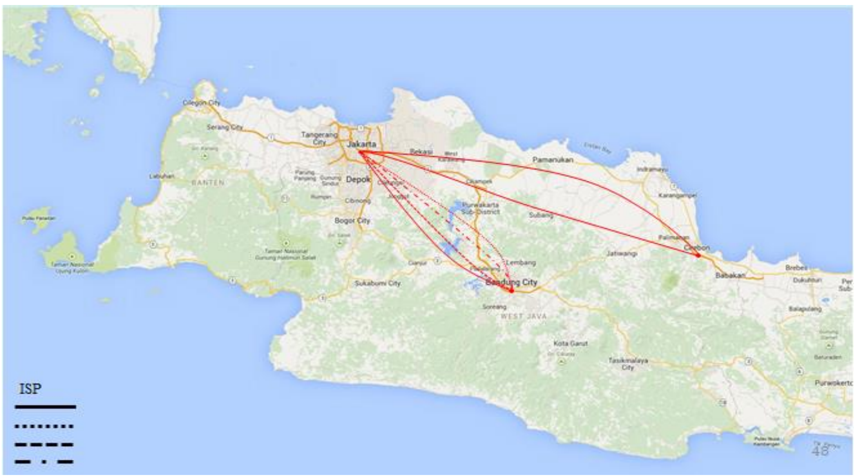
[Figure 6-10] Test Result for Indonesia – Geo-Routing



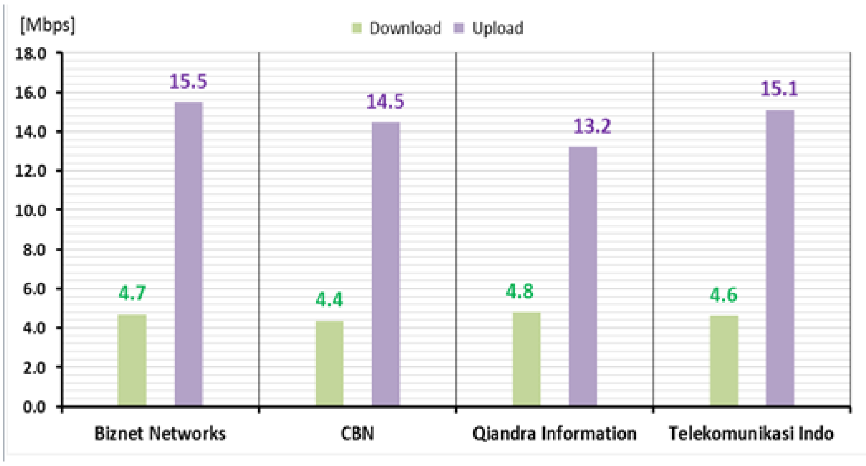
[Figure 6-11] Routing Map from Indonesia to Capital Cities



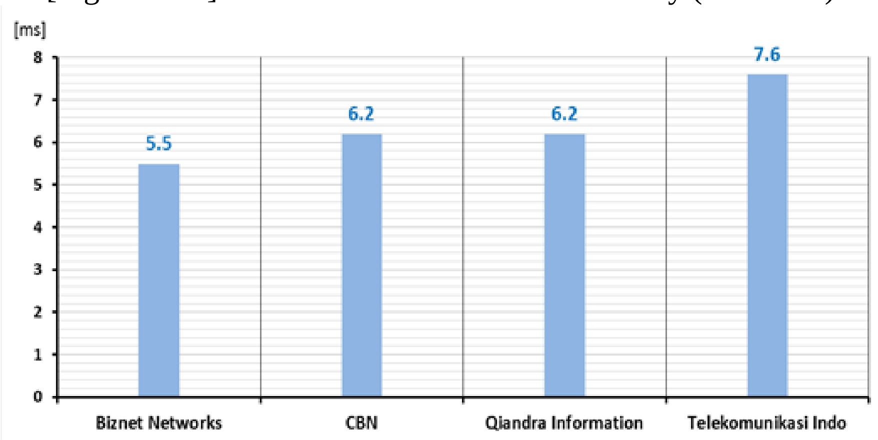
[Figure 6-12] Routing Map from Indonesia to Domestic City



[Figure 6-13] Test Result for Indonesia – Download and Upload Speed (Domestic)



[Figure 6-14] Test Result for Indonesia – Latency (Domestic)



[Table 6-6] Routing Trace from Indonesia to Capital Cities

To	ISP	Hop	Trace
Cambodia	Mekong Net	12(0)	Indonesia > Singapore > Cambodia
Lao PDR	Lao Telecom	7(1)	Indonesia > Singapore > Lao PDR
Malaysia	U Mobile	8(24)	Indonesia > Singapore
	Maxis	7(3)	Indonesia > Malaysia
Myanmar	RedLink	15(16)	Indonesia > Singapore > US > Hong Kong > Japan > China > India > Malaysia > Myanmar
Thailand	CS LOXINFO	11(0)	Indonesia > Singapore > US > China > Thailand
	Internet Thailand PCL	11(1)	Indonesia > Singapore > Thailand
	PEA	13(5)	Indonesia > Singapore > Thailand
	Shama Thunder	12(2)	Indonesia > Singapore > Thailand
Philippines	SKY Broadband	11(1)	Indonesia > Hong Kong > Philippines

	Dunham Bush International	10(1)	Indonesia > Singapore > Philippines
Vietnam	Viettel	6(3)	Indonesia > Vietnam
Singapore	Viewqwest Pte. Ltd	6(2)	Indonesia > Singapore > US > Singapore
	New Media Express	6(1)	Indonesia > Singapore
	SGIX	7(24)	Indonesia > Singapore
	SingTel	7(24)	Indonesia > Singapore
Brunei	DST Communications Sd	9(22)	Indonesia > Singapore > Malaysia > Brunei

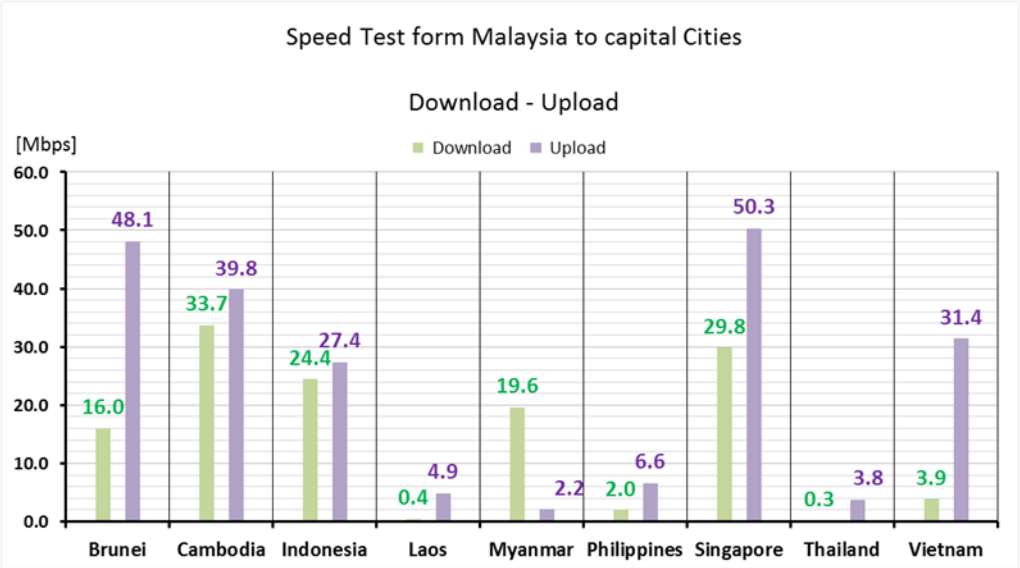
< Malaysia >

[Table 6-7] Test Results From Malaysia to Capital Cities[21]

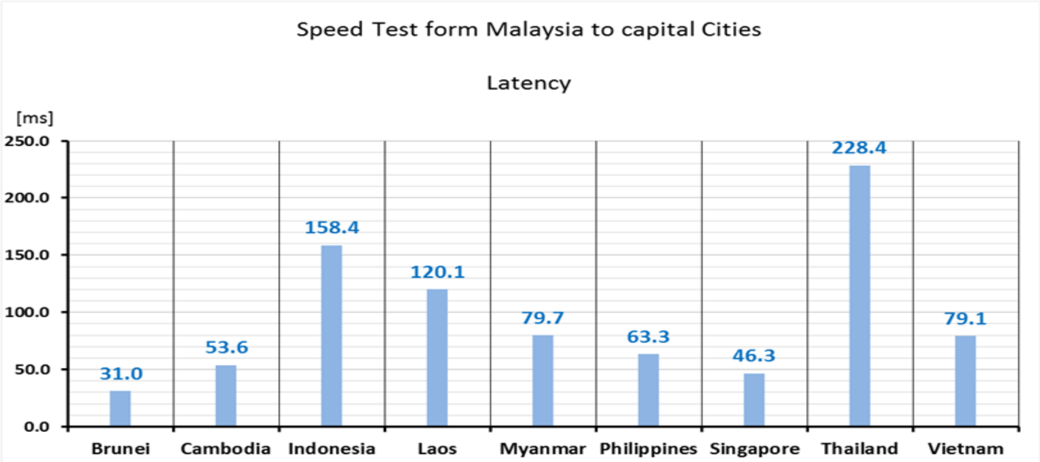
Destinations		Speed (Mbps)		Latency (msec)	No. of Hops	Trace Route		
To (Target)	ISP (Target)	Down	Up			Tromboning Index(B/A)	Geo. Distance (km) -A	Routing Distance (km)-B
Cambodia	Mekong Net	33.7	39.8	53.6	10(2)	2.2	1287.5	2846
Indonesia	**Telekomunikasi Indo**	**24.4**	**27.4**	**158.4**	**15(2)**	**33.9**	**1126.5**	**38139**
	Biznet Networks	46	47.3	27.8	13(1)	5.0	1126.5	5616
	CBN	22.8	13.6	71.5	12(1)	2.8	1126.5	3119
	Qiandra Information	0.4	25.6	56.3	13(1)	3.0	1126.5	3339
Lao PDR	Lao Telecom	0.4	4.9	120.1	12(1)	15.5	2011.7	31245
Malaysia (Domestic)	U Mobile	31.4	52.3	8.5	8(23)	2.0	1207	2457
	Maxis	32.2	52.8	7.5	11(0)	2.1	1207	2520
Myanmar	RedLink	19.6	2.2	79.7	9(22)	1.5	2414	3646
Philippines	**SKY Broadband**	**2**	**6.6**	**63.3**	**10(1)**	**19.0**	**1609.3**	**30537**
	Dunham Bush International	3.5	0.3	240.6	12(1)	20.0	1609.3	32173
Thailand	Shama Thunder	20.8	32.3	81.2	16(2)	1.6	1850.7	2986
	Internet Thailand PCL	**0.3**	**3.8**	**228.4**	**11(1)**	**1.8**	**1850.7**	**3357**
	PEA	7.3	43.1	44.8	18(4)	14.6	1850.7	27086
	CS LOXINFO	1.8	2.1	98.9	11(1)	16.6	1850.7	30726
Vietnam	Viettel	3.9	31.4	79.1	9(3)	14.0	2172.6	30469
Brunei	DST Communications Sd	16	48.1	31	9(22)	9.8	402.3	3938
Singapore	New Media Express	39.5	52.3	13.3	11(1)	2.3	965.6	2225
	Viewqwest Pte. Ltd	**29.8**	**50.3**	**46.3**	**8(1)**	**30.7**	**965.6**	**29677**
	SGIX	28.9	52.8	18.1	12(19)	2.3	965.6	2225
	SingTel	14.1	56.9	16.1	11(1)	2.3	965.6	2226

[21] Figures in ( ) are estimates due to lack of accurate data on routing such as IP, country, long/lat, etc. Data in blue shows test results on domestic traffic.

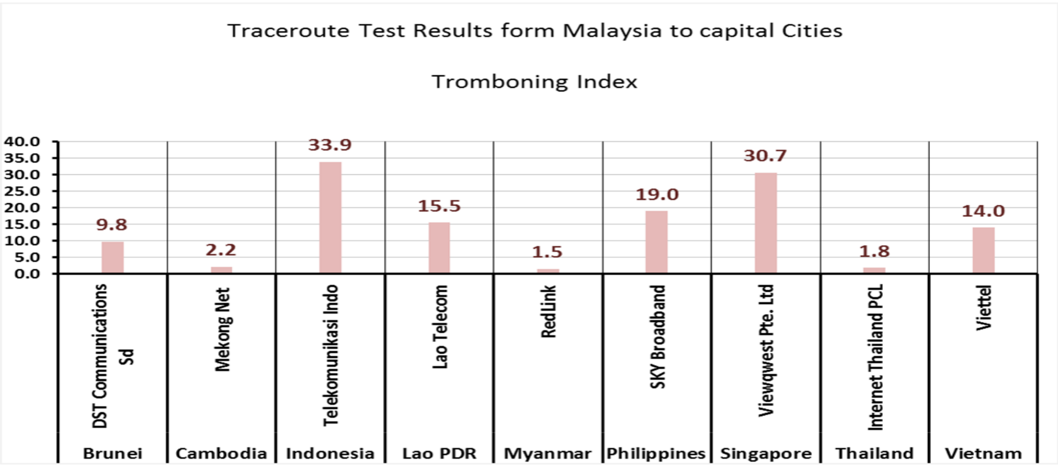
[Figure 6-15] Test Result for Malaysia - Download and Upload Speed



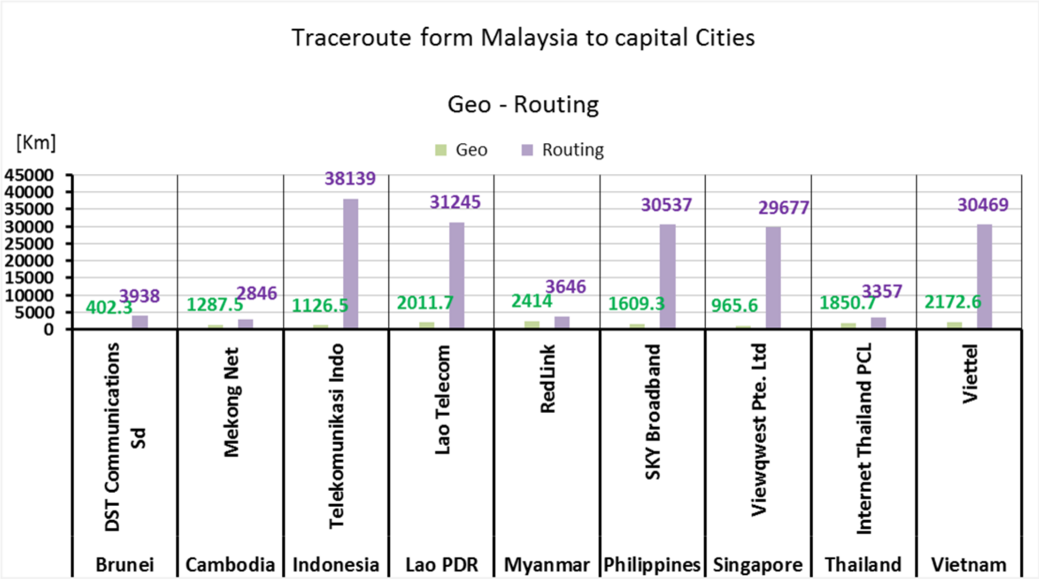
[Figure 6-16] Test Result for Malaysia - Latency



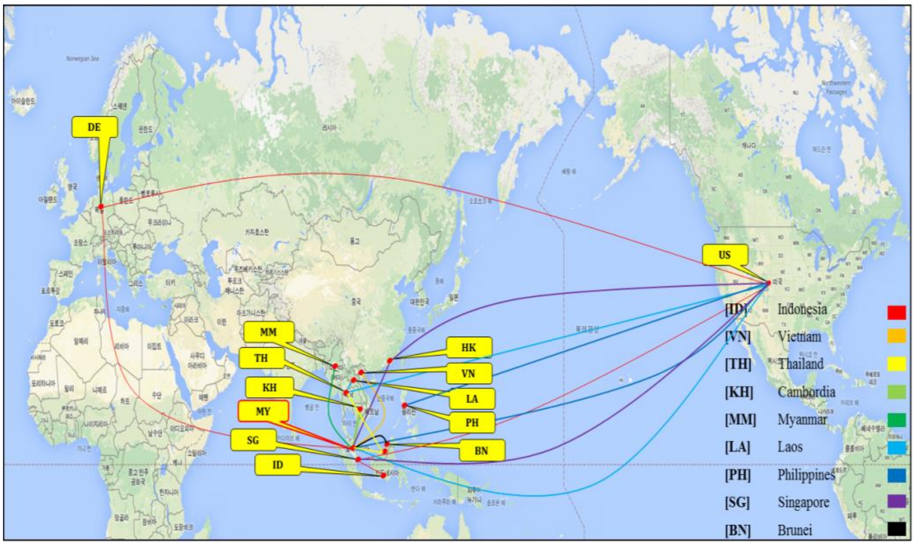
[Figure 6-17] Test Result for Malaysia - Tromboning Index



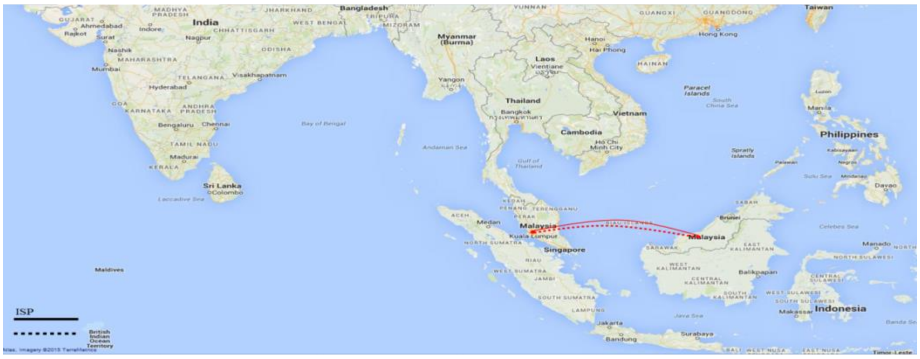
[Figure 6-18] Test Result for Malaysia – Geo-Routing



[Figure 6-19] Routing Map from Malaysia to Capital Cities



[Figure 6-20] Routing Map from Malaysia to Domestic City



[Table 6-8] Routing Trace from Malaysia to Capital Cities

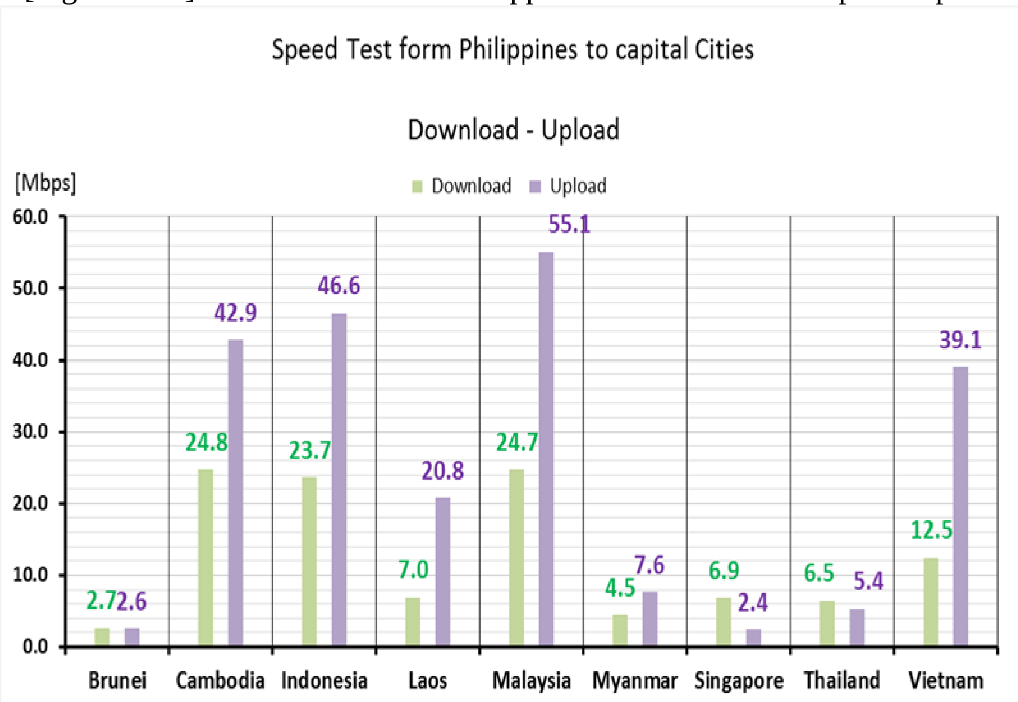
To	ISP	Hop	Trace
Cambodia	Mekong Net	10(2)	Malaysia > Cambodia
Indonesia	Telekomunikasi Indo	15(2)	Malaysia > Germany > US > Singapore > Indonesia
	Biznet Networks	13(1)	Malaysia > Singapore > Indonesia
	CBN	12(1)	Malaysia > Singapore > Indonesia
	Qiandra Information	13(1)	Malaysia > Singapore > Indonesia
Lao PDR	Lao Telecom	12(1)	Malaysia > US > Thailand > Lao PDR
Thailand	PEA	18(4)	Malaysia > US > Spain > Hong Kong > Thailand
	CS LOXINFO	11(1)	Malaysia > US > Thailand
	Shama Thunder	16(2)	Malaysia > Singapore > Thailand
	Internet Thailand PCL	11(1)	Malaysia > Thailand
Myanmar	RedLink	9(22)	Malaysia > Myanmar
Philippines	SKY Broadband	10(1)	Malaysia > US > Philippines
	Dunham Bush International	12(1)	Malaysia > US > Philippines
Vietnam	Viettel	9(3)	Malaysia > US > Vietnam
Singapore	Viewqwest Pte. Ltd	8(1)	Malaysia > Hong Kong > US > Singapore
	New Media Express	11(1)	Malaysia > Singapore
	SGIX	12(19)	Malaysia > Singapore
	SingTel	11(1)	Malaysia > Singapore
Brunei	DST Communications Sd	9(22)	Malaysia > Brunei

< Philippines >

[Table 6-9] Test Results From the Philippines to Capital Cities[22]

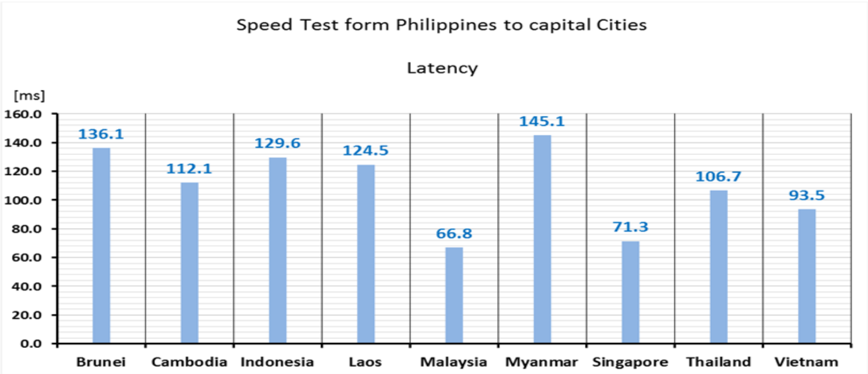
Destinations		Speed (Mbps)		Latency (msec)	No. of Hops	Trace Route		
To (Target)	ISP (Target)	Down	Up			Tromboning Index(B/A)	Geo. Distance (km) -A	Routing Distance (km)-B
Cambodia	Mekong Net	24.8	42.9	112.1	8(3)	13.6	1770.3	24050
Indonesia	**Telekomunikasi Indo**	**23.7**	**46.6**	**129.6**	**8(0)**	**2.1**	**2816.4**	**5949**
	Biznet Networks	8.5	4.6	88.7	14(0)	9.7	2816.4	27201
	CBN	7.5	7.1	109.8	8(2)	10.1	2816.4	28317
	Qiandra Information	0.7	6	120.1	13(0)	1.7	2816.4	4850
Lao PDR	Lao Telecom	7	20.8	124.5	12(1)	13.6	2011.7	27352
Malaysia	U Mobile	11	22.3	76.8	5(26)	10.0	2494.5	25049
	Maxis	**24.7**	**55.1**	**66.8**	**7(0)**	**1.5**	**2494.5**	**3768**
Myanmar	RedLink	4.5	7.6	145.1	13(18)	11.8	2655.4	31281
Philippines (Domestic)	SKY Broadband	0.15	0.02	156.6	6(9)	300.0	80.5	24153
	Dunham Bush International	4.2	3.1	1	8(0)	297.4	80.5	23941
Thailand	Shama Thunder	7.3	46.9	108.8	15(0)	12.3	2172.6	26792
	Internet Thailand PCL	**6.5**	**5.4**	**106.7**	**12(11)**	**2.0**	**2172.6**	**4259**
	PEA	22.4	20.3	103.7	20(3)	10.4	2172.6	22699
	CS LOXINFO	5.5	1	120.5	9(0)	11.7	2172.6	25437
Vietnam	Viettel	12.5	39.1	93.5	5(3)	2.4	1770.3	4169
Brunei	DST Communications Sd	2.7	2.6	136.1	7(24)	20.9	1287.5	26915
Singapore	New Media Express	5.3	4.4	73	5(2)	1.5	2414	3701
	Viewqwest Pte. Ltd	**6.9**	**2.4**	**71.3**	**6(1)**	**11.1**	**2414**	**26882**
	SGIX	2.2	1	126.6	6(25)	10.3	2414	24961
	SingTel	3.4	2.5	123.8	11(2)	10.4	2414	25049

[Figure 6-21] Test Result for the Philippines - Download and Upload Speed

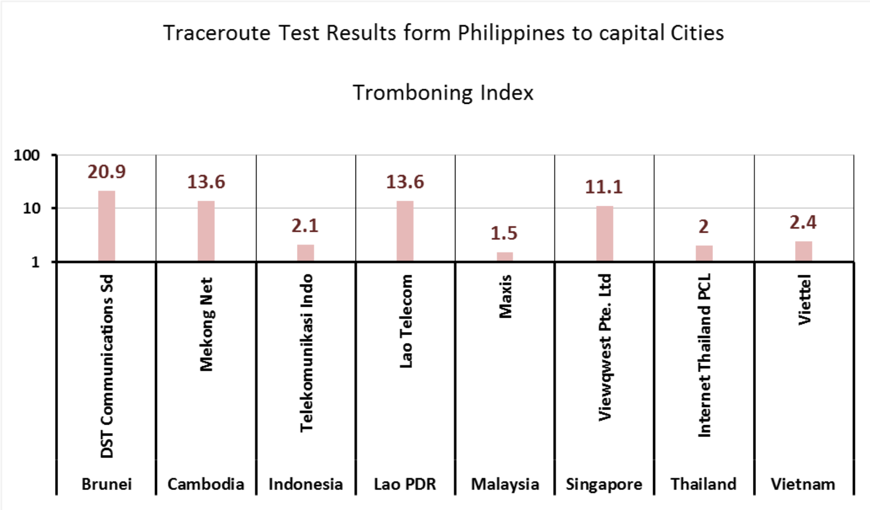


22 Figures in ( ) are estimates due to lack of accurate data on routing such as IP, country, long/lat, etc. Data in blue shows test results on domestic traffic.

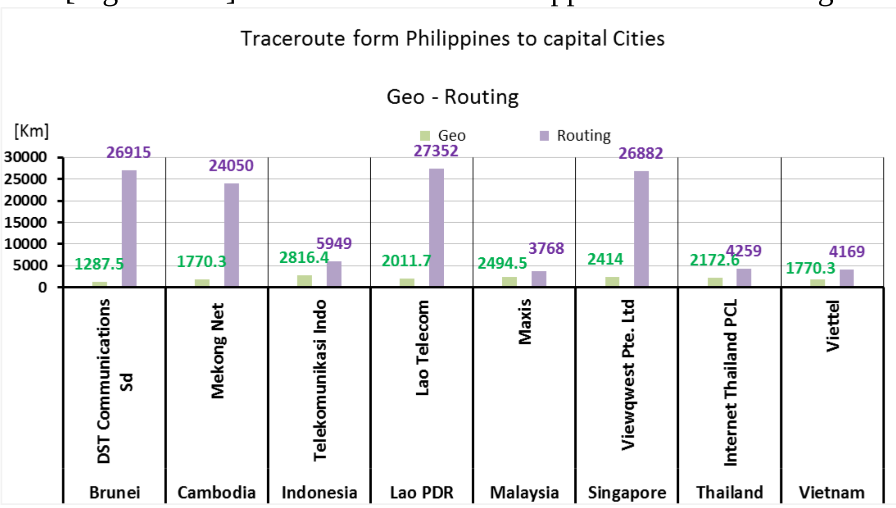
[Figure 6-22] Test Result for the Philippines – Latency



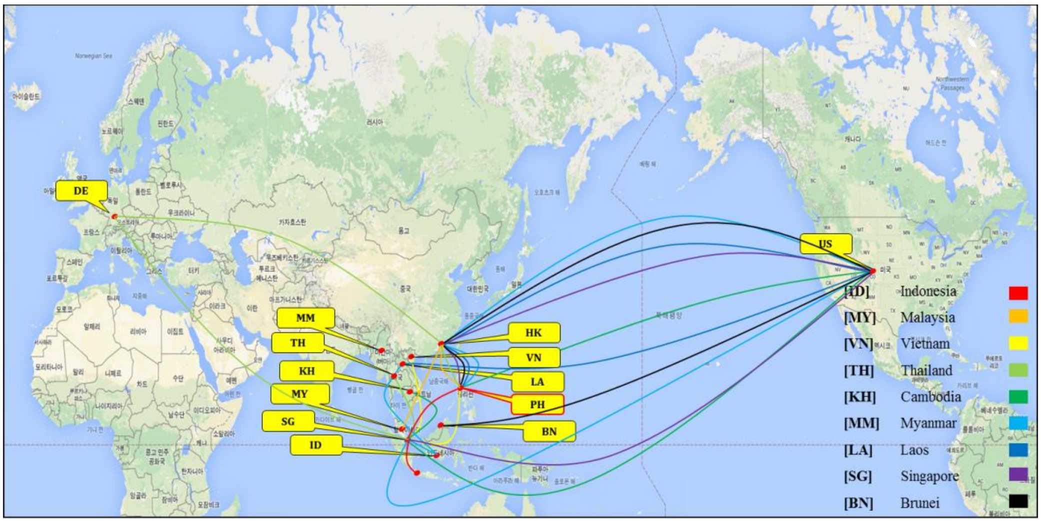
[Figure 6-23] Test Result for the Philippines - Tromboning Index



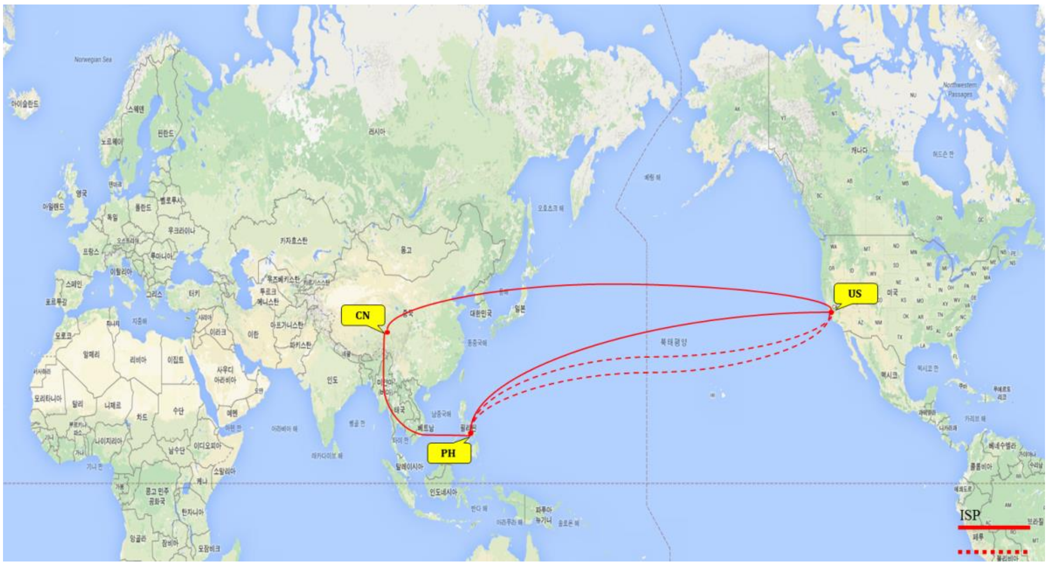
[Figure 6-24] Test Result for the Philippines – Geo-Routing



[Figure 6-25] Routing Map from the Philippines to Capital Cities



[Figure 6-26] Routing Map from the Philippines to Domestic City



[Table 6-10] Routing Trace from the Philippines to Capital Cities

To	ISP	Hop	Trace
Cambodia	Mekong Net	8(3)	Philippines > US > Cambodia
Indonesia	CBN	8(2)	Philippines > Hong Kong > US > Indonesia
	Biznet Networks	14(0)	Philippines > US > Philippines > Indonesia
	Qiandra Information	13(0)	Philippines > Hong Kong > Indonesia
	Telekomunikasi Indo	8(0)	Philippines > Singapore > Indonesia
Lao PDR	Lao Telecom	12(1)	Philippines > Hong Kong > US > Thailand > Lao PDR

Malaysia	U Mobile	5(26)	Philippines > US > Singapore > Malaysia
	Maxis	7(0)	Philippines > Hong Kong > Malaysia
Myanmar	RedLink	13(18)	Philippines > Hong Kong > US > Singapore > Malaysia > Myanmar
Thailand	CS LOXINFO	9(0)	Philippines > Hong Kong > US > China > Thailand
	Shama Thunder	15(0)	Philippines > US > Singapore > Thailand
	PEA	20(3)	Philippines > Hong Kong > Europe > Singapore > Thailand
	Internet Thailand PCL	12(11)	Philippines > Singapore > Thailand
Vietnam	Viettel	5(3)	Philippines > Singapore > Vietnam
Singapore	Viewqwest Pte. Ltd	6(1)	Philippines > Hong Kong > US > Singapore
	SGIX	6(25)	Philippines > US > Singapore
	SingTel	11(2)	Philippines > US > Singapore
	New Media Express	5(2)	Philippines > Hong Kong > Singapore
Brunei	DST Communications Sd	7(24)	Philippines > Hong Kong > US > Brunei

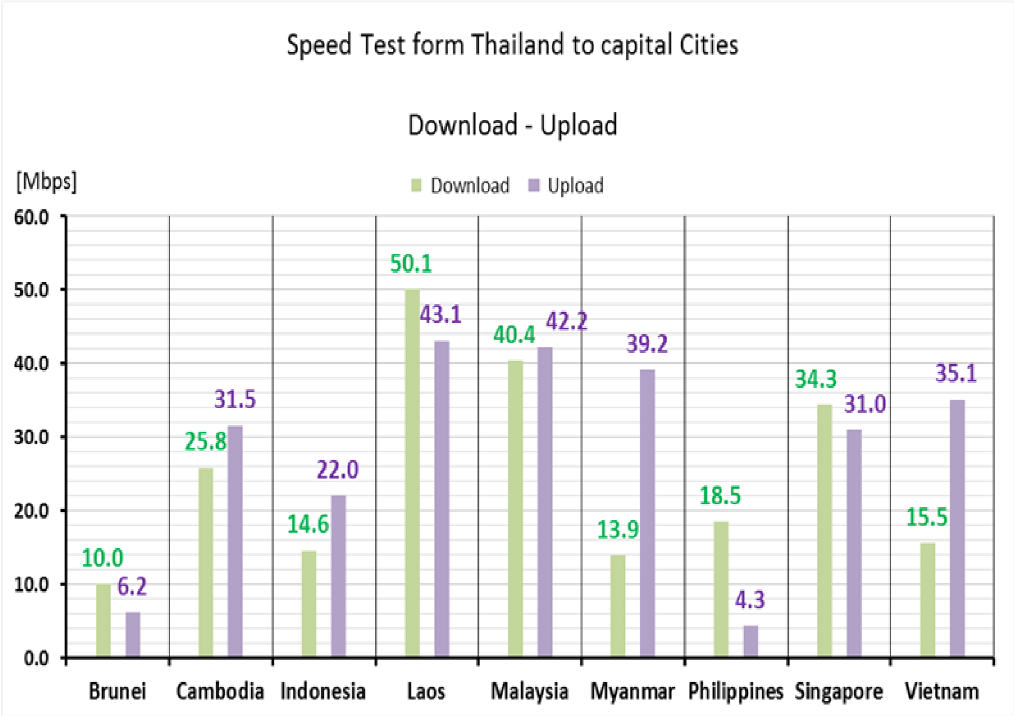
< Thailand >

[Table 6-11] Test Results From Thailand to Capital Cities[23]

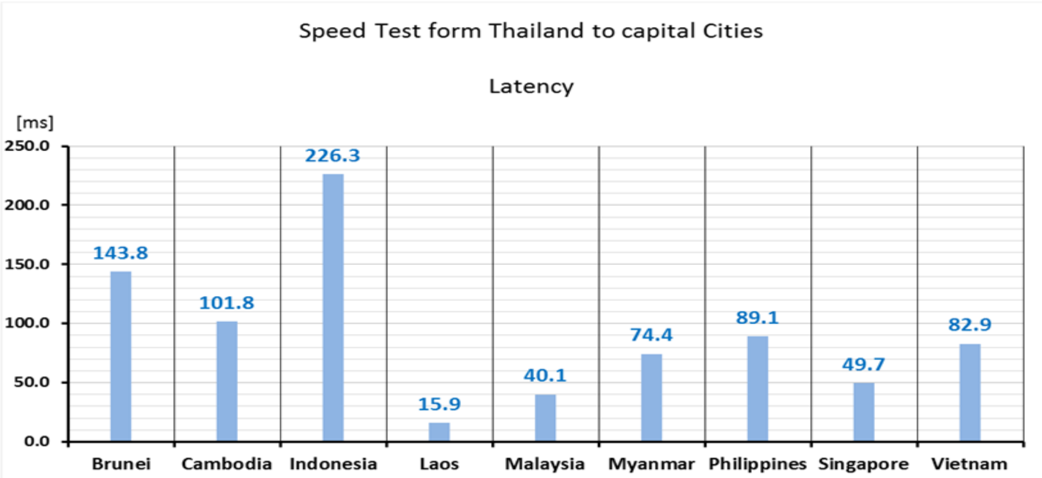
Destinations		Speed (Mbps)		Latency (msec)	No. of Hops	Trace Route		
To (Target)	ISP (Target)	Down	Up			Tromboning Index(B/A)	Geo. Distance (km) -A	Routing Distance (km)-B
Cambodia	Mekong Net	25.8	31.5	101.8	19(6)	11.5	563.3	6486
Indonesia	**Telekomunikasi Indo**	**14.6**	**22**	**226.3**	**11(1)**	**2.3**	**2333.5**	**5463**
	Biznet Networks	15.4	21.7	226.5	17(0)	12.3	2333.5	28591
	CBN	37	34.9	48.3	12(1)	1.3	2333.5	2921
	Qiandra Information	0.2	17.8	50.2	8(2)	1.3	2333.5	2921
Lao PDR	Lao Telecom	50.1	43.1	15.9	13(0)	1.7	482.8	817
Malaysia	U Mobile	34.1	41.1	41.2	7(24)	-	1207	-
	Maxis	**40.4**	**42.2**	**40.1**	**12(0)**	**2.0**	**1207**	**2399**
Myanmar	RedLink	13.9	39.2	74.4	14(17)	15.8	563.3	8921
Philippines	**SKY Broadband**	**18.5**	**4.3**	**89.1**	**12(0)**	**1.5**	**2253.08**	**3476**
	Dunham Bush International	3.6	1.7	363.9	20(0)	13.3	2253.1	30030
Thailand (Domestic)	Shama Thunder	20.5	36	118.3	6(3)	3.7	80.5	298
	Internet Thailand PCL	24	20.8	80	9(0)	3.7	80.5	298
	PEA	34.5	38.9	34.4	10(0)	3.7	80.5	298
	CS LOXINFO	44.5	41.2	9.9	10(0)	1	80.5	80.5
Vietnam	Viettel	15.5	35.1	82.9	11(1)	3.8	965.6	3683
Brunei	DST Communications Sd	10	6.2	143.8	14(17)	1.6	1850.7	2964
Singapore	New Media Express	40.8	41.2	31.9	9(0)	1.4	1448.4	2030
	Viewqwest Pte. Ltd	**34.3**	**31**	**49.7**	**10(0)**	**21.0**	**1448.4**	**30358**
	SGIX	33.6	41.3	34.8	10(21)	1.4	1448.4	2030
	SingTel	19.2	29.5	127.2	12(0)	1.4	1448.4	2030

23 Figures in ( ) are estimates due to lack of accurate data on routing such as IP, country, long/lat, etc. Data in blue shows test results on domestic traffic.

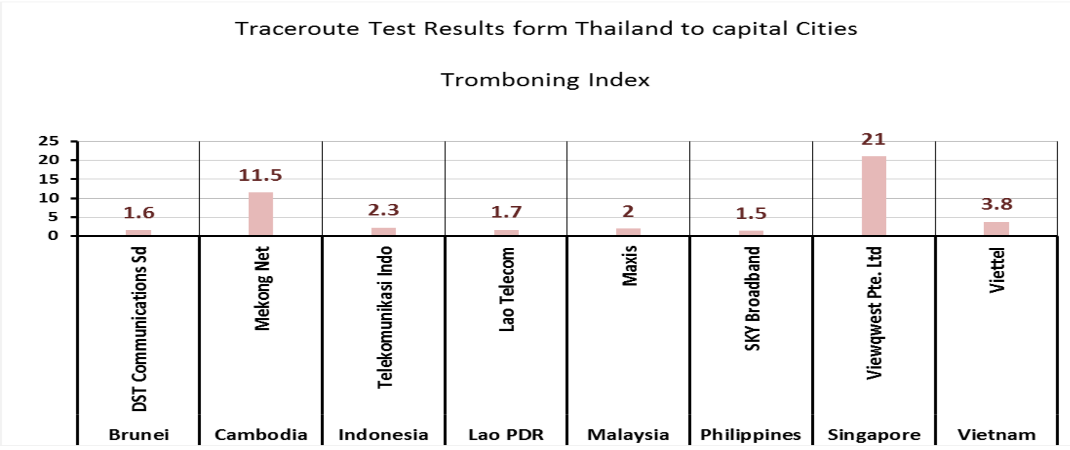
[Figure 6-27] Test Result for Thailand - Download and Upload Speed



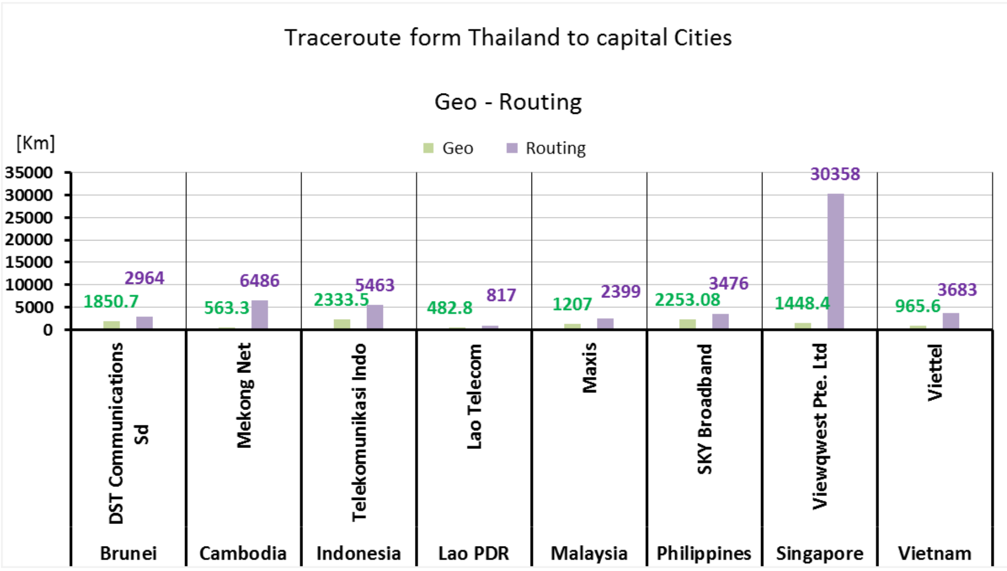
[Figure 6-28] Test Result for Thailand – Latency



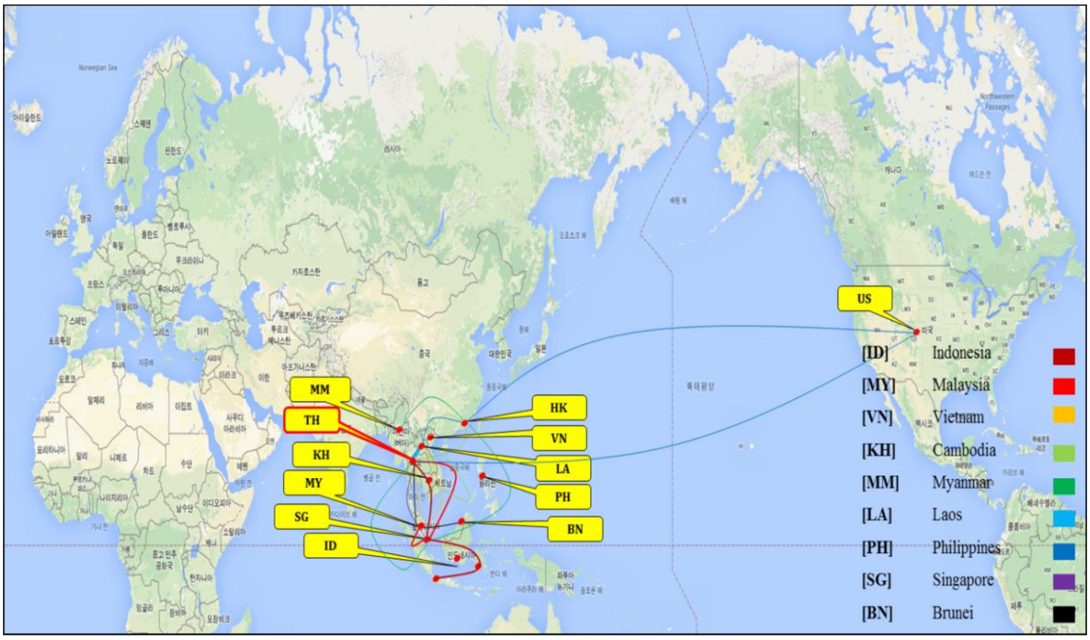
[Figure 6-29] Test Result for Thailand - Tromboning Index



[Figure 6-30] Test Result for Thailand – Geo-Routing



[Figure 6-31] Routing Map from Thailand to Capital Cities



[Figure 6-32] Routing Map from Thailand to Domestic City

[Table 6-12] Routing Trace from Thailand to Capital Cities

To	ISP	Hop	Trace
Cambodia	Mekong Net	25(6)	Thailand > Hong Kong > Vietnam > Cambodia
Indonesia	Biznet Networks	17(0)	Thailand > US > Indonesia
	Telekomunikasi Indo	11(1)	Thailand > Singapore > Indonesia
	CBN	12(1)	Thailand > Indonesia
	Qiandra Information	8(2)	Thailand > Indonesia
Lao PDR	Lao Telecom	13	Thailand > Lao PDR
Malaysia	Maxis	12(0)	Thailand > Singapore > Malaysia
	U Mobile	7(24)	Thailand
Myanmar	RedLink	14(17)	Thailand > Singapore > Hong Kong > Myanmar
Philippines	Dunham Bush International	20(0)	Thailand > US > Hong Kong > Philippines
	SKY Broadband	12(0)	Thailand > Hong Kong > Philippines
Vietnam	Viettel	11(1)	Thailand > Singapore > Vietnam
Singapore	New Media Express	9(0)	Thailand > Singapore
	Viewqwest Pte. Ltd	10(0)	Thailand > Singapore
	SGIX	10(21)	Thailand > Singapore
	SingTel	12(0)	Thailand > Singapore
Brunei	DST Communications Sd	14(17)	Thailand > Malaysia > Brunei

Network Technology Trends

Fiber networks form the basis of backbone or backhaul networks, with some niche applications for microwave and satellite. A fiber pair can carry as much traffic as all geosynchronous satellites combined. In most developed countries, networks have become interconnected meshes crossing borders and complimented by multiple Internet Exchange Points (IXPs) and direct interconnections between networks. This allows traffic to be rerouted when necessary and provides competition and alternative paths. In many developing nations such as the ASEAN member countries, backhaul networks have the shape of a river system, where first mile tributaries bring the data into ever-widening backhaul connections that end in an international submarine fiber. Network resilience in these areas could benefit from regional and cross-border meshes of connectivity.[24]

Backhaul networks can cover a city, a region or a country and are known under different specific names. Historically, the terms used for backhaul networks have included 'trunk networks', inter-local or long distance networks. Other commentators use terms such as "middle mile", "metro", "core", "submarine", "backbone" and "international network". These terms do not, however, necessarily specify any specific network length or particular technological deployment.

Fiber has become the predominant technology for backbone networks. Using commercially available equipment, a single fiber pair can carry 160 wavelengths at 40 Gbps carrying 6.4 Tbps. Some ISPs, like a rule of thumb, use the figure 200-500 Kbit/s to estimate the interconnection capacity they need per customer. This means, in terms of backhaul, that a single fiber pair could carry the interconnection needs of 12.8 to 32 million broadband customers. A single fiber pair could, therefore, be overcapacity for almost any network, except for all but the very largest networks.

In practice, Dense Wavelength Division Multiplexing (DWDM) technology is costly, and it is less expensive to use more fibers, which means it is only used on specific routes or for submarine fiber. Networks will also keep capacity available for backup; therefore not all possible capacity will be used. Today most Internet backhaul networks are built on the Ethernet suite of standards. This was originally designed for offices and data centers. The speeds of 1 Gbps and 10 Gbps are now those most commonly used, with 100 Gbps becoming more and more available. Ethernet became dominant because the high volumes used in data centers created a high volume market that overshadowed the demands generated by the traditional telecom voice market.

Transmission network evolves to flexible, scalable, and cost-effective by converging Packet & Optical. Long-haul technology for ASEAN backbone network should be considered.

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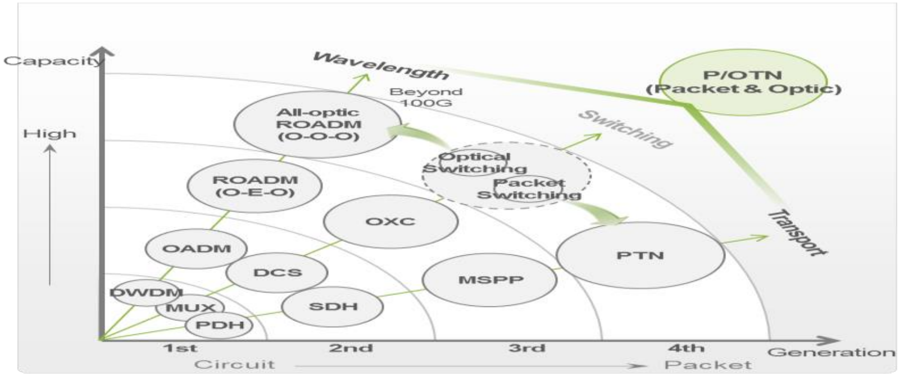
[24] OECD Report, Cross Border Cables, Gateways, and Backhaul, 2013

[Figure 6-33] Fiber Network Technologies Candidates



ROADM[25] system is becoming the operator's standard long-haul solution for providing flexibility and efficiency in modern multichannel fiber optic networks.

[Table 6-13] Long Haul Transmission Technology

	Item	DWDM	LH-ROADM
Function	Topology	Point-to-Point	Mesh, Point-to-Point, Ring
	Wavelength	Fixed channel (no wavelength switching)	Tunable & WSS(Wavelength selective switching)
	Client Interface	SDH(SONET) : 2.5G/10G Ethernet : GbE/10GbE other : SAN, Fiber channel, etc.	SDH (SONET) : 2.5G/10G/40G Ethernet : GbE/10GbE/100GbE OTN : OTU1/2/3 other : SAN, Fiber channel, etc.
	Degree	2 Degree (West, East)	Up to 8 Degree Colorless/Directionless/Contentionless
	Distance	Over 560Km	Over 960Km (~3,000Km)
Operation	Provisioning	Manual (Back-to-Back connection)	One click Provisioning
	Management	Manual	Optical Power Monitoring Auto Power Control

[Table 6-14] Subscriber Network Technologies

	NG-PON 1		NG-PON 2	
	10G EPON	XG GPON	TWDM-PON	WDM-PON
Maximum Speed	10 Gbps	10 Gbps	40 Gbps	10 Gbps
Guaranteed Speed	300 Mbps	80 Mbps	160 Mbps	10 Gbps
Technological Features	Symmetrical structure,	Asymmetrical structure,	Asymmetrical structure,	Tunable ONU dedicated

25 ROADM: Re-configurable Optical Add-Drop Multiplexer

	downstream broadcast, upstream burst transmission	downstream broadcast, upstream burst transmission	tunable ONU, wavelength management	wavelength, wavelength management
Coverage	20 Km	20 Km	20 Km	40 Km
Network Architecture	PtMP	PtMP	PtMP	PtP
No. of Working Wavelength	1	1	4-16	> 32
Number of branch	32	128	256	64
International Standard	IEEE802.3av	ITU-T G.987.x	ITU-T G.989.x	ITU-T G.multi

Fiber networks are increasingly used for the backhaul necessary for mobile networks. The data demands of 3G and 4G networks make existing copper and wireless backhaul less competitive. LTE+ can deliver up to 3.3 Gbps per antenna, which is at the far end of what wireless solutions can deliver. LTE+ will also allow two antennas to send data to the same device, when it is at the edge of both networks. This will greatly increase the possible bandwidth at the edges of cells. It does, however, require adequate timing data to be sent, which requires signaling of timing information between the controllers of the antennas. This requires fiber to be rolled out deeper into the network.

Wireless networks are the other mainstay for providing backhaul. Wireless is used where fiber does not reach a location or as a temporary solution until it is rolled out. The three main variants are: satellite, wireless optical, microwave and millimeter wave point-to-point connections and femtocell/Wi-Fi offload. Satellite supports the widest reach, but at a higher cost. Microwave and millimetere wave point-to-point connections are used in many locations to reach mobile base stations. In contrast, femtocell/Wi-Fi offload has the shortest reach, but the lowest associated cost, as it uses an existing broadband connection.

Microwave, millimetere wave and optical transmitters are used extensively by mobile networks to link antenna locations. Wireless networks can scale up to 1-2 Gbps for a location. The technology is constrained by the need for line of sight between a sender and a receiver to achieve high speeds or operate at much lower speeds for non-line of sight. The weather can also affect the performance of this technology. Microwave backhaul is therefore generally a short to middle range solution.

Operators use Wi-Fi and femtocell as “offload options” to reduce the demands on mobile networks. They make use of unlicensed Wi-Fi spectrum or their own licensed 2G/3G/4G spectrums. This type of approach is also known as heterogeneous networking. The goal is to relieve demands on the operator’s mobile first mile and backhaul networks.

Users, of course, do actively use Wi-Fi offload. Mobidia calculates from their measurement, for a range of countries, that on average, between 50% and 80% of data traffic for Android mobile phones is offloaded over a user’s private Wi-Fi.

Abbreviations

4G LTE	4th Generation Long Term Evolution
ABC	ASEAN Broadband Corridor
AIM 2015	ASEAN ICT Masterplan 2015
APCC	Asia Pacific Carriers Coalition
AP-IS	Asia Pacific Information Super highway
AS Number	Autonomous System Number
BGP	Border Gate Protocol
CAPEX	Capital Expenditure
ccTLD	Country code Top-Level Domain
CDN	Contents Delivery Network
CP	Contents Provider
DCS	Telephone Data-Carrier System
DNS	Domain Name System
FCC	Federal Communications Commission
FTTx	Fiber To The x
GMS	Great Mekong Sub-region
HFC	Hybrid Fiber Coaxial
ICT	Information and communication Technology
IDC	Internet Data Center
IPTD	IP Packet Transfer Delay
IPTV	Internet Protocol Television
ISP	Internet Service Provider
IXP	Internet eXchange Point
LAN	Local Area Network
MLP	multi-lateral peering
MMLP	mandatory multi-lateral peering
MPLS-TP	Multi-Protocol Label Switching-Transport Profile
MRTG	Multi Router Traffic Grapher
MSPP	Multi Service Provisioning Platform
NAP	Network Access Point
NDA	Non-disclosure Agreement
NIC	Network Information Center
NTP	Network Time Protocol
OADM	Optical Add Drop Multiplexer
OAN	Open Access Network
OSI	Open System Interconnection
OTH	Optical Transport Hierarchy
PACE	Pan-ASEAN ICT Connectivity and Exchange
PBB-TE	Backbone Bridge Traffic Engineerings
PBB	Provider Backbone Bridges
POP	Point of Presence
POTS	Plain Old Telephone Services
PTN	Packet Transport Network
ROADM	Re-configurable Optical Add-Drop Multiplexer
SASEC	South Asia Sub-regional Economic Cooperation
SNS	Social Networking Service
SOC	Social Overhead Capital

SPV	Special Purpose Vehicle
TACACS+	Terminal Access Controller Access-Control System Plus
TASIM	Trans-Eurasian Information Super highway
TCP/IP	Telecommunication Protocol/Internet Protocol
TEIN	Trans-Eurasia Information Network
TLD	Top Level Domain
UN MDG	United Nations Millennium Development Goals
UTP	Unshielded Twisted Pairs
VLAN	Virtual Local Area Network
VoIP	Voice over Internet Protocol
WDM	Wavelength Division Multiplexing
xDSL	x Digital Subscriber Line

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