Promoting ICT Connectivity through Internet Exchange Points in South-East Asia

Dae Keun Cho and Chang Yong Son
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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAE-1</td>
<td>Asia–Africa–Europe–1</td>
</tr>
<tr>
<td>AAG</td>
<td>Asia–America Gateway</td>
</tr>
<tr>
<td>ACMECS</td>
<td>Ayeyawady–Chao Phraya–Mekong Economic Cooperation Strategy</td>
</tr>
<tr>
<td>ADC</td>
<td>Asia Direct Cable</td>
</tr>
<tr>
<td>AP-IS</td>
<td>Asia-Pacific Information Superhighway</td>
</tr>
<tr>
<td>APG</td>
<td>Asia-Pacific Gateway</td>
</tr>
<tr>
<td>ASEAN</td>
<td>Association of Southeast Asian Nations</td>
</tr>
<tr>
<td>BGP</td>
<td>Border Gateway Protocol</td>
</tr>
<tr>
<td>BKNIX</td>
<td>Bangkok Neutral Internet Exchange</td>
</tr>
<tr>
<td>CLVT</td>
<td>Cambodia, Lao PDR, Viet Nam and Thailand</td>
</tr>
<tr>
<td>CNX</td>
<td>Cambodia Network Exchange</td>
</tr>
<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
</tr>
<tr>
<td>ESCAP</td>
<td>Economic and Social Commission for Asia and the Pacific</td>
</tr>
<tr>
<td>FEA</td>
<td>FLAG Europe Asia</td>
</tr>
<tr>
<td>FTTH</td>
<td>Fibre-to-the-Home</td>
</tr>
<tr>
<td>Gbps</td>
<td>Gigabit per Second</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communications</td>
</tr>
<tr>
<td>IAX</td>
<td>India–Asia–Xpress</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>ISP</td>
<td>Internet Service Provider</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>IXP</td>
<td>Internet Exchange Point</td>
</tr>
<tr>
<td>LAK</td>
<td>Lao Kip</td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
</tr>
<tr>
<td>Mbps</td>
<td>Megabit per Second</td>
</tr>
<tr>
<td>MCT</td>
<td>Malaysia–Cambodia–Thailand</td>
</tr>
<tr>
<td>MOU</td>
<td>Memorandum of Understanding</td>
</tr>
<tr>
<td>PSTN</td>
<td>Public Switched Telephone Network</td>
</tr>
<tr>
<td>SIM</td>
<td>Subscriber Identity Module</td>
</tr>
<tr>
<td>SJC2</td>
<td>South-East Asia–Japan–2</td>
</tr>
<tr>
<td>SMW3</td>
<td>South-East Asia–Middle East–Western Europe–3</td>
</tr>
<tr>
<td>SMW4</td>
<td>South-East Asia–Middle East–Western Europe–4</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Tbps</td>
<td>Terabit per Second</td>
</tr>
<tr>
<td>TGN-IA</td>
<td>Tata TGN-Intra Asia</td>
</tr>
<tr>
<td>TIS</td>
<td>Thailand–Indonesia–Singapore</td>
</tr>
<tr>
<td>UNCTAD</td>
<td>United Nations Conference on Trade and Development</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>VNIX</td>
<td>Vietnam National Internet Exchange</td>
</tr>
<tr>
<td>VNNIC</td>
<td>Vietnam Internet Network Information Center</td>
</tr>
<tr>
<td>VNPT</td>
<td>Vietnam Posts and Telecommunications Group</td>
</tr>
<tr>
<td>WEF</td>
<td>World Economic Forum</td>
</tr>
<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
</tr>
</tbody>
</table>
Abstract

The Asia-Pacific region has witnessed marked improvements in digital connectivity and digital transformation thanks to innovative information and communications technology (ICT) development. Moreover, the COVID-19 pandemic has demonstrated the vital roles of digital technology and connectivity in making societies safer, more resilient and connected in the region. However, inefficiencies in connectivity remain a challenge in South-East Asia. The subregion still needs to build more of its scarce network infrastructure to meet demands.

In this context, this working paper analyses the status of cross-border connectivity in four South-East Asian countries – Cambodia, Lao PDR, Viet Nam and Thailand (CLVT), and proposes a network promotion construction plan to strengthen cross-border connectivity between CLVT and improve Internet traffic management.

Section 1 discusses the importance of developing and using ICTs to secure competitiveness in South-East Asian countries in the digital economy era, and presents the structure and methodology of this working paper.

Section 2 briefly describes the policy environment in CLVT, and provides an update on the Internet infrastructure, including submarine cables, terrestrial cables, Internet exchange points (IXPs) and the access networks in the countries. In addition, the current status of fixed- and mobile-broadband usage in each country is presented.

Section 3 features case studies from Thailand and the Republic of Korea on the ICT infrastructure. In the case of Thailand, the Ayeyawady–Chao Phraya–Mekong Economic Cooperation Strategy and Thailand’s IXP Hub Initiative to support cross-border connectivity in CLVT are introduced. In the case of the Republic of Korea, IXP development and national roaming strategies for expanding 5G coverage are summarized, highlighting how three mobile carriers have promoted the co-deployment and use of 5G networks, and how the Korean government played a role in shared national roaming.

Section 4 presents the Internet infrastructure construction model to secure cross-border connectivity between CLVT. The proposed modality to enhance cooperation on connectivity in the subregion is explained. The modality proposes the creation of a standard model for CLVT to refer to and utilize to estimate the expected construction cost. Section 5 concludes the working paper with some recommendations.

The appendix provides the latest information on submarine cables connecting CLVT, and presents a standard memorandum of understanding to create a working group for CLVT to design and implement a cross-border connectivity project.

Keywords: Cambodia, Lao PDR, Viet Nam, Thailand, IXP, Submarine Cable, Terrestrial Cable, Access, IXP Model, MOU
1. Introduction

1.1 The Digital Economy in South-East Asia

The Fourth Industrial Revolution represents a fundamental change in the way we live, work and relate to one another. The Fourth Industrial Revolution is more than just technology-driven change; it is an opportunity to help everyone, including leaders, policymakers, and people from all income groups and nations, to harness converging technologies to create an inclusive, human-centred future (WEF, n.d.).

The World Economic Forum (WEF) and Association of Southeast Asian Nations (ASEAN) have emphasized the need to transition to the digital economy and prepare South-East Asia for the Fourth Industrial Revolution to secure the competitiveness of the subregion. The COVID-19 pandemic has intensified this need with digital technology emerging as a critical means to resolve public health challenges and facilitate the new online consumer landscape. This accelerated digitalization is disrupting the world’s economy, making it one of the most significant growth engines for many developing nations. We are already seeing how digitalization is reshaping Asia. The digital transformation of South-East Asia is opening a range of opportunities for its citizens, especially for younger generations. Many Asian countries are even global leaders in certain sectors of digitalization (WEF, 2022).

The Technology and Innovation Report of the United Nations Conference on Trade and Development (UNCTAD, 2021) urges all developing nations to prepare for a period of deep and rapid technological change that will profoundly affect markets and societies. All countries will need to pursue science, technology and innovation policies appropriate to their developmental stage and economic, social and environmental conditions. The report calls for strengthened international cooperation to build innovation capacities in developing countries. This requires strengthening and building digital skills.

The main components of the digital economy\(^1\) are: core aspects (e.g., enabling infrastructures, Internet and telecommunications networks); the digital and information and communications technology (ICT) sectors; and a wider set of digitalizing sectors. These components are being used in various ways as a basis for measuring the extent and impact of the digital economy. It may be useful to consider the different levels of digital infrastructure: (1) ICT networks (the core digital infrastructure for connectivity); (2) data infrastructure (data centres, submarine cables and cloud infrastructure); (3) digital platforms; and (4) digital devices and applications (UNCTAD, 2019).

The digital economy refers to activities and transactions driven by the public and private sectors, as well as citizens to produce, adopt and innovate digital technologies and services in relation to socioeconomic functions for enhanced wealth creation, productivity and quality of life. Figure 1 shows UNCTAD’s methodology (2019) focused on measures of the core and digital/ICT sectors, most notably related to investment and policies of the digital economy (e.g., digital infrastructure investments, broadband adoption, and IXP backbone and access networks), and their relevance to the growth of the digital economy. These ICT sector advancements need to be considered when examining the broader impacts of the digital economy.

From the perspective of the transition to the digital economy, the changes in the digital environment in South-East Asia are noteworthy among developing countries. Their use of mobile-related products and the improvement of infrastructure are increasing rapidly, which is higher than the penetration rate of electricity and quality of sanitary facilities.

South-East Asia, one of the most dynamic economic subregions in the world, is undergoing rapid digital transformation, and the South-East

---

\(^1\) With digital technologies underpinning an ever-increasing amount of transactions, the digital economy is becoming increasingly inseparable from the functioning of the economy as a whole. The different technologies and economic aspects of the digital economy can be broken down into three broad components (Source: Adapted from Bukht and Heeks, 2017, Malecki and Moriset, 2007, and UNCTAD, 2019). There is an ongoing debate about which firms in specific sectors or categories should be included or excluded as digital or ICT. For example, gaming, digital media and financial services firms, which might arguably be seen as key firms in the digital economy, have not been included in some of the measurements (HoC, 2016).
Asian countries represented by ASEAN are rapidly transitioning to digital economies despite disparate stages of economic development. The ASEAN’s digital economy has been shaped by the rapid growth of Internet users, and benefits from the subregion’s large and literate young population and growing middle-income class (ASEAN, 2021).

According to the Tech for Good Institute (2021) report, the number of Internet users in the six largest South-East Asian countries is expected to increase from 400 million in 2020 to 525 million in 2025, and the Internet economy gross merchandise value is expected to surpass USD300 billion by 2025.

The ASEAN economy is poised to be accelerated by the Fourth Industrial Revolution. With new technologies to enhance the subregion’s trade facilitation at unprecedented rates, ASEAN, as a digitally trading economy, can become increasingly competitive and attractive in the global space.

An important sector of the country’s digital economy is the ICT sector, including hardware manufacturing, information services, software and ICT consulting (WEF, 2022). The technological leap in South-East Asia requires large-scale infrastructure investment and ICTs to hold its position as a leading sector of the digital economy. To realize ASEAN’s long-term vision, the subregion must capitalize and capture opportunities in the following strategic priority areas: digital trade, Industry 4.0, service sectors of the new economy, and smart agriculture (ASEAN, 2021).

This working paper builds on the results of previous studies on Internet exchange points (IXPs) in the South-East Asian subregion, and presents opportunities for building IXPs in Cambodia, Lao PDR, Viet Nam and Thailand (CLVT) to improve the connectivity and reliability of IXPs. The growth of the ICT industry has resulted in increasing demand for network traffic and digital infrastructure. The transition to the digital economy needs to meet the demand for such traffic to bolster digital transformation.

Particularly, CLVT face demands from the user side of the IXP backbone network and the access networks, which are indispensable for both domestic and international Internet traffic. The conceptual framework of this study is based on this analysis.

Cross-border connectivity contributes to the digital economy and requires cooperation between neighbouring South-East Asian countries. As such, this working paper proposes a memorandum of understanding (MOU) to build the IXP backbone and access networks in CLVT (see Appendix 2).

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1.2 Methodology

The Asia-Pacific region has witnessed marked improvements in digital connectivity and digital transformation thanks to innovative ICT development. Moreover, the COVID-19 pandemic has demonstrated the vital roles of digital technology and connectivity in making society safer, more resilient and connected in the region. However, inefficiencies in connectivity remain a challenge in South-East Asia. The subregion still needs to build more of its scarce network infrastructure to meet demands.

In this context, this working paper analyses the status of cross-border connectivity in CLVT, and proposes a network promotion construction plan to strengthen cross-border connectivity between CLVT and improve Internet traffic management in South-East Asia.

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modality proposes the creation of a standard model for CLVT to refer to and utilize to estimate the expected construction cost. Section 5 concludes the working paper with some recommendations.

The appendix provides the latest information on submarine cables connecting CLVT, and presents a standard MOU to create a working group for CLVT to design and implement a cross-border connectivity project.
2. Digital Infrastructure in the Asia-Pacific Region

2.1 Asia Internet Traffic Trend

The demand for the Internet in Asian countries continues to grow with the expansion of mobile business. Many people are using apps such as Google and Facebook. As a result, major providers such as Google and Facebook are installing content-cache servers directly in Asia to improve the customer experience of Asian users, which means the global Internet traffic capacity of direct connections to the United States and Canada is decreasing. On the other hand, intra-Asia traffic is expected to continue to increase as emerging Asian countries connect to the global Internet through Asian hubs in neighbouring countries, which are easier to access than those in the United States and Canada.

As shown in Table 1, Asia’s total international bandwidth continues to nearly double every two years. Five years ago in 2017, intra-Asian Internet bandwidth was about 1.6 times that of what was connected to the United States and Canada. In 2021, this ratio went up to 2.6 times as intra-Asia capacity recorded a total of 110Tbps, far ahead of the trans-Pacific route at 42Tbps.

Table 1: International Internet bandwidth connected to Asia by region (2017-2021)

(Unit: Gbps)

<table>
<thead>
<tr>
<th>Region</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>97</td>
<td>138</td>
<td>109</td>
<td>127</td>
<td>162</td>
</tr>
<tr>
<td>Asia</td>
<td>26,779</td>
<td>39,990</td>
<td>54,572</td>
<td>81,195</td>
<td>110,432</td>
</tr>
<tr>
<td>Europe</td>
<td>9,471</td>
<td>13,619</td>
<td>19,017</td>
<td>24,255</td>
<td>32,776</td>
</tr>
<tr>
<td>Latin America</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Middle East</td>
<td>937</td>
<td>1,730</td>
<td>2,312</td>
<td>3,083</td>
<td>4,136</td>
</tr>
<tr>
<td>Oceania</td>
<td>579</td>
<td>827</td>
<td>1,368</td>
<td>1,914</td>
<td>2,516</td>
</tr>
<tr>
<td>United States and Canada</td>
<td>16,862</td>
<td>20,648</td>
<td>25,554</td>
<td>33,570</td>
<td>41,888</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>54,724</strong></td>
<td><strong>76,953</strong></td>
<td><strong>102,932</strong></td>
<td><strong>144,145</strong></td>
<td><strong>191,910</strong></td>
</tr>
</tbody>
</table>

Notes: Data reflects Internet bandwidth connected across international borders including links within each region. Data as of mid-year. Domestic routes omitted.
Source: Global Internet Geography Asia.

In the past five years, capacity has gradually become less concentrated among the largest carriers in Asia in terms of Internet bandwidth (Figure 2). The proportion of traffic capacity handled by other carriers is constantly increasing. In 2021, 58 per cent of the region’s bandwidth was operated by the top 20 carriers of the region, and 25 per cent of it by the top five. This has gone down over the past five years, as 61 per cent of total bandwidth was once owned by the top 20 and 29 per cent by the top five. This is because Internet usage has increased significantly in some countries in the region over this period, which has served to counterbalance the spread across the carriers.
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Figure 2: Concentration of Asian Internet bandwidth

Notes: Data represents percentage of total international Internet capacity held by the top five companies, the 6th-20th ranked companies, and all other carriers with international Internet capacity in the given year. Data as of mid-year. Domestic links excluded.

Source: Global Internet Geography Asia.

With the development of mobile service technology and the expansion of coverage, the number of subscribers to mobile-based broadband and voice services is increasing. On the other hand, the number of subscribers to traditional fixed-telephone services is decreasing.

In addition, fixed-broadband technology has moved from digital subscriber line (DSL) to fibre-to-the-home (FTTH), and both the speed and number of subscribers are increasing.

Table 2: Number of subscribers in Cambodia, Lao PDR, Viet Nam and Thailand (2017-2020)

(Unit: thousand)

<table>
<thead>
<tr>
<th>Country</th>
<th>Indicator</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>Fixed telephone</td>
<td>133</td>
<td>88</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile-cellular telephone</td>
<td>18,573</td>
<td>19,417</td>
<td>21,419</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fixed broadband</td>
<td>134</td>
<td>166</td>
<td>184</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile broadband</td>
<td>10,703</td>
<td>13,458</td>
<td>15,899</td>
<td></td>
</tr>
<tr>
<td>Lao PDR</td>
<td>Fixed telephone</td>
<td>1,125</td>
<td>1,482</td>
<td>1,491</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile-cellular telephone</td>
<td>3,712</td>
<td>3,662</td>
<td>4,362</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fixed broadband</td>
<td>27,217</td>
<td>45,379</td>
<td>76,280</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile broadband</td>
<td>2,742</td>
<td>2,966</td>
<td>3,484</td>
<td></td>
</tr>
<tr>
<td>Viet Nam</td>
<td>Fixed telephone</td>
<td>4,385</td>
<td>4,296</td>
<td>3,658</td>
<td>3,206</td>
</tr>
<tr>
<td></td>
<td>Mobile-cellular telephone</td>
<td>120,016</td>
<td>140,639</td>
<td>136,230</td>
<td>138,935</td>
</tr>
<tr>
<td></td>
<td>Fixed broadband</td>
<td>11,270</td>
<td>12,994</td>
<td>14,802</td>
<td>16,699</td>
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<tr>
<td></td>
<td>Mobile broadband</td>
<td>44,855</td>
<td>68,692</td>
<td>69,895</td>
<td>78,999</td>
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<tr>
<td>Thailand</td>
<td>Fixed telephone</td>
<td>9,955</td>
<td>6,059</td>
<td>5,415</td>
<td>5,003</td>
</tr>
<tr>
<td></td>
<td>Mobile-cellular telephone</td>
<td>121,530</td>
<td>125,098</td>
<td>129,614</td>
<td>116,294</td>
</tr>
<tr>
<td></td>
<td>Fixed broadband</td>
<td>8,208</td>
<td>9,189</td>
<td>10,109</td>
<td>11,600</td>
</tr>
<tr>
<td></td>
<td>Mobile broadband</td>
<td>55,179</td>
<td>58,054</td>
<td>60,348</td>
<td>63,060</td>
</tr>
</tbody>
</table>

2.2 Cambodia

2.2.1 Regulatory Policy

The Ministry of Posts and Telecommunications is in charge of establishing policies across the telecommunications industry with the goal of contributing to socioeconomic development and poverty reduction by promoting efficient network infrastructure connectivity and accessible services in the postal, telecommunications and ICT fields across Cambodia. Information protection policies are also included here. The Telecommunication Regulator of Cambodia is an independent regulatory body that oversees telecommunications regulation in Cambodia. It was established by royal decree in 2015 to establish and enforce telecommunications network regulations and government policies for the telecommunications sector, and promote fair, efficient and transparent use.

The law governing the telecommunications sector in Cambodia is the Telecom Act. According to this act, a person who wants to build a telecommunications network or provide telecommunications services must obtain a license.

More specifically, those wishing to provide construction or services for utility of infrastructure, network supporting telecommunications infrastructure, or provide telecommunications services (e.g., mobile network operators and Internet service providers) must obtain a license.

2.2.2 ICT Infrastructure

There are four IXPs in Cambodia. Previously, only the Cambodia Network Exchange (CNX) and TC DIX existed, but recently, MekongIX and HTN-IX were added. MekongIX was established in 2020 and is located in Phnom Penh with 14 Internet service provider (ISP) members. HTN-IX can be found in PeeringDB, but appears to be inactive. HTN Company Limited, registered in Cambodia, was the first IXP company licensed by the Ministry of Posts and Telecommunications.

Despite the presence of IXPs, the demand for global content takes up a large portion of total traffic, and ISPs must directly connect to the global ISPs and content providers to fulfil domestic demands in Cambodia.

Figure 3: IXP configuration in Cambodia

![A new neutral IXP to be established](image)

![Operated by Sabay](image)

![Operated by Telecom Cambodia](image)

Source: Department of Telecommunication Regulation, Telecommunication Regulator of Cambodia, July 2020.
Figure 4: Planned IXP configuration in Cambodia

Source: digitalreach.asia.

The Government of Cambodia established a national Internet gateway with a single point of entry for traffic into the country. Together, the IXPs can ensure more efficient traffic exchange and provide users with more stable network services (Figure 4).

Cambodia has two submarine cable systems landing in Sihanoukville for the Malaysia–Cambodia–Thailand (MCT, see Appendix A.2) and the Asia–Africa–Europe–1 (AAE-1, see Appendix A.3) cable systems. The Mittapheap Cable Landing Station along the MCT is owned and operated by Telcotech, and the Sihanoukville Cable Landing Station along the AAE-1 is owned and operated by Cambodia Fiber Optic Cable Network, a subsidiary of HyalRoute (Table 3).

Table 3: Submarine cable networks in Cambodia

<table>
<thead>
<tr>
<th>Country</th>
<th>Cable name</th>
<th>Service commencement</th>
<th>Landing station</th>
<th>System capacity (Lit – MAX)</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>MCT</td>
<td>2017</td>
<td>Sihanoukville</td>
<td>1.5T-30T</td>
<td>Telcotech</td>
</tr>
<tr>
<td></td>
<td>AAE-1</td>
<td>2017</td>
<td>Sihanoukville</td>
<td>17T-50T</td>
<td>HyalRoute</td>
</tr>
</tbody>
</table>


Table 4: Terrestrial cable networks in Cambodia

<table>
<thead>
<tr>
<th>Division</th>
<th>Path</th>
<th>Connection city</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cambodia ↔ Viet Nam</td>
<td>Phnom Penh, Ho Chi Minh</td>
</tr>
<tr>
<td>2</td>
<td>Cambodia ↔ Thailand</td>
<td>Phnom Penh, Bangkok</td>
</tr>
</tbody>
</table>

2.2.3 Access Network

With the development of wireless technology and the popularization of smartphones, the number of mobile subscribers worldwide is increasing while the number of fixed-telephone subscribers is decreasing. Cambodia is experiencing the same trend. The number of mobile phone subscribers is increasing and reached about 21.6 million in 2019, driven by fierce competition and various promotions offered by operators. The number of fixed-broadband connections reached 184,379 at the end of 2019, while the number of fixed-voice connections fell to around 42,000 due to fixed-mobile substitution, which is a general trend with the explosive growth of wireless services.

Figure 5: Number of mobile phone and fixed-telephone subscribers in Cambodia (2017-2021)

Cambodia's mobile market is comprised of three major players. In Cambodia, as of 2021, Viettel (Metfone) and Axiata (Smart) offer mobile services and fixed-broadband access (Metfone via FTTH and Smart via fixed wireless), while CamGSM (Cellcard) offers solely mobile services. Metfone and Smart have a market share of more than 65 per cent. Cambodia's fixed-broadband market remains underdeveloped. DSL and FTTH are the dominant fixed-broadband technologies in Cambodia. DSL is a technology that uses telephone lines, and it is difficult to increase the transmission speed due to ageing media and distance limitations. Thus, changing media to FTTH based on fibre-optic cables is seen as advantageous in the long term.
2.3 Lao PDR

2.3.1 Regulatory Policy

The Ministry of Technology and Communications is in charge of Lao PDR’s ICT policies and regulations. On 5 November 2021, the Ministry of Technology and Communications announced a five-year digital national economic revitalization plan. Technology and Communications minister, Thansamay Kommasith, said the plan is part of the 2021-2030 Strategic Economic Development Strategy, and focuses on e-commerce development and digital technology use by small- and medium-sized enterprises and startups.

According to the Law on Telecommunications amended in 2011, Lao PDR has four types of telecommunications licenses (Table 5). Those who obtain the Type I license can provide network and telecommunications services, which means operators that can participate in cross-border connectivity are Type I license holders. The Ministry of Technology and Communications holds the authority to grant licenses.

Table 5: License types for telecommunications service operations in Lao PDR

<table>
<thead>
<tr>
<th>Type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Network services and telecommunications services.</td>
</tr>
<tr>
<td>II</td>
<td>Telecommunications services of those who do not have their own networks, Internet services, Internet domain names, Internet connection and value-added services.</td>
</tr>
<tr>
<td>III</td>
<td>Consulting services, installation, repair services; export, import, manufacturing and distribution of telecommunications equipment.</td>
</tr>
<tr>
<td>IV</td>
<td>Installation of private telecommunications networks.</td>
</tr>
</tbody>
</table>

Source: Lao PDR Law on Telecommunications, 2011.

2.3.2 ICT Infrastructure

The Lao National Internet Center was established in 2010 in accordance with the National Socio-Economic Development Plan to advance socioeconomic development and transform Lao PDR from a landlocked country into a land-linked country. An IXP, LANIX, which currently has seven ISP members, was also established.

Based on research survey, little progress has been made in developing LANIX. It is unclear whether an international Internet transit service provider is connected to LANIX.
LANIX’s total connection capacity is 49Gbps, which is smaller than the other three countries. Each ISP has multiple connections with LANIX to improve connectivity and reliability, but LaoSat has a single failure point structure.

In 2017, Lao Telecom joined the Bangkok Neutral Internet Exchange (BKNIX) as a member to minimize the high fees they pay to global transit providers. Other ISPs in Lao PDR are paying Internet transit fees to neighbouring transit providers like China Telecom, CAT Telecom, Vietnam Posts and Telecommunications Group (VNPT) and Viettel.

Lao PDR is a landlocked country in South-East Asia bordered by Cambodia, China, Myanmar, Thailand and Viet Nam. Therefore, it is difficult for Lao PDR to participate in a submarine cable project.

In Lao PDR, Lao Telecom has an international capacity of 5.7Gbps, and STL and ETL have terrestrial networks at 2.6Gbps and 2.4Gbps, respectively. Lao PDR’s international bandwidth is 200Gbps, and the Internet gateway is established via Viet Nam, Thailand and China. Additionally, Lao PDR and China have agreed to deploy a fibre pair along the railroad in 2022 to connect Vientiane, Lao PDR with Kunming, China.

There are five points of interconnection across Lao PDR’s border with Thailand, nine with Viet Nam, and two with Cambodia (Table 6).

Table 6: Terrestrial cable networks in Lao PDR

<table>
<thead>
<tr>
<th>Division</th>
<th>Path</th>
<th>Connection city</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lao PDR ↔ Viet Nam</td>
<td>Vientiane, Ha Noi, Da Nang</td>
</tr>
<tr>
<td>2</td>
<td>Lao PDR ↔ Thailand</td>
<td>Vientiane, Bangkok</td>
</tr>
<tr>
<td>3</td>
<td>Lao PDR ↔ Cambodia</td>
<td>Vientiane, Phnom Penh</td>
</tr>
</tbody>
</table>


2.3.3 Access Network

The latest available data from the International
Telecommunication Union (ITU) database (2021) shows that there are four major mobile service providers in Lao PDR – LTC, Beeline, Unitel and ETL. The number of mobile-broadband subscribers in Lao PDR is increasing as the coverage of 3G and 4G networks expands. Fixed-broadband subscribers have been increasing slowly, with DSL technology using legacy copper cables and cable modem technology using coaxial cables until the mid-2010s, but the number of FTTH subscribers using fibre-optic cables began decreasing after the late-2010s.

With the change of subscribers by media, the number of subscribers with speed above 2Mbps is increasing, but the high service charges delay access to digital services. Lao PDR’s fixed-broadband costs LAK144,000 (USD12.70) a month without data, LAK83/MB during the day and LAK50/MB at night.

Table 7: Telecommunications players in Lao PDR

<table>
<thead>
<tr>
<th>Telecom operator / ISP</th>
<th>Services</th>
<th>Shareholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprise of Telecommunications Lao (ETL)</td>
<td>• PSTN</td>
<td>• 40% Government of Lao PDR</td>
</tr>
<tr>
<td></td>
<td>• 2.5G (GSM 900/1800, GPRS)</td>
<td>• 51% JIAFU (China)</td>
</tr>
<tr>
<td></td>
<td>• 3G (GSM 2.1 GHz)</td>
<td></td>
</tr>
<tr>
<td>Lao Telecom (LTC)</td>
<td>• PSTN</td>
<td>• 51% Government of Lao PDR</td>
</tr>
<tr>
<td></td>
<td>• 2.5G (GSM 900/1800, GPRS)</td>
<td>• 49% Foreign ownership</td>
</tr>
<tr>
<td></td>
<td>• 3G/4G (GSM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ISP (XDL, IP Star)</td>
<td></td>
</tr>
<tr>
<td>Star Telecom (Unitel)</td>
<td>• PSTN</td>
<td>• 51% Government of Lao PDR</td>
</tr>
<tr>
<td></td>
<td>• 2.5G (GSM 900/1800, GPRS)</td>
<td>• 49% Viettel Global</td>
</tr>
<tr>
<td></td>
<td>• 3G (GSM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• ISP (XDL, FTTx)</td>
<td></td>
</tr>
<tr>
<td>T.plus</td>
<td>• 2.5G (GSM 900/1800, Edge)</td>
<td>• 100% Lao Telecom (LTC)</td>
</tr>
<tr>
<td></td>
<td>• WiMAX, 3G, FTTx</td>
<td></td>
</tr>
<tr>
<td>Sky Telecom</td>
<td>• Fibre, FTTx, WiFi &amp; Quad Play</td>
<td>• 100% Government of Lao PDR</td>
</tr>
<tr>
<td></td>
<td>• DPLC, IPLC, Dark Fibre</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• IPTV, VoIP, IDC, BISS &amp; SI</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Mobile Broadband (BB-WiFi, BB Mobile 3G/4G)</td>
<td></td>
</tr>
</tbody>
</table>


The number of mobile-broadband users is rapidly increasing. The number of mobile-broadband subscribers increased from about 2.48 million in 2016 to 3.48 million in 2019. Over four years, the compound annual growth rate was about 12 per cent.

The number of fixed-broadband subscribers increased from about 15,000 in 2015 to 78,000 in 2017, and the number of FTTH subscribers increased from about 9,000 to 24,000 over the same period. With the increase in FTTH subscribers, more subscribers are using fixed broadband with speeds greater than 10Mbps.
Table 8: Number of fixed-broadband subscribers by technology in Lao PDR (2015-2019)

<table>
<thead>
<tr>
<th>Technology</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subscriptions</td>
<td>14,550</td>
<td>24,426</td>
<td>27,217</td>
<td>45,379</td>
<td>76,280</td>
</tr>
<tr>
<td>Cable modem</td>
<td>4,988</td>
<td>15,018</td>
<td>10,007</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DSL</td>
<td>12,316</td>
<td>12,363</td>
<td>10,788</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>FTTH</td>
<td>8,768</td>
<td>15,383</td>
<td>24,448</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>


2.4 Viet Nam

2.4.1 Regulatory Policy

The Vietnamese government intends to promote national digital transformation through policies such as the 2030 National Digital Transformation Program (Decision No. 749/QD-TTg) and 2025 Step-by-Step Digital Transformation Business Support Program (Decision No. 426/QD-BKHDT).

The 2030 National Digital Transformation Program aims to have the digital economy account for 30 per cent of gross domestic product and increase labour productivity by 8 per cent. The 2025 Step-by-Step Digital Transformation Business Support Program aims to support 100,000 companies and produce about 100 digital transformation model companies (Government of Viet Nam, n.d.).

IXP and cross-border connectivity can be promoted by providers of network infrastructure services who have obtained a network construction license in accordance with the Law on Telecommunications in 2009. Viet Nam’s Ministry of Information and Communications is responsible for ICT policy development, and the telecommunications regulatory body is the Viet Nam Telecommunications Authority.

2.4.2 ICT Infrastructure

The IXP, Vietnam National Internet Exchange (VNIX), is constructed, operated and managed by the Vietnam Internet Network Information Center (VNNIC), according to Document No.1513/BBCVT-VT (2003) of the Ministry of Post and Telematics (now, Ministry of Information and Communications).

VNIX has been working effectively in three regions of the country – the northern region (Ha Noi), southern region (Ho Chi Minh) and central region (Da Nang), but they operate independently without any connections among them.

VNIX has two types of connections – N x 1Gbps/port and N x 10Gbps/port.
Ha Noi has 16 members connected with 128Gbps bandwidth capacity, Ho Chi Minh has 23 members connected with a maximum of 200Gbps bandwidth capacity, and Da Nang has 7 members connected with 36Gbps bandwidth capacity. Connection capacity through VNIX in 2020 amounted to 335Gbps.
Figure 8: VNIX bandwidth by province/city and VNIX members by connection location (Unit: Gbps)


VNIX members and bandwidth remained unchanged from 2015 to 2019, but the number of member ISPs for VNIX increased in 2020 by 38 per cent (from 21 to 29 member ISPs) and bandwidth increased by about 26 per cent (from 290Gbps to 364Gbps) since 2019.

Figure 9: VNIX members and bandwidth (2000-2020)


According to the National Digital Transformation Program, Viet Nam will expand domestic Internet connection through direct peer-to-peer connections to the IXP and VNIX national Internet exchange station.

Expanding regional and international Internet connectivity, especially the development of undersea fibre-optic cables, will make Viet Nam one of the regional connectivity centres.

Viet Nam has seven submarine cable systems and three cable landing stations – in Da Nang for South-East Asia–Middle East–Western Europe–3 (SMW3, see Appendix A.4) and the Asia-Pacific Gateway (APG, see Appendix A.5);
in Vung Tau for AAE-1, TGN-Intra Asia (see Appendix A.7) and the Asia–America Gateway (AAG, see Appendix A.6); and in Quy Nhon for Asia Direct Cable (ADC, see Appendix A.8) and South-East Asia–Japan–2 (SJC2, see Appendix A.9) that will begin service in 2022 or 2023. Da Nang is the largest city in the south-central coast of Viet Nam and one of the country’s most important ports.

The VNPT and Viettel Vung Tau Cable Landing Station for the AAE-1 cable system is located at Vung Tau, which is a resort town in the province of Dong Nai, approximately 125km from Ho Chi Minh City. VNPT and Viettel are the dominant international submarine cable operators in Viet Nam.

Table 9: Submarine cable networks in Viet Nam

<table>
<thead>
<tr>
<th>Country</th>
<th>Cable name</th>
<th>Service commencement</th>
<th>Landing station</th>
<th>System capacity (Lit – MAX)</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viet Nam</td>
<td>SMW3</td>
<td>1999</td>
<td>Da Nang</td>
<td>755G</td>
<td>VNPT</td>
</tr>
<tr>
<td></td>
<td>TGN-Intra Asia</td>
<td>2009</td>
<td>Vung Tau</td>
<td>25T-30T</td>
<td>TATA</td>
</tr>
<tr>
<td></td>
<td>AAG</td>
<td>2011</td>
<td>Vung Tau</td>
<td>11T-14TG</td>
<td>VNPT</td>
</tr>
<tr>
<td></td>
<td>APG</td>
<td>2016</td>
<td>Da Nang</td>
<td>600G-5.8T</td>
<td>VNPT</td>
</tr>
<tr>
<td></td>
<td>AAE-1</td>
<td>2017</td>
<td>Vung Tau</td>
<td>17T-50T</td>
<td>VNPT/Viettel</td>
</tr>
<tr>
<td></td>
<td>ADC</td>
<td>2022</td>
<td>Quy Nhon</td>
<td>More than 140T</td>
<td>Viettel</td>
</tr>
<tr>
<td></td>
<td>SJC2</td>
<td>2022</td>
<td>Quy Nhon</td>
<td>144T</td>
<td>VNPT</td>
</tr>
</tbody>
</table>


Table 10: Terrestrial cable networks in Viet Nam

<table>
<thead>
<tr>
<th>Division</th>
<th>Path</th>
<th>Connection city</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Viet Nam ↔ Cambodia</td>
<td>Da Nang, Phnom Penh</td>
</tr>
<tr>
<td>2</td>
<td>Viet Nam ↔ Thailand</td>
<td>Ho Chi Minh, Bangkok</td>
</tr>
</tbody>
</table>


2.4.3 Access Network

There are currently eight mobile network providers in Viet Nam, which are MobiFone, Viettel, Vinaphone, Vietnamobile (formerly HT Mobile), Indochina Telecom, EVN Telecom, S-Fone and Beeline.

Viettel, MobiFone and VNPT have been trialing 5G services with their users since November 2020. During the pandemic, Viet Nam has recorded the highest number of new Internet users in the South-East Asian subregion. The total number of fixed-broadband subscribers in Viet Nam exceeds 17.2 million and the total number of mobile-broadband subscribers is nearly 69.5 million, according to statistics from the Telecommunications Department.
Figure 10: Average download and upload speed of mobile networks in Viet Nam (2020)

Figure 10 shows data on Vietnamese users’ Internet speed measurement by VNNIC. In 2020, VNNIC worked with ISPs and relevant organizations in Viet Nam to deploy more than 21 test servers at VNIX and ISPs’ networks with the aim to provide more comprehensive Internet speed data to the community and encourage a transparent Internet market in Viet Nam. The country’s average upload speed is 48.25Mbps, and the average download speed is 38.09Mbps. The average download and upload speed of mobile networks is 39.9Mbps and 24Mbps, respectively. The average download and upload speed of fixed-broadband networks is 56.5Mbps and 52.17Mbps, respectively.

2.5 Thailand

2.5.1 Regulatory Policy

The Thai government has established a mid- to long-term economic development roadmap, “Thailand 4.0”. This policy aims to foster future growth industries by combining ICTs such as the Internet of Things and artificial intelligence across primary (agriculture), secondary (manufacture) and tertiary (service) industries. The Ministry of Digital Economy and Society and the Ministry of Industry are responsible for ICT policy development in Thailand.

The law governing the telecommunications sector in Thailand is the Telecommunications Business Act. Under the act, there are three types of telecommunications licenses, which are categorized into Type 1, Type 2 and Type 3, based on the functions and nature of services provided to customers. IXP s and cross-border connectivity can be promoted by providers who have a Type 3 license. In the case of providing an IXP only, a Type 2 license will also do (Table 11).
Table 11: Licenses for cross-border connectivity and IXP in Thailand

<table>
<thead>
<tr>
<th>License</th>
<th>Network usage</th>
<th>Nature of service</th>
<th>Examples of service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 2</td>
<td>With network</td>
<td>• Providing service:</td>
<td>• International Internet gateway</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Only to some specific groups of people; or</td>
<td>• National Internet exchange</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- With no negative effects on fair trade, competition or public interest and consumers.</td>
<td></td>
</tr>
<tr>
<td>Type 3</td>
<td>With network</td>
<td>• Providing service:</td>
<td>• Mobile network</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- To the general public;</td>
<td>• International private leased circuit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- May cause negative effects on fair trade, competition or the public interest; or</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- In the manner required to protect consumers.</td>
<td></td>
</tr>
</tbody>
</table>


2.5.2 ICT Infrastructure

The Internet in Thailand is mainly used to access content from overseas, such as the United States, European countries, Hong Kong and Singapore.

In this situation, it seems that it has contributed greatly to international gateway growth to enable access to these international content.

There are 11 IXPs in Thailand – CAT, TOT, IIR-NECTEC, TICC (True), CS LOXINFO, TCCT, BB Connect, Symphony Communication, AWN, JASTEL and BKNIX.

BKNIX is the first neutral IXP in Thailand. It was launched in 2015 with five members, but has grown quickly and is expanding its service coverage to Chonburi, an attractive place for ISPs, content delivery networks, universities and other carriers, with switching equipment that can carry peak data in the terabits per second (Tbps) range.
Thailand has eleven submarine cable systems and four cable landing stations – in Satun for FLAG Europe Asia (FEA, see Appendix A.10), SMW3, South-East Asia–Middle East–Western Europe–4 (SMW4, see Appendix A.12), AAE-1 and India–Asia–Xpress (IAX, see Appendix A.13); in Songkhla for FEA, Thailand–Indonesia–Singapore (TIS, see Appendix A.11), APG, AAE-1 and SJC2; in Sriracha for AAG and ADC; and in Rayong for MCT.
Table 12: Submarine cable networks in Thailand

<table>
<thead>
<tr>
<th>Country</th>
<th>Cable name</th>
<th>Service commencement</th>
<th>Landing station</th>
<th>System capacity (Lit – MAX)</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thailand</td>
<td>FEA</td>
<td>1997</td>
<td>Satun/Songkhla</td>
<td>440G-1.1T</td>
<td>Global Cloud Xchange</td>
</tr>
<tr>
<td></td>
<td>SMW3</td>
<td>1999</td>
<td>Satun</td>
<td>755G</td>
<td>National Telecom</td>
</tr>
<tr>
<td></td>
<td>TIS</td>
<td>2003</td>
<td>Songkhla</td>
<td>6.4T</td>
<td>National Telecom</td>
</tr>
<tr>
<td></td>
<td>SMW4</td>
<td>2005</td>
<td>Satun</td>
<td>10T-15T</td>
<td>National Telecom</td>
</tr>
<tr>
<td></td>
<td>AAG</td>
<td>2011</td>
<td>Sriracha</td>
<td>11T-14TG</td>
<td>National Telecom</td>
</tr>
<tr>
<td></td>
<td>APG</td>
<td>2016</td>
<td>Songkhla</td>
<td>600G-5.8T</td>
<td>National Telecom</td>
</tr>
<tr>
<td></td>
<td>AAE-1</td>
<td>2017</td>
<td>Satun/Songkhla</td>
<td>17T-50T</td>
<td>National Telecom</td>
</tr>
<tr>
<td></td>
<td>MCT</td>
<td>2017</td>
<td>Rayong</td>
<td>1.5T-30T</td>
<td>DTAC</td>
</tr>
<tr>
<td></td>
<td>SJC2</td>
<td>2022</td>
<td>Songkhla</td>
<td>144T</td>
<td>True</td>
</tr>
<tr>
<td></td>
<td>ADC</td>
<td>2022</td>
<td>Sriracha</td>
<td>More than 140T</td>
<td>National Telecom</td>
</tr>
<tr>
<td></td>
<td>IAX</td>
<td>2023</td>
<td>Satun</td>
<td>-</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Source: TeleGeography, "Submarine Cable Map". Available at https://www.submarinecablemap.com/.

Thailand has 14 major local providers (National Telecom, AWN, True, Jastel, etc.) that have 30,000km of full optical fibre across Thailand with a domestic bandwidth of 9.5Tbps. It has the necessary basic digital infrastructure in the form of well-connected lakes, roads, highways, railways, etc. to handle networks across the country.

Table 13: Terrestrial cable networks in Thailand

<table>
<thead>
<tr>
<th>Division</th>
<th>Path</th>
<th>Connection city</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thailand ↔ Cambodia</td>
<td>Bangkok, Phnom Penh</td>
</tr>
<tr>
<td>2</td>
<td>Thailand ↔ Lao PDR</td>
<td>Bangkok, Vientiane</td>
</tr>
<tr>
<td>3</td>
<td>Thailand ↔ Viet Nam</td>
<td>Bangkok, Ho Chi Minh</td>
</tr>
</tbody>
</table>


2.5.3 Access Network

The fixed-broadband market is experiencing strong growth mostly driven by three players – AIS, Jasmine and TrueOnline – who are all investing in full-fibre networks.

Jasmine actively migrated its DSL subscribers to its fibre-optic network while TrueOnline and AIS are growing their subscriber base by capturing many new broadband subscribers.

Forecasts show that mobile subscriptions will continue to grow in the period up to 2025, and fixed-broadband subscribers will also continue to grow and increase household penetration over the same period.

Mobile revenue is growing faster than mobile subscription numbers leading to average revenue per user growth as the market transitions from 2G and 3G to 4G mobile data services.
The Village Broadband Internet Project or Net Pracharat is a flagship digital infrastructure development project in Thailand. The main objective of Net Pracharat is to strengthen the national broadband network by expanding high-speed Internet networking to reach all villages in the country so that local Thai people who live in remote areas will be able to access broadband or high-speed Internet as easily as those who live in the cities, resulting in bridging the digital divide and building an inclusive and sustainable connected society.

In December 2017, the Ministry of Digital Economy and Society and TOT Public Company Limited completed the installation of fibre-optic cables to 24,700 target rural villages throughout the country. In addition to providing the Internet network, the government equipped Thai people with Wi-Fi for communities to provide free public Wi-Fi hotspots at a speed of 30Mbps (download) and 10Mbps (upload). As of November 2018, there were about 4.5 million users registered to access Wi-Fi Net Pracharat. New registrations increase around 200,000-300,000 every month. Fixed-broadband subscribers are also increasing, especially FTTH subscribers.

### Table 14: Internet connection speed in Thailand (2018-2021)

<table>
<thead>
<tr>
<th>Internet connection speed</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average download speed of mobile Internet connections</td>
<td>13.61Mbps</td>
<td>17.58Mbps</td>
<td>25.98Mbps</td>
<td>51.75Mbps</td>
</tr>
<tr>
<td>Year-on-year change in average speed of mobile Internet connections</td>
<td>29%</td>
<td>48%</td>
<td>99.20%</td>
<td></td>
</tr>
<tr>
<td>Average download speed of fixed Internet connections</td>
<td>38.85Mbps</td>
<td>57.63Mbps</td>
<td>125.12Mbps</td>
<td>308.35Mbps</td>
</tr>
<tr>
<td>Year-on-year change in average speed of fixed Internet connections</td>
<td>48%</td>
<td>117%</td>
<td>146.60%</td>
<td></td>
</tr>
</tbody>
</table>


### Table 15: Number of fixed-broadband subscribers by technology in Thailand (2017-2020)

<table>
<thead>
<tr>
<th>Technology</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subscriptions</td>
<td>8,208</td>
<td>9,189</td>
<td>10,109</td>
<td>11,600</td>
</tr>
<tr>
<td>Cable modem</td>
<td>1,584</td>
<td>1,514</td>
<td>1,129</td>
<td>-</td>
</tr>
<tr>
<td>DSL</td>
<td>4,760</td>
<td>3,653</td>
<td>3,599</td>
<td>-</td>
</tr>
<tr>
<td>FTTH</td>
<td>1,693</td>
<td>3,871</td>
<td>5,230</td>
<td>-</td>
</tr>
</tbody>
</table>

3. Case Studies

This section features case studies from Thailand and the Republic of Korea. In the case of Thailand, the ACMECS and IXP Hub Initiative to support cross-border connectivity in CLVT are introduced. In the case of the Republic of Korea, IXP development and national roaming strategies for expanding 5G coverage are summarized, highlighting how three mobile carriers have promoted the co-deployment and use of 5G networks, and how the Korean government played a role in shared national roaming.

3.1 Thailand: ACMECS and IXP Hub Initiative

Thailand is embracing the Fourth Industrial Revolution through the country’s medium- and long-term development plans. Digital Thailand, the ICT sector development plan for the Thailand Industry 4.0 policy, has a goal to digitally transform Thailand within 10 years and secure global digital leadership within 20 years (Figure 13).

Figure 13: Thailand’s Fourth Industrial Revolution Strategy

<table>
<thead>
<tr>
<th>Digital Thailand</th>
<th>Thailand 4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20-YEAR THAILAND DIGITAL LANDSCAPE</strong></td>
<td><strong>THAILAND 4.0</strong></td>
</tr>
<tr>
<td><strong>Phase 1</strong></td>
<td>Smart industry + smart city + smart people</td>
</tr>
<tr>
<td>Digital foundation Investing and building digital foundation</td>
<td>Agriculture</td>
</tr>
<tr>
<td>1 year 6 months</td>
<td>Light industry</td>
</tr>
<tr>
<td><strong>Phase 2</strong></td>
<td>low wages</td>
</tr>
<tr>
<td>Digital Thailand: inclusion Ensuring everyone can reap the benefits of digital technology</td>
<td>Heavy industry</td>
</tr>
<tr>
<td>5 years</td>
<td>advanced machinery</td>
</tr>
<tr>
<td><strong>Phase 3</strong></td>
<td>Creativity + innovation</td>
</tr>
<tr>
<td>Digital Thailand: full transformation Driving the country with digital technology and innovation</td>
<td>Smart Thailand</td>
</tr>
<tr>
<td>10 years</td>
<td></td>
</tr>
<tr>
<td><strong>Phase 4</strong></td>
<td></td>
</tr>
<tr>
<td>Global digital leadership Leading with digital technology and innovation (becoming a developed country)</td>
<td></td>
</tr>
<tr>
<td>10-20 years</td>
<td></td>
</tr>
<tr>
<td><strong>Phase 5</strong></td>
<td></td>
</tr>
</tbody>
</table>

Sources: Thailand’s Ministry of Digital Economy and Society and the Bangkok Post.

The ACMECS was established in 2003 at the suggestion of former Prime Minister Thaksin Shinawatra, which contributed to enhancing Thailand’s economic cooperation in the Mekong subregion.

ACMECS countries have been participating in summit meetings every two years, and after the 8th Summit in June 2018, a plan was developed for the next five years (2019-2023), incorporating the 3S strategies. The 3S refers to Seamless ACMECS, Synchronized ACMECS, and Smart and Sustainable ACMECS.

In June 2019, the Thai government declared a total of USD500 million for the ACMECS development fund over the next five years to implement the plan, with the Thai government contributing USD200 million, other Mekong countries contributing USD100 million, and the remaining USD200 million from Australia, Japan, the Republic of Korea and the United States. Through this initiative, ACMECS intends to promote various development cooperation projects in the 3S fields, including a digital infrastructure construction plan for cross-border connectivity. Thailand’s National Telecom proposed a Digital ACMECS IXP Hub Initiative based on this action plan.
The National Telecom pointed out that many ISPs in the Mekong subregion must exchange local content in Hong Kong and Singapore, resulting in prohibitive costs due to high international private leased circuit fees and access fees to Hong Kong and Singapore. These prohibitive fees result in high user charges and the lack of affordable access to the Internet, as well as poor Internet quality due to latency from the prolonged transmission distance.
The National Telecom proposed the Digital ACMECS IXP Hub Initiative to address these issues. According to National Telecom's proposal, if ACMECS participating countries access Thailand IXP in a star-pattern manner, they will not incur additional international private leased circuit fees in Hong Kong and Singapore and will reduce latency. Thailand's National Telecom led this initiative and a consortium was proposed as the participation method. As a first step, it was proposed to use the existing Thailand IXP (TH-IX) as a regional IXP. National Telecom planned to actively utilize fibre-optic cable and data centres in Thailand for this project. As shown in Figures 15 and 16, fibre-optic cables can be used for connectivity with neighbouring countries as they are built throughout Thailand.

The National Telecom expects the IXP Hub Initiative to reduce Internet cost and improve Internet quality of ACMECS countries. In addition, investment in digital content in CLVT...
is expected to increase and help revitalize the local economy. In order to promote the Digital ACMECS IXP Hub Initiative, cooperation between Thailand and neighbouring countries will be essential.

Table 16: The benefits and costs of the Digital ACMECS IXP Hub Initiative

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce the cost of Internet</td>
<td>Equipment cost</td>
</tr>
<tr>
<td>Improve the quality of intraregional traffic</td>
<td>Transmission and usage costs</td>
</tr>
<tr>
<td>Attract content providers to invest in the region</td>
<td>Labour cost</td>
</tr>
<tr>
<td>Enhance regional business environment (on connectivity)</td>
<td></td>
</tr>
</tbody>
</table>


3.2 Connectivity in the Republic of Korea

In the Republic of Korea, there are four IXPs in operation:

1. KTIX, operated by KT, interconnects 15 ISPs and the three other IXPs.
2. DIX, operated by LG U+, interconnects 18 ISPs and the three other IXPs.
3. SKBIX, operated by SK Broadband, interconnects 24 ISPs and the three other IXPs.
4. KINX, a neutral IXP, interconnects 70 ISPs and the three other IXPs.

To enable connection between content and users through the Internet, direct and indirect connections are required with the ISPs providing Internet access services.

There are many ISPs in line with the increase in Internet use, and the high number of ISPs leads to excessive line cost, investment cost and traffic from many connecting lines.

Accordingly, IXPs have been developed for efficient line connection. The four IXPs are interconnected with high-speed fibre-optic links, which means for new ISPs, they can take advantage of the peering and transit arrangements by simply becoming a member of one IXP.

The Korean IXP model demonstrates an effective Internet exchange environment for ISPs to interconnect with each other to provide users with fast, affordable services.

The Korean government has provided guidelines for the interconnection market to rule out unilateral terms and conditions by major ISPs and encourage fair contract conditions.
Figure 17: Interconnection structure of IXPs in the Republic of Korea (as of July 2020)

![Interconnection structure of IXPs in the Republic of Korea](image)


Table 17: Linkage status of IXPs in the Republic of Korea (as of July 2020)

<table>
<thead>
<tr>
<th>IXP</th>
<th>Operating institution</th>
<th>Number of ISPs connected</th>
<th>Total connection capacity (Gbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KTIX</td>
<td>KT</td>
<td>15</td>
<td>625</td>
</tr>
<tr>
<td>DIX</td>
<td>LG U+</td>
<td>18</td>
<td>2,443</td>
</tr>
<tr>
<td>SKBIX</td>
<td>SK Broadband</td>
<td>24</td>
<td>2,566</td>
</tr>
<tr>
<td>KINX</td>
<td>KINX</td>
<td>70</td>
<td>2,823</td>
</tr>
</tbody>
</table>


KTIX has the largest backbone network in the Republic of Korea with a dual-node configuration. Its total connection capacity is 625Gbps, linking three IXPs and 15 ISPs (Table 18). In 2020, KTIX began Internet Protocol (IP) version 6 traffic exchange with DIX and SKBIX.

Table 18: KTIX linkage status in the Republic of Korea (as of July 2020)

<table>
<thead>
<tr>
<th>Linkage status</th>
<th>Linkage method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkage method</td>
<td>POS, Ethernet</td>
</tr>
<tr>
<td>IXP linkage</td>
<td>DIX (910G), SKBIX (1,270G), KINX (60G)</td>
</tr>
<tr>
<td>ISP linkage</td>
<td>625G linkage of 15 providers including: SK Telecom (280G), LG U+ (160G), Sejong Telecom (130G), T-broad (60G), Dreamline (60G), Samsung SDS (20G), LG Hello Vision (40G), Hyundai HCN (80G), Government Information Integration (20G)</td>
</tr>
</tbody>
</table>


DIX, operated by LG U+, has a dual-node configuration that is geometrically separated. KIDC, the largest Internet data centre in the Republic of Korea, and DIX are co-located at the same node. Currently, DIX interconnects around 18 ISPs and has a capacity of 2,443Gbps (Table 19).
Table 19: DIX linkage status in the Republic of Korea (as of July 2020)

<table>
<thead>
<tr>
<th>Linkage method</th>
<th>Linkage status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkage method</td>
<td>POS, Ethernet</td>
</tr>
<tr>
<td>IXP linkage</td>
<td>KTIX (1,110G), SKBIX (870G)</td>
</tr>
<tr>
<td>ISP linkage</td>
<td>2,443G linkage of 18 providers including: SK Telecom (160G), Sejong Telecom (33G), Dreamline (110G), D’Live (140G), Hyundai HCN (60G), LG HelloVision (71G)</td>
</tr>
</tbody>
</table>


SKBIX has a dual-node configuration that is geometrically separated, and exchanges domestic Internet traffic through two IXPs and 24 ISPs with a link capacity of 2,566Gbps. It provides services such as the Internet, voice over IP, and IP television by establishing redundancy and bypass routes between nodes across the country (Table 20).

Table 20: SKBIX linkage status in the Republic of Korea (as of July 2020)

<table>
<thead>
<tr>
<th>Linkage method</th>
<th>Linkage status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkage method</td>
<td>POS, Ethernet</td>
</tr>
<tr>
<td>IXP linkage</td>
<td>KTIX (1,210G), DIX (880G)</td>
</tr>
<tr>
<td>ISP linkage</td>
<td>2,566G linkage of 24 providers including: Dreamline (20G), Sejong Telecom (50G), SK Telecom (920G), CJ (160G), Hyundai HCN (60G), CMB (90G)</td>
</tr>
</tbody>
</table>


KINX provides bilateral and multilateral peering services using an L2 switch and route server. Peering policy is determined by voluntary agreement between members.

Currently, it provides IP version 6 L2 peering service in a dual-stack environment. The total linkage bandwidth is 2,823Gbps and is connected through 100GE, 10GE, GE and FE interfaces.

KINX interconnects 70 ISPs and content providers, including global content providers such as Amazon Web Services, Apple and Microsoft, giving them space and network connectivity to set up local content servers (Table 21).

Table 21: KINX linkage status in the Republic of Korea (as of July 2020)

<table>
<thead>
<tr>
<th>Linkage method</th>
<th>Linkage status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linkage method</td>
<td>Ethernet</td>
</tr>
<tr>
<td>ISP linkage</td>
<td>2,823G linkage of 70 providers including: Samsung SDS (20G), NexG (1G), LG CNS (20G), Dreamline (10G), Centurylink (10G), Delive (170G), LGHV (100G), Beautiful Broadcast (20G), Hyundai HCN (70G), Kakao (40G), Akamai (10G), CD Networks (40G), Naver (40G), Samsung Electronics (1G), Government Integrated Computer Center (20G), Elimnet (10G), Microsoft (60G), Amazon (200G), Limelight (20G), SoftLayer (80G), Apple (200G), Twitch (100G), Tencent (200G), Facebook (20G), Netflix (20G), KDDI Korea (1G), Hurricane Electric (10G)</td>
</tr>
</tbody>
</table>

KINX is the only neutral IXP in the Republic of Korea. It has the same network structure as other countries’ IXPs like HKIX of Hong Kong, AMS-IX of the Netherlands and JPIX of Japan.

Figure 18 shows the KINX network diagram. The overseas points of presence in Hong Kong and Japan enhance global connectivity for IXP members and customers.

In addition to providing a dedicated line between the Republic of Korea and Hong Kong and/or the Republic of Korea and Japan at a reasonable price, users can peer with IXPs, ISPs and content service providers from various countries.

Figure 18: KINX network diagram

Box 1: 5G and Addressing the Regional Divide in the Republic of Korea

In April 2019, the Republic of Korea launched the world’s first smartphone-based, business-to-consumer 5G commercial services. As of the end of September 2021, the country’s 5G subscribers surpassed 18 million, accounting for 25.6 per cent of total mobile subscriptions.

Nevertheless, there were many complaints from users due to the sluggish spread of 5G coverage in the Republic of Korea and the lack of investment in 5G in rural areas such as farming and fishing villages.

Figure 19: Status of 5G coverage of three mobile carriers in the Republic of Korea (2021)

![Figure 19: Status of 5G coverage of three mobile carriers in the Republic of Korea (2021)](image)


On 15 July 2020, the Ministry of Science and ICT and three mobile carriers – SK Telecom, KT Corporation and LG U+ – agreed to share networks so that 5G services can be accessed in rural areas.

Subsequently, on 1 September 2020, the Ministry of Science and ICT launched the Rural 5G Roaming Task Force to review ways to share networks among the three mobile carriers in rural areas.

In April 2021, the Ministry of Science and ICT announced that the carriers signed an agreement that enables 5G users access to the high-speed network regardless of the carrier they are subscribed to in 131 rural and remote locations across the country. Under the agreement, 5G users will be able to use the networks of other carriers in regions that are not serviced by their carrier.

Figure 20: Illustration of subscribers’ access to 5G networks in the Republic of Korea

![Figure 20: Illustration of subscribers’ access to 5G networks in the Republic of Korea](image)

Roaming in outskirt areas such as farming and fishing villages is based on the Telecommunications Business Act. According to Article 37, the common carriers can allow other common carriers to share wireless telecommunications facilities when they make a request by signing an agreement. The expense of use is determined by the Minister of Science and ICT.

4. An Analytics Tool for IXPs and Access Networks

4.1 Conceptual Framework for the IXP Model for Cross-border Connectivity

The conceptual framework focuses on both the IXP backbone and the access networks in CLVT to calculate the network infrastructure investment cost required for the transition to the digital economy. The framework is divided into four parts (Table 22). In Table 22, the horizontal plane is divided into equipment and optical line cable, and the vertical plane is divided into IXP backbone network and access network. With this approach, it is possible to explain the infrastructure factors that are needed to provide domestic and global communications services.

Table 22. I is calculated based on the necessary upper surface and the device investment cost from the viewpoint of building the IXP backbone network device. If there is no space for installing equipment, the investment cost for securing space can be included.

Table 22. II is calculated based on the investment cost for the upper surface and the line construction required from the viewpoint of the IXP backbone network line.

Table 22. III is calculated based on the necessary top surface and capital investment cost from the viewpoint of equipment construction of the subscriber network.

Table 22. IV is calculated based on the required top surface and the line construction investment cost from the viewpoint of subscriber network line construction.

Table 22: The conceptual framework for the proposed IXP model

<table>
<thead>
<tr>
<th>Division</th>
<th>Equipment</th>
<th>Optical line cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backbone (IXP)</td>
<td>Area Space</td>
<td>Area Space</td>
</tr>
<tr>
<td></td>
<td>Equipment Cost</td>
<td>Optical Cable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Construction Cost</td>
</tr>
<tr>
<td>Access Network</td>
<td>Area Space</td>
<td>Area Space</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>IV</td>
</tr>
</tbody>
</table>

Source: Created by the authors.

4.2 IXP Model for CLVT

This subsection proposes an IXP model for CLVT based on the findings of previous studies. The proposed IXP model aims to enhance connectivity in CLVT and contribute towards the goals of the Asia-Pacific Information Superhighway (AP-IS) initiative.

Cooperation between CLVT is important in developing and harmonizing Internet traffic management policies and practices, including technology network configuration and routing standards in an open, neutral and non-discriminatory manner. As part of CLVT cooperation to build the IXP, building technology capabilities and sharing knowledge for efficient management of Internet traffic are also important.

The Internet, which is comprised of countless networks and hubs, looks like a huge intricate web but has a hierarchy with its own rules. In terms of physical hierarchy, an example is shown in Figure 22 for ISPs and IXPs connectivity in which Tier 2/3 providers are linked to both IXPs and Tier1 providers.
The Border Gateway Protocol (BGP) determines the optimal path based on current reachability, number of hops and other path characteristics.

By using BGP between two autonomous systems, network information such as IP address can be exchanged and communicated.

When multiple paths are available within a major hosting facility, the BGP policy conveys the organization’s preferences for which path traffic should enter and exit. The BGP community tag can control route notification behaviour between peers.

BGP is the most used protocol between providers, IXPs and enterprises with the following advantages:

- The standard operation of the BGP optimal path selection algorithm selects a path for each destination with AS_PATH length. This is the same as the lowest number of hops when each device adds one autonomous system number to AS_PATH.

- The standard operation of the BGP multipath algorithm dispenses traffic to all paths with the same AS_PATH length.

- When a link goes down in the topology, the BGP session immediately breaks down if fast failover is enabled. This can lead to the dissemination of new BGP optimal routes by routers at each end of the failed session. Other routers can also inform others of their own new best path, but typically failure does not propagate beyond routers that do not change their best path.

- Additional autonomous system numbers can be added to AS_PATH to reroute traffic to all nodes in the topology.
In order to access all online content or connect with other users, providers must connect directly or indirectly to all ISPs or IXPs, both domestically and internationally.

Figure 23 shows the diagram of a mesh with ISPs and a mesh with IXPs. Typical peering in a full-mesh eBGP with ISPs may look similar to the diagram on the left-hand side.

If the number of ISPs is small, direct interconnection between all ISPs is efficient, but direct interconnection inevitably increases the cost of leased line circuits and port investment of router or switch equipment due to an increase in the number of circuits.

Moreover, traffic has increased with the advent of 5G and 10G services, and new types of traffic have emerged because of rapid changes in the Internet environment since COVID-19. The growth in traffic and the emergence of content providers are increasing the number of cases of large traffic.

Compared to the past, it is becoming considerably difficult and complex for ISPs to respond to flexible traffic due to the rapid increase in Internet traffic and large-capacity traffic. Therefore, IXPs are needed to prepare for changes in the Internet environment and to resolve the lack of connectivity in CLVT.

The diagram on the right in Figure 23 shows the efficiency of line and traffic management when a line is connected through an IXP with a route server rather than a direct connection for each ISP.

Figure 24 shows the diagram of a route server, which is installed in IXPs where ISPs and enterprises interconnect with each other to streamline path exchange processing between members. The purpose of interconnection of members is to inform and establish each member’s (ISPs, enterprise, etc.) path information. The provider’s path uses BGP-4 to provide its subscriber path information to another provider’s path.

Bilateral peering means there is one session between members, and only you and the specific peer exchange route advertisements. Imagine a large IXP with many (500+) members. This can very quickly become cumbersome, especially when filtering per-peer on correct route advertisements is based on an Internet Routing Registry containing prefixes, AS-path, etc. It is always advisable to use an easier solution when one is available.
Route servers provide multilateral peering between member IXP environments. Unlike standard BGP peering, where everyone must establish a BGP connection, setting up a route server allows IXP members to search all IXP networks with only one connection.

Internet exchange is typically based on the Layer 2 or Layer 3 method:

1. **Layer 2 IXP**
   - Each ISP brings a router and connects to the IXP switch at the same building.
   - Alternatively, the ISP uses the fibre from their point of presence to the IXP location and connects to the IXP switch.

2. **Layer 3 IXP**
   - Typically, Layer 3 IXP is an ISP concept used by transit ISPs.

The Layer 2 IXP model is recommended, which needs a single physical or remote (backhaul) port connected to the IXP peering local area network (LAN) and an assigned IP address from the LAN subnet.

The Layer 2 IXP is a neutral IXP where members are linked through the IXP switch for public or direct peering between members. The Layer 2 IXP facilitates interconnection between ISPs using BGP to exchange routing information. Typically, the network is referred to as the IXP LAN or peering LAN. Currently, fibre used for 10Gbps and 100Gbps connects to IXP switches, but it depends on the requirement or usage.

Figure 25 shows two types of IXP models that can be divided into a space-providing model and a non-space-providing model. When space is provided, several things must be considered in terms of operations and facilities. For the stable operation of network equipment installed in the IXP, continuous power supply facilities, power generation facilities, constant temperature port facilities and remote support services must be supplied. Switch equipment is located inside the IXP centre.
If the IXP is set up without considering individual internetworking between ISPs, only a small space will be needed in consideration of the remote connection to the IXP model. On the contrary, extensive space is needed for colocation.

The benefits of IXPs in CLVT can be summarized as follows:

- **Reduction of a network’s operational costs** – Using bilateral peering for traffic exchange between members in IXP reduces network operating costs. IXP reduces transit costs by reducing the portion of traffic through the Tier 1 ISP and it becomes cheaper to provide services to its customers.

- **Keeping local traffic local and reducing latency** – Direct interconnection of members in an IXP allows networks to exchange local traffic and forward traffic destined via the IXP switch to keep the lowest latency.

- **Enhancing control efficiency and autonomy of the network** – IXPs give networks more autonomy and control over the network’s own resources, including routing and traffic management, because it decreases a network’s dependency on third-party networks.

- **Improving the stability and resilience of local networks** – Increasing the number of direct linkages between members increases the stability and resilience against network outages.

The recommended IXP model for CLVT is presented in Figure 26.
Key Highlights and Recommendations

- Deploy a hybrid (ring+direct) type IXP model for CLVT rather than a full-mesh type IXP model to reduce latency and network costs for neighbouring countries’ traffic. However, there is a need to check the cable conduits between neighbouring countries. The most important features are dark fibre and easy access both inside and outside the country.

- Connect IXPs to primary and redundant trunk lines in 10G increments. Fibre-optic networks of telecommunications providers in four countries are connected bilaterally at the border junction.

- The following links are proposed:
  - Lao PDR–Viet Nam/Thailand link can be made with terrestrial and submarine cables (AAE-1).
  - Viet Nam–Thailand link can be made with terrestrial and submarine cables (SMW3, AAG, AAE-1, APG, ADC, SJC2).

- Establish an IXP hub for CLVT. Cambodia, Viet Nam and Thailand have submarine cable landing stations that are sufficient for IXP hubs. As shown in Figure 26, Cambodia can serve as a gateway to Malaysia and Thailand through the submarine cable landing station. Viet Nam, with three submarine cable landing stations can serve as a gateway to Hong Kong and North Asia. Thailand, with four submarine cable landing
stations, can serve as a gateway to Singapore, Malaysia and Europe.

- Deploy an interconnected IXP system for CLVT that is connected by land, has good accessibility and is geographically centrally located. This will enhance resilience by diversifying traffic routes and strengthening cooperation.

- Finally, the location of the IXP requires easy installation of terrestrial cables and IXP neutrality and scalability.
  - Terrestrial cables – Each terrestrial cable connection between adjacent IXP, and primary and redundant cables must avoid the same route for reliable operation.
  - Neutrality – Any ISP can install fibre optics or use other circuitry for the connection to access the IXP.
  - Scalability – Consider the scalability of IXPs in the design.
5. Conclusion

5.1 Summary and Implications

The world is striving to deal with two tasks – overcoming COVID-19 and responding to the challenges of digital transformation. Enhanced Internet infrastructure can support the development of solutions for the two tasks. In fact, governments of CLVT have been eager to improve their Internet infrastructure and access network. Thanks to such efforts, the utilization rate of fixed and mobile broadband of CLVT is increasing and the quality of service is also gradually improving. However, there is much room for improvement when compared with other countries.

In this context, the objective of this study is to improve cross-border connectivity through enhanced ICT infrastructure in the region, with a focus on IXPs in CLVT. This working paper provides an update on recent IXP trends in CLVT, focusing on challenges and opportunities for enhanced broadband connectivity among countries. In addition, the case studies from Thailand and the Republic of Korea recognize the significance of partnership and cooperation in building cross-border networks in South-East Asian countries. Building on previous studies, and based on the recent trends and case studies, an IXP model for cross-border connectivity between CLVT is proposed.

In terms of the Internet backbone, including submarine and terrestrial cables, there does not appear to be any significant developments in CLVT in recent years. Related to IXPs, CLVT show some degree of infrastructure expansion through IXP construction and equipment installation. However, there remain differences in the level of performance between countries. Generally, securing connectivity between IXPs of CLVT is still needed, and it is insightful to learn from the Thailand and Republic of Korea case studies. CLVT may reference these case studies to expand their Internet use and reduce construction costs with similar policies, especially when installing cross-border connectivity.

5.2 Recommendations

In conclusion, the study provides the following solution-oriented recommendations to improve transborder connection and inclusive ICT development in the region:

- Recommendation 1: Suggest an agreement for implementing a cross-border connectivity project in CLVT. This working paper provides a standard MOU in Appendix 2.
  - In order to promote cross-border connectivity between CLVT, it is necessary to harmonize each country’s policies and regulations. In other words, they need to implement policies to eliminate network investment obstacles such as infrastructure sharing and national roaming among countries through a working group based on an MOU.
  - The working group can function as a secretariat to make important decisions for project implementation as representatives of ESCAP and CLVT participate.

- Recommendation 2: Secure sufficient financial resources to promote the cross-border connectivity project. Due to COVID-19 and the economic crisis, it is a challenge to secure financial resources for building the digital infrastructure. CLVT will need to reach consensus on the way forward, including modalities to secure investment.
  - According to previous research carried out by ESCAP (2021), the authors recommended the donor financing model for establishing the Internet Data Centre with IXP in Cambodia, Lao PDR, Myanmar and Viet Nam because it requires a relatively large amount of investment, as well as multinational collaboration with telecommunications
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Providers.

- The previous research proposed that international development banks are suited to handle multilateral issues and raise funds for the project.
- This recommendation is still valid. It is desirable to seek support from international development organizations for improving the connectivity of countries that are having difficulties in securing financial resources.

**Recommendation 3: Promote cross-border connectivity as a national digital agenda.** The cross-border connectivity project goes beyond simply building the digital infrastructure, it is fundamental for digital transformation and building a digital economy. As such, target countries should treat the research and recommendations for cross-border connectivity as a national policy and regional cooperation agenda.

- The governments of CLVT should establish the cross-border connectivity project as a part of their digital policy and strategy, and make a legal reference for the relevant authorities to carry out obligatory implementation.
- A joint project using cross-border Internet networks should be developed to promote policies such as economic cooperation, e-commerce and logistics to expand exchanges between neighbouring countries.

**Recommendation 4: Share information on infrastructure among countries.** It is necessary to share relevant information such as telecommunications equipment, utility facilities and IXP buildings in each country. Each authority or regulator in CLVT and neighbouring countries needs to cooperate to achieve the agenda.

- In order to design an efficient cross-border Internet network, it is necessary to share information on network resources such as conduit, roads, railways and bridges to identify potential co-deployment opportunities.
- Specifically, it is recommended to create a map for cross-border connectivity between countries. The map can include information related to the topography and geographical characteristics, the current status of telecommunications facilities to be used for Internet network construction, and information related to the utility status. Each national government should update this information on a regular basis. This information can be used to continuously expand the cross-border Internet network.

Finally, the challenges and limitations of this study should be noted. Due to COVID-19, data collection was limited to desk research as in-person interviews to gather evidence were not possible. However, efforts have been made to obtain information through virtual meetings with CLVT officials. Moreover, when designing the IXP model, different national situations and environments for each country should be reflected, but such points could not be fully verified.

Despite such limitations, the authors expect the solution-oriented and forward-looking recommendations highlighting enhanced ICT infrastructure in the region would contribute to affordable and meaningful access to the Internet in South-East Asia and the Asia-Pacific region.
Appendix 1. Submarine Cables

A.1 Overview

The appendix summarizes the recent status of submarine cables in CLVT. Figure A.1 is a schematic diagram of the overall submarine cable status in CLVT. In the subsections below, each submarine cable is described.

Figure A.1: Submarine cable system in South-East Asia

Source: Created by the authors based on TeleGeography, “Submarine Cable Map”. Available at https://www.submarinecablemap.com/.

A.2 MCT Cable

The Malaysia–Cambodia–Thailand (MCT) cable system connects Malaysia, Cambodia and Thailand, spans approximately 1,300km, adopts 100Gbps technology with a system capacity of 30Tbps.

The MCT cable system lands at Sihanoukville in Cambodia, Rayong in Thailand and Cherating in Malaysia.

The MCT cable system is jointly built by Telcotech, a subsidiary of EZECOM in Cambodia, Symphony Communication of Thailand and Telekom Malaysia.

A.3 AAE-1 Cable

The Asia–Africa–Europe 1 (AAE-1) is a 25,000km consortium cable system connecting South-East Asia to Europe via Egypt, the largest submarine cable to be constructed in almost 15 years.

The cable system connects Hong Kong, Viet Nam, Cambodia and Thailand with Malaysia and Singapore, then onwards to Myanmar, India, Pakistan, Oman, United Arab Emirates, Qatar, Yemen, Djibouti, Saudi Arabia, Egypt, Greece, Italy and France.

AAE-1 cable system deploys state-of-the-art 100Gbps transmission technology, with a minimum design capacity of 40Tbps.

A.4 SMW3 Cable

The South-East Asia–Middle East–Western Europe–3 (SMW3) is a submarine cable linking 39 cable landing stations in 33 countries and 4 continents, including Asia, Australia, Africa and Europe. SMW3 is the longest submarine cable system in the world with a total length of 39,000km.

The SMW3 cable system was supplied by ASN and Fujitsu, and officially put into service on 30 September 1999.

The SMW3 consortium comprises 92 telecom operators.
A.5 APG Cable
The Asia-Pacific Gateway (APG) is a 10,400km submarine cable system linking eight countries and regions in Asia, i.e., Malaysia, Singapore, Viet Nam, Hong Kong, Taiwan, China, Japan and the Republic of Korea.
The APG cable system consists of six fibre pairs in the trunk, initially designed with 128*40Gbps dense wavelength division multiplexing technology and system capacity of 30.72Tbps, upgradable to 100Gbps wavelength. The APG consortium announced the system capacity as 54.8Tbps based on a different calculation.

A.6 AAG Cable
The Asia–America Gateway (AAG) is 20,000km and the first submarine cable system linking South-East Asia directly with the USA, provides connectivity between Malaysia, Singapore, Thailand, Brunei Darussalam, Viet Nam, Hong Kong, Philippines, Guam, Hawaii and the US West Coast.
The AAG consists of two fibre pairs from Hong Kong to Hawaii via the Philippines and Guam, three fibre pairs from Hong Kong to Singapore with branching units to Viet Nam, Brunei, Malaysia and Thailand, and three fibre pairs from Hawaii to the US West Coast.

A.7 TGN-IA Cable
The TGN-Intra Asia Cable System (TGN-IA) is a private intra-Asia submarine cable system constructed, owned and operated by Tata Communications. The TGN-IA cable spans 6,800km, consists of four fibre pairs linking Singapore, Hong Kong and Japan with an additional connection to the Philippines, Viet Nam and Guam, and a design capacity of 3.84Tbps. The TGN-IA cable route was deliberately designed to avoid areas prone to earthquakes and other hazardous areas, such as the south and east coast of Taiwan. The TGN-IA cable system was put into service on 18 August 2009, immediately after its commission test to facilitate capacity for traffic restoration caused by Typhoon Morakot.

A.8 ADC Cable
The Asia Direct Cable (ADC) is a 9,400km submarine cable connecting China (Hong Kong and Guangdong Province), Japan, the Philippines, Singapore, Thailand and Viet Nam.
The ADC cable system will feature eight fibre pairs and is designed to carry more than 140Tbps of traffic, enabling high-capacity transmission of data across the East and South-East Asian subregions.
The ADC consortium comprises CAT, China Telecom, China Unicom, PLDT Inc., Singtel, SoftBank Corp., Tata Communications and Viettel. The ADC consortium has awarded the supply contract to NEC. ADC is expected to be completed by the fourth quarter of 2022.

A.9 SJC2 Cable
The South-East Asia–Japan–2 (SJC2) submarine cable system spans 10,500km, connecting 11 cable landing stations in Singapore, Thailand, Viet Nam, Hong Kong, Taiwan, China, the Republic of Korea and Japan.
The SJC2 cable features eight fibre pairs, at least 18Tbps of capacity per fibre pair, with initial design capacity of 144Tbps. SJC2 consortium comprises of China Mobile International, SingTel, Chunghwa Telecom, Donghwa Telecom, Facebook, KDDI, Singtel, SK Broadband, Telin, TICC (True) and VNPT.
A.10 FEA Cable

The FLAG Europe Asia (now FEA), originally called Fibre-optic Link Around the Globe (FLAG), is a 28,000km submarine cable connecting 18 countries and regions in Asia, Africa and Europe. FEA was opened for commercial service on 22 November 1997.

The FEA was originally a private cable owned by FLAG Telecom. FEA, FLAG North Asia Loop/REACH North Asia Loop, FALCON and FLAG Atlantic 1 formed FLAG Global Network.

In 2003, Reliance Communications, now branded as Global Cloud Xchange, acquired FLAG Telecom for USD207 million.

A.11 TIS Cable

The Thailand–Indonesia–Singapore (TIS) is a 1,100km regional submarine network linking Songkhla (Thailand), Batam (Indonesia) and Changi (Singapore).

The TIS consortium includes CAT Telecom Public Company Ltd. of Thailand, PT Telekomunikasi Indonesia (Telin) and Singapore Telecommunications Limited (SingTel), which jointly invested USD36 million to build the TIS cable network.

The TIS was ready for service on 2 December 2003, with a lit capacity of 30Gbps and upgradeable up to 320Gbps.

A.12 SMW4 Cable

The South-East Asia–Middle East–West Europe–4 (SMW4) is an approximately 18,800km submarine cable connecting Singapore, Malaysia, Thailand, Bangladesh, India, Sri Lanka, Pakistan, United Arab Emirates, Saudi Arabia, Egypt, Italy, Tunisia, Algeria and France.

The SMW4 cable system consists of two fibre pairs, with initial design capacity of 1.28Tbps, upgraded to 4.6Tbps in 2015. The SMW4 cable system was ready for service on 13 December 2005. The SMW4 consortium comprises 16 telecom operators and lands at 17 cable landing stations.

A.13 IAX Cable

The India–Asia–Xpress (IAX) is a submarine cable connecting Mumbai and Chennai to Singapore, and interconnects with other Far East countries towards the west coast of the United States.

The IAX is built by Reliance Jio Infocomm and is expected to be operational in early 2023.
Appendix 2. MOU

Memorandum of Understanding

between

Cambodia, Lao PDR, Viet Nam and Thailand

concerning

Cross-border Connectivity between CLVT

Whereas the representatives of the Ministry of Telecommunications and ICT and delegated authorities of the United Nations Economic and Social Commission for Asia and the Pacific (hereinafter referred to as “ESCAP”) member States (hereinafter referred to as “Parties”), are domestic competent authorities for coordinating the project of cross-border connectivity between member States, and Cambodia, Lao PDR, Viet Nam and Thailand (CLVT) are referred to as “Initial Parties”;

Reconfirming the importance of strengthening the information and communications technology (ICT) infrastructure between Initial Parties in South-East Asia towards inclusive sustainable development;

Highlighting the urgent need to increase the connectivity between Initial Parties in a cost-effective way to improve cross-border connectivity, strengthen the competitiveness of the region, respond to the digital transformation and digital economy, and address the digital divide;

Noting that the promotion of cross-border connectivity between Initial Parties can improve Internet quality and affordability in each country through many benefits, including but not limited to:

a. Reduce the use of submarine cables and third-party Internet backbone for local traffic and increase the traffic flow between neighbouring countries,

b. Lower costs for providers and retail price of fixed and mobile broadband,

c. Strengthen local Internet connectivity,

d. Reduce the digital divide,

e. Increase the development of local Internet and broader ICT industry and skills, and

f. Improve the competitiveness of industry and society,

Recognizing ESCAP resolution 75/7 from 20 December 2019 regarding the secretariat support to ESCAP members and associate members in the subregional implementation of the Asia-Pacific Information Superhighway (AP-IS) platform;

Whereas the Initial Parties and ESCAP have conducted in-depth research for cross-border connectivity promotion. Various efforts have been made to meet the increasing demand for broadband, to provide low-cost usage to its citizens, and to improve Internet quality between neighbouring countries.

Now, therefore, on the basis of mutual trust and in a spirit of cooperation, the Parties have entered into the present Memorandum of Understanding (hereinafter referred to as the “MOU”),

And hereby agree as follows:
Objective

1. The objective of the present MOU is to support the construction of a cross-border Internet backbone network between the Initial Parties through connecting each country’s Internet Exchange Points (IXPs) in order to reduce the use of submarine cables and third-party Internet backbone for local traffic and increasing the traffic flow between Initial Parties.

Scope

2. The present MOU applies to the construction of a cross-border Internet backbone network between the Initial Parties.

3. Each Initial Party is committed to support the Working group for cross-border connectivity (hereinafter referred to as “Working group”) based on this MOU. The Working group is composed of government representatives of the Initial Parties, network and IXP experts of each country, and ESCAP representatives.

4. Each Initial Party is further committed to a principle of “open access” connection, to permitting, enabling and facilitating Internet providers from other States and locations to establish international facilities and connections to infrastructure located within their borders such as the Internet backbone and IXP, subject to all local applicable laws, such that providers from other States may also connect to each country’s IXP for the mutual benefit of all participants connecting to infrastructure located within their borders such as the Internet backbone and IXP regardless of location.

5. For efficient network design, each Initial Party is further committed to provide their country’s infrastructure and IXP information mutually.

Definitions

6. For the purpose of the present MOU:

(a) “Cross-border connectivity” refers to the construction and operation of an Internet backbone for the purpose of interconnecting IXPs (both state-owned and private) between neighbouring countries such as Cambodia, Lao PDR, Viet Nam and Thailand.

(b) “Internet Exchange Point” (hereinafter referred to as “IXP”) means switching equipment or the physical building in which such equipment is located (depending on context), where different networks connect to exchange Internet traffic.

(c) “Internet Service Provider (hereinafter referred to as “ISP”)” is an organization that operates a network that connects or wishes to connect to an IXP.

Institutional arrangements

7. ESCAP and Partners shall, for the purposes of the present MOU, support the Parties on the establishment of the Working group comprising one (1) high-level nominee from each Party. The Working group shall meet upon request but at least once per quarter each year.

8. The Working group shall elect a Chair and a Vice Chair from members of the Working group. The Chair shall lead the work of the Working group for a duration of not more than two (2) years.

9. In the performance of its functions, the Working group shall be supported by regulators and competent authorities in each Initial Party, which shall supervise and coordinate the implementation of the present MOU.

10. The Working group shall be designated the secretariat of the present MOU. It shall provide support in coordinating, reviewing and supervising the implementation of the present MOU and in all related matters.
11. The Working group shall, by a two-thirds majority vote, adopt such rules of procedure as may be required for the performance of its functions. Except as otherwise provided for in the present MOU, decisions by the Working group shall be taken by a majority of votes cast by members present and voting, provided that at least two thirds of the participating States are present.

Reporting

12. The Initial Parties shall report to the Working group on the progress of the construction of the Internet backbone and IXP to facilitate the sharing of experience and lessons learned and to establish a collection of best practices for interoperability of the cross-border Internet backbone and IXPs. The exchange of experience and lessons learned shall extend beyond the Initial Parties to the present MOU, to the extent possible and as appropriate, in an effort to promote faster broadband connectivity and affordability through the establishment of cross-border IXPs throughout the region and beyond.

Capacity building

13. The Initial Parties may cooperate to provide technical support and assistance to each other in order to facilitate the implementation of the present MOU.

14. The Initial Parties may invite development partners and other national/regional stakeholders for more effective technical and financial assistance in the implementation of the present MOU.

Dispute resolution

15. Any disputes that may arise among the Initial Parties regarding the interpretation and application of the present MOU shall be settled by means of negotiation or consultation among the Initial Parties concerned.

16. In the event that the Initial Parties involved in a dispute relating to the present MOU are unable to settle it by negotiation or consultation, they shall be referred for conciliation if requested by the Initial Parties involved.

17. The dispute shall be submitted to one or more conciliators selected by the Initial Parties involved in the dispute. If the Initial Parties involved in the dispute fail to agree on the choice of a conciliator or conciliators within three (3) months of the request for conciliation, any of those Initial Parties may request the Working group to appoint a single conciliator to whom the dispute shall be submitted.

18. The recommendation of the conciliator or conciliators appointed, while not binding in character, shall become the basis of renewed consideration by the Initial Parties involved in the dispute.

19. By mutual consent, the Initial Parties involved in the dispute may decide in advance to accept the recommendation of the conciliator or conciliators as binding.

20. The provisions of the present article shall not be construed as excluding other measures for the settlement of disputes mutually agreed upon between the Initial Parties involved in the dispute.
Procedure for signing and becoming a Party

21. The present MOU shall be open for signature to the ESCAP member States from 1 May 2022 to 30 November 2022.

22. The ESCAP members and associate members may become Parties to the present MOU by adding their signature to the present MOU.

Final agreement

23. By signing the MOU, the Initial Parties agree to work in good faith to consummate applicable final agreements embodying the necessary obligations to initiate and complete the project.

Procedures for amending the MOU

24. Amendments to the present MOU may be proposed by any Initial Party.

25. The text of any proposed amendment shall be circulated to all members of the Working group by the secretariat at least sixty (60) days before the Working group meeting at which it is proposed for adoption.

26. An amendment shall be adopted by a two-thirds majority of the Initial Parties present and voting at the meeting of the Working group. The amendment as adopted shall be communicated by the secretariat to all Party members.

Withdrawal

27. Any Party may withdraw from the present MOU by written notification addressed to the Working group. The withdrawal shall take effect three (3) months after the date of receipt by the Working group of such written notification.

Depositary

28. The Chair of the Working group shall be designated the depositary of the present MOU.

29. In witness hereof, the undersigned, being duly authorized thereto, have signed the present MOU, in a single copy in the English language.

Governing Law and Venue of Suit

30. This MOU shall be governed by and construed in accordance with the laws of ______________. Any action that may be brought in relation to, arising from, or in connection with this MOU shall be subject to the exclusive jurisdiction of ______________ and brought in a proper court in ____________

31. For the Initial Parties on inception of this MOU:
For and on behalf of
Cambodia

By: ________________________________
Date: ___________________
Name:
Title:
For and on behalf of
Lao PDR

By: __________________________ Date: __________________
Name: _______________________
Title: ________________________
For and on behalf of
Viet Nam

By: _______________________________ Date: ____________________
Name: 
Title: 
For and on behalf of
Thailand

By: ___________________________ Date: ___________________
Name: 
Title: 
For and on behalf of
ESCAP

By: __________________________ Date: ____________________
Name:
Title:
References


