Research Report on the Network Planning for the Greater Mekong Subregion

Asia-Pacific Information Superhighway (AP-IS) Working Paper Series

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Abbreviation

Abbreviations used in this report are as follows:

AP-IS:	Asia-Pacific Information Superhighway
ESCAP:	Economic and Social Commission for Asia and the Pacific
Lao PDR:	Lao People's Democratic Republic
XUPT:	Xi'an University of Posts &Telecommunications
MIIT of China:	Ministry of Industry and Information Technology of China
NBS of China:	The National Bureau of Statistics of China
ICT:	Information and Communication Technology
FBB:	Fixed Broadband
GMS:	Greater Mekong Subregion
GMS-IS[1]:	Greater Mekong Subregion Information Superhighway
B2B:	Business-to-Business
B2C:	Business-to-Customer
MOU:	Memorandum of Understanding
C&MA:	Construction and Maintenance
IMC:	Interim Management Committee
IPG:	Initial Procurement Group
II&ASC:	Initial Investment and Agreement Sub-Committee
MC:	Management Committee
PG:	Procurement Group
O&MSC:	Operations and Maintenance Sub-Committee
NA/NOC:	Network Administrator/ Network Operation Center

[1] GMS-IS is a cross-border fibre-optic cable connectivity project jointly implemented by China, Viet Nam, Lao PDR, Myanmar, Thailand and Cambodia. The international connection of GMS-IS and the optical cable laying between Thailand, Cambodia and Viet Nam are operated by Telecom Cambodia. Details please refer to the report "Research on the Transnational Land Optical Cable Operation Mode - Implementation of Asia-Pacific Information Superhighway", September 2019. Available at https://www.unescap.org/resources/operation-cross -border-terrestrial-fibre-optic-networks-asia-and-pacific

1. Introduction

1.1 Background

The Asia-Pacific region has witnessed a remarkable growth in ICT interconnection in recent years. According to ESCAP[2] 55.6 per cent of the world`s fixed-broadband subscriptions are concentrated in Asia and the Pacific, while the fixed-broadband subscription rates of Europe and North America lie at 20.3 per cent and 13.1 per cent respectively. However, the broadband development among ESCAP subregions and member countries is uneven. ESCAP analysis shows that 75 per cent of fixed-broadband subscribers in the Asia-Pacific region comes from East and North-East Asia, and the China alone accounts for 50 per cent of fixed-broadband subscribers in the whole region. In the Republic of Korea, there are over 40 fixed-broadband subscribers per 100 inhabitants. At the other end of the spectrum, there are 18 ESCAP member States with less than 2 fixed-broadband subscribers per 100 inhabitants. Southeast Asia is no exception. For example, in terms of the 2017 ICT Development Index, Singapore, Brunei Darussalam and Malaysia ranked 18th, 53rd and 63rd respectively, while Cambodia, Myanmar and Lao PDR ranked 128th, 135th and 139th respectively.

ESCAP member States, aware of the persistent imbalance in interconnection, endorsed the Asia-Pacific Information Superhighway (AP-IS) as a regional cooperation initiative to promote broadband connectivity between countries. The AP-IS initiative focuses on four pillars, namely: infrastructure connectivity (promoting investment in infrastructure connectivity); efficient Internet traffic and network management (including the establishment of Internet exchange points among others); e-resilience (resilient ICT infrastructure from natural disasters); and broadband for all. The AP-IS initiative implementation is guided by a Master Plan 2019-2022[3] and Regional Cooperation Framework Document 2019-2022.[4] These documents articulate activities, outputs, schedules and financial mechanisms, in an effort to bridge the digital divide and accelerate the achievement of the SDGs. ESCAP cooperates with academia partners to carry out research on broadband infrastructure and policy, which intend to guide the overall ICT infrastructure development in all subregions.

According to a report by ESCAP,[5] while the ASEAN countries have made significant efforts

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[2] ESCAP “Artificial Intelligence and Broadband Divide: State of ICT connectivity in Asia and the Pacific 2017”, (Bangkok, 2017). Available at: https://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017

[3] ESCAP/75/INF/5

[4] ESCAP/75/INF/6

[5] ESCAP “A Pre-Feasibility Study on the Asia-Pacific Information Superhighway in the ASEAN Sub-region:

to enhance their respective ICT infrastructure, challenges remain in the below areas:

a) relatively weak interconnection level;
b) insufficient terrestrial optical-fibre cable development;
c) excessive dependence on submarine cables; and
d) high transport and IP transit costs.

The afore-mentioned report also pointed out that Cambodia, Myanmar, Lao PDR and Viet Nam, compared with other ASEAN countries, are lagging behind in their infrastructure development and connectivity, leading to high transport and transit costs. Therefore, improving the ICT infrastructure of these four countries could contribute to the overall ICT connectivity in the ASEAN subregion.

1.2 Objective

This report aims to develop recommendations and a planning scheme for the development of ICT infrastructure in the Greater Mekong Subregion (GMS) as a reference in this field. Based on the current status of the ICT infrastructure development, the analysis of this report aims to support an integrated and balanced development of the ICT infrastructure, which would further contribute to the development of the ICT business in the region.

Section 2 of this report introduces the current status of ICT development among the GMS countries. Section 3 then evaluates the status of ICT infrastructure and business in the GMS. Section 4 discusses the development of a planning scheme for the development of ICT infrastructure with the main aim of assisting the GMS based on the analysis done in the earlier chapters. Section 5 gives an indication on how to organize and implement the planning scheme of infrastructure development in the GMS based on the regional cooperation mechanism of the AP-IS initiative which is supported by ESCAP. In addition, this section refers to relevant research conducted by ESCAP, the AP-IS Master Plan, and the Regional Cooperation Framework Documents. Section 6 concludes by discussing the way forward and recommendations.

Conceptualization, International Traffic & Quality Analysis, Network Topology Design and Implementation Model", March 2016. Avilable at https://www.unescap.org/resources/pre-feasibility-study-asia-pacific-information-superhighway-asean-sub-region

2. Status of ICT infrastructure development in the Greater Mekong Subregion

2.1 The ICT infrastructure development in the GMS

According to an ESCAP report[6], while most countries in the GMS are connected with their neighboring countries via fiber optic cables, some still lack direct fiber cable connections in the subregion (see figure 1). It leads to gaps and inefficiency in connectivity and a weak level of overall connectivity in the subregion. As a result, a series of problems, such as insufficient network transfer point, excessively long network connection route, high transit price, and high network service price, occur. Therefore, improving the level of ICT infrastructure is crucial to the improvement of connectivity between different countries in the subregion.

Figure 1: The status of fiber cable connectivity in GMS

	Cambodia	Lao PDR	Myanmar	Vietnam
Cambodia				
Lao PDR	O (2)			
Myanmar	X	O (3)		
Vietnam	O (1)	O (9)	X	
Thailand	O(1)	O (5)	O (1)	X

Source: ESCAP, Presentation on GMS-IS introduction, meeting presentation (2014). Available at: https://www.unescap.org/resources/presentation-brief-introduction-international-cooperation-telecom-infrastructure.

Notes: O (n) represents that there are n connections, while "X" represents that there is no connection.

The same report[7] also pointed out that the GMS countries suffer tromboning (long network routing) and insufficient network switching points, and the resulting insufficient switchover traffic as well as a high network service price.

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[6] ESCAP, "A Pre-Feasibility Study on the Asia-Pacific Information Superhighway in the ASEAN Sub-region: Conceptualization, International Traffic & Quality Analysis, Network Topology Design and Implementation Model", Asia-Pacific Information Superhighway Working Paper Series (Bangkok, 2016). Available at https://www.unescap.org/resources/pre-feasibility-study-asia-pacific-information-superhighway-asean-sub-region /resources/pre-feasibility-study-asia-pacific-information-superhighway-asean-sub-region.

[7] Ibid

2.2 Status of ICT services in the GMS

Against this background, this section investigates in more detail the current status of ICT services among the GMS countries from two aspects: service type and subscriber base (mobile subscribers and fixed-broadband subscribers).

2.2.1 ICT Service type

According to the Digital Economy Report 2019[8] and Information and Economy Report 2017[9] released by the United Nations (UN), the Internet has become an important driver of global economic and social development. Digital economy. The Internet has entered to a sustained and rapid development phase and has permeated into all aspects of the economy and society. According to the above reports, the Internet user base in the world continued to grow, and the global production of ICT products and services accounted for more than 7per cent of global GDP in 2018. In parallel, the digital economy is developing rapidly in developed and developing countries. Information and communication technology (ICT), mobile Internet, e-commerce and relevant digital applications have opened up new ways for the small and medium enterprises (SMEs) in developing countries to enter global market and operate business and generate revenue in more diversified methods. At the same time, the development and application of digital information technology have expanded the channels for women in underdeveloped areas to communicate with the outside world, creating new opportunities for themselves and other groups.

The digital economy of the GMS has also been transforming economy and society - from online taxi hailing tools to online shopping and real-time chat tools for customer services. The governments in the subregion view the development of cross-border e-commerce as an opportunity to actively explore new models of cross-border commerce[10]. To support such endeavors, the governments have been formulating measures regarding infrastructure construction, legal framework, transaction and payment system improvement, logistics and transportation, human resources training and other aspects. In order to jointly promote the development of cross-border e-commerce and establish cross-border e-commerce cooperation channels in the subregion, the GMS countries established a cross-border e-commerce cooperation platform in 2016. Enterprises from all the countries can register on the platform to carry out business-to-business (B2B), business-to-consumer (B2C) and other e-commerce

[8] United Nations, Digital Economy Report: Value Creation and Capture, Implications for Developing Countries (2019). Available at https://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=2466

[9] United Nations, Information and Economy Report: Digitalization, Trade and Development 2017 (2017). Available at https://unctad.org/en/PublicationsLibrary/ier2017_overview_en.pdf

[10] State Council, State Council webpage, The China, online website. Available at http://www.gov.cn/xinwen/2016-06/11/content_5081058.htm (accessed 4 February 2020).

businesses. On this platform, the GMS countries can introduce their own e-commerce enterprises to the consumer markets in the subregion and promote their products and services in the subregion, while exploring access to the global e-commerce market beyond the subregional boundary.

According to the two UN reports mentioned above, a significant number of data platforms have emerged in various regions around the world in the past decade. The data platforms have become an important driver of the global digital economy. In recent years, developing countries, including China, for example, has witnessed the thriving data application platforms such as *Alibaba, Taobao* and *JD.com*. In addition, social networking platforms like *Tencent, WeChat*, and *QQ*, as well as transportation sharing platforms like *Didi Chuxing* and *Mobike*, are notable examples. These online platforms have greatly changed how people consume, pay, communicate, and transport. These platforms, based on a large number of user data, are continuously expanding new business applications and business models. For example, the precision marketing strategy used by organizations such as *Alibaba, Taobao* and *JD.com* are based on customer spending habits. Additionally, the data collected through *Didi Chuxing* enables *Alipay*, *Tencent and WeChat* payments, driver assignment and order pick-up. The application of the above business platforms in China can serve as an example of successful cases for the countries where the application of the subregional business platform is weak.

2.2.2 Subscriber base

The GMS is composed of six countries and regions, namely Thailand, Viet Nam, Lao PDR, Myanmar, Cambodia, and the Yunnan Province of China. The GMS covers a total area of 2,332,000km^2 and has a population of approximately 290 million. At the end of 2018, the average penetration of fixed line, mobile phone and household FBB was 4.39 per cent, 121 per cent, and 11.54 per cent respectively. These trends indicate an overall high mobile phone user base and relative low level of fixed line and FBB in the subregion. The basic information on socio-economic and telecommunication development in the GMS in 2018 is shown in Table 1:

Table 1: Basic information on economic and social development of GMS Countries in 2018

Country (Region)	Area[11] (1,000km²)	Population[12] (1,000,000)	GDP[13] (US$100,000,000)	Fixed line penetration (per cent)[14]	Mobile phone penetration (per cent)[15]	Household FBB penetration (per cent)[16]
Myanmar	676.6	53.71	712.1	4.8	104.6	6.5
Lao PDR	236.8	7.06	181.3	113.6	76.8	4.9
Thailand	514.0	69.43	5049.9	15.5	139.4	42.9
Cambodia	181.0	16.25	245.7	2.6	119.5	4.2
Viet Nam	329.6	95.54	2449.5	16.5	137.9	48.1
Yunnan Province, China	394	48.30	2602.9	5.73	97.05	64.83
GMS Total	2332	290.29	11241.4	4.39	121	11.54

Source: As for Yunnan Province of China , the data source of the area, population and GDP is the National Bureau of Statistics of China[17], the data source of the Fixed line penetration, Mobile phone penetration and Household FBB penetration is the Ministry of Industry and Information Technology of China[18]

In recent years, the sustained economic growth of the countries of the GMS (Table 2), the relatively stable political environment and the gradual improvement of the population's living standards have created sound external conditions for the development of telecommunication services.

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[11] World Bank, Data Bank, Online database. Available at https://data.worldbank.org/indicator/AG.LND.TOTL.K2?view=chart (accessed 4 February 2020)

[12] Ibid.

[13] Ibid.

[14] ITU, Statistics, Online database. Available at https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx (accessed 4 February 2020).

[15] Ibid.

[16] Ibid.

[17] National Bureau of Statistics of China, Data, Online database. Available at http://www.stats.gov.cn/english/Statisticaldata/AnnualData/ (accessed 4 February 2020)

[18] Ministry of Industry and Information Technology, Ministry's website, online. Available at http://www.miit.gov.cn/n1146312/n1146904/n1648372/index.html (accessed 4 February 2020)

Table 2: Growth in GDP of GMS countries in the period 2014-2018 (per cent)

Country	2014	2015	2016	2017	2018
Myanmar	7.99	6.99	5.86	6.76	6.20
Lao PDR	7.61	7.27	7.02	6.85	6.50
Thailand	0.98	3.13	3.36	4.02	4.13
Cambodia	7.14	7.04	7.03	7.02	7.52
Viet Nam	5.98	6.68	6.21	6.81	7.08
China	7.30	6.91	6.74	6.76	6.60

Source: World Bank, Data Bank, Online database. Available at https://data.worldbank.org/indicator/NY.GDP.MKTP.CD (accessed 4 February 2020)

However, the current development of telecommunication services in GMS is imbalanced. Data collected from 2018 indicates that the telecommunication service penetration of countries in the GMS and the mobile phone penetration in the period 2014-2018 (Table 3) in the subregion is maintained at a high-level and constitutes well-developed mobile phone markets. However, it also indicates inadequate as well as low levels of fixed line services and poor broadband penetration (the household broadband penetration in Myanmar, Lao PDR and Cambodia is less than 10 per cent) as shown in the above Table 2.

Table 3: Mobile phone penetration of GMS countries in the period 2014-2018 (per cent)

Country	2014	2015	2016	2017	2018
Myanmar	36.3	81.6	106.1	104.3	104.6
Lao PDR	73.6	74.2	78.7	78.5	76.8
Thailand	145.1	126.4	136.8	136.5	139.4
Cambodia	133.8	130.8	126.2	116.0	119.5
Viet Nam	150.1	135.1	139.2	122.8	137.9
Yunnan Province, China	79.98	80.4	83.15	88.64	97.05

Source: TeleGeography, ICT Statistics, Online database. Available at https://www.telegeography.com/login/login?service=https%3a%2f%2fwww.telegeography.com%2fproducts%2fglobalcomms%2f (accessed 4 February 2020), and Ministry of Industry and Information Technology, Ministry’s website, online. Available at http://www.miit.gov.cn/n1146312/n1146904/n1648372/index.html (accessed 4 February 2020)

In the last 5 years, there has been a high rate of mobile services penetration in the GMS, and 3G and 4G mobile subscribers are rapidly increasing. In 2018, 3G and 4G subscribers accounted for more than 50 per cent of the total number of mobile subscribers in almost all of the countries of the GMS, other than Cambodia which accounted for 48.2 per cent of its total mobile subscribers. The 3G and 4G subscribers in Thailand and China accounted for 97.2 per cent and 87.1 per cent respectively. From the perspective of 4G mobile subscribers alone, in 2018, the proportion of 4G mobile subscribers in Thailand and Yunnan Province, of China, reached 55.1 per cent and 72.4 per cent respectively (Table 4).

Table 4: Proportion of 3G and 4G mobile subscribers in GMS countries (2018)

Country (region)	Proportion of 3G mobile users[19]	Proportion of 4G mobile users	Proportion of 3G and 4G mobile users
Myanmar	32.8	15.4	48.2
Lao PDR	53.7	17.0	70.7
Thailand	42.1	55.1	97.2
Cambodia	38.9	20.8	59.7
Viet Nam	45.3	21.1	66.4
Yunnan Province, China	6.1	72.4	78.5

Source: TeleGeography, ICT Statistics, Online database. Available at https://www.telegeography.com/login/login?service=https%3a%2f%2fwww.telegeography.com%2fproducts%2fglobalcomms%2f (accessed 4 February 2020), and Ministry of Industry and Information Technology, Ministry's website, online. Available at http://www.miit.gov.cn/n1146312/n1146904/n1648372/index.html (accessed 4 February 2020)

3. ICT services development projection in the GMS

This section provides an overview of projected development of ICT services and user base in the GMS for the next three years, based on the development status of infrastructure and ICT services in the subregion. It will first give a projection of the future development of ICT

[19] In this report, the proportion of 3G or 4G mobile subscribers in a country is calculated as follows: the proportion of 3G or 4G mobile subscribers in a country = 3G or 4G mobile users in such country/total mobile users in such country.

services in the GMS, based on the current ICT service status in the GMS and the global development trends. Second, it will list several common projection methods to estimate future user base of telecom services. Following that, it will choose the appropriate methods that suit the current telecom services user base in the GMS to project the user base of telecom services in the next few years (mobile users and broadband users).

3.1 ICT service development projection

3.1.1 The mobile Internet traffic growth

According to the Internet Development Trend Report[20] released by the China Academy of Information and Communications Technology (CAICT), global Internet traffic has grown rapidly, with a significant amount of growth observed in the Asia-Pacific region. In the context of the rapid development of the global digital economy, we predict that a rapid growth in Internet traffic will continue in the GMS.

Firstly, this is because the LTE network will stimulate mobile data consumption. At present, the global mobile network has entered the LTE network era. Operators in various countries have accelerated the deployment of the LTE networks and its evolution of technology networks because it will not only improve the data carrying capacity, but also reduce the data traffic cost. Moreover, the cost of the LTE technology is only about 1/4-1/3 of that of 3G technology. The evolution of LTE technology brings higher download rates and improved subscriber experience. The average mobile data traffic per subscriber will continue to increase and the mobile Internet traffic will continue to grow rapidly.

Secondly, the mobile device will become an important means of Internet access. With the rapid development of the mobile Internet and the rapid popularization of smartphones in the GMS, more and more subscribers in this region will access the Internet through the mobile devices, which will make Internet access more convenient and the scope of Internet application will expand further.

3.1.2 New service model as an important driving force for future development

According to the Digital Economy Report 2019 and Information and Economy Report 2017 released by the UN, the global digital economy is developing rapidly, and new business models are emerging in all regions of the world (especially in developing countries). We predict a rapid growth of digital economy in the subregion on par with the expanding global digital economy. The new business applications such as mobile payment and online services

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[20] China Academy of Information and Communications Technology, *The Trend of Internet Development,* Information and Economy Report 2017 (2017). Available at http://www.cac.gov.cn/2018-04/25/c_1122741920.htm

will continue to develop as a driving force for the economic and social development of the subregion in the future. In addition, with the development and application of a new generation of information technology such as mobile Internet, cloud computing, big data and Internet of Things, the new technologies will be continuously integrated into various industries and widely used in such fields as e-government, smart health, smart transportation and smart education to promote future innovations as well as the development of the economy and society.

3.1.3 Mobile subscribers with rapid growth

As detailed in the below section 3.2.2 on mobile subscribers and with reference to 3G and 4G subscribers in the GMS countries, mobile subscribers in the subregion have maintained a rapid growth in recent years. We predict that in the next few years, mobile subscribers will continue to grow, and 3G and 4G services will develop rapidly. In 2018, the mobile subscribers in Myanmar, Thailand, Cambodia, Viet Nam and Yunnan Province, China all exceeded 95 per cent per population. The rapid development of the mobile Internet and the mobile subscribers in the GMS is expected to grow rapidly.

The development of 3G and 4G service is also well underway; according to the development status of 3G and 4G services in the GMS during the period 2014-2018, the 3G and 4G services have ushered in a momentum of accelerated growth in recent years. In 2018, 3G and 4G mobile subscribers in Lao PDR, Thailand, Cambodia, Viet Nam and Yunnan Province, China reached more than half of their mobile subscribers, with 4G mobile subscribers in Thailand and Yunnan Province, China reaching 55.1 per cent and 72.4 per cent respectively. Together with the popularization of the applications based on 3G and 4G technologies, 3G and 4G mobile subscribers in the GMS will continue to grow steadily, and gradually complete the transition from 3G to 4G.

3.2 Subscriber base projection[21]

3.2.1 Projection on the mobile subscribers in the GMS

This part mainly focuses on the projected growth in the mobile subscribers and the 4G subscribers. According to the mobile subscriber penetration in the GMS countries during the period 2015-2018 shown in Figure 2, the number of mobile subscribers is experiencing a linear and steady growth. **The linear prediction method**[22] based on a trend extrapolation of the time series prediction method can be used to estimate the change in the mobile subscriber numbers in the GMS countries in the next few years, which is shown below in Figure 2 and 3.

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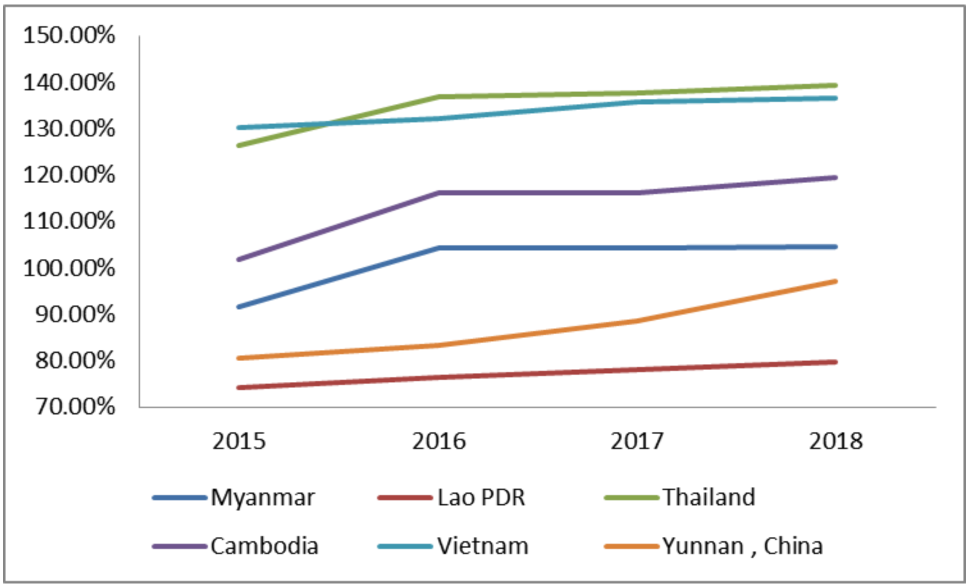
[21] For further details on prediction methodology, refer to Annex 1.

[22] Linear prediction equation: $y=a+bt$, where the prediction object is the dependent variable y, time is the independent variable t, and a and b are constants.

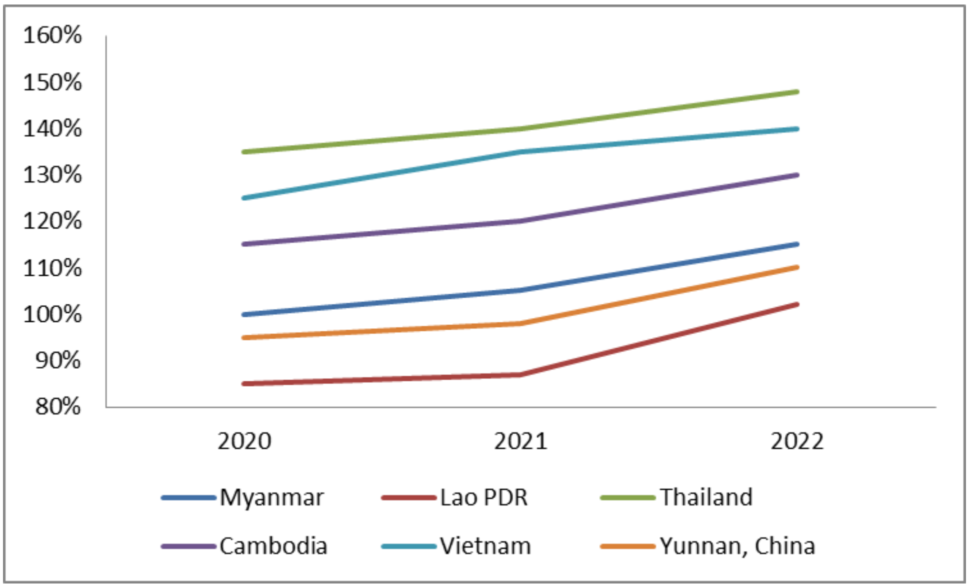
The detailed explanation of various models is found in Annex 1 of this report. Based on the calculation, the mobile subscriber penetrations in Thailand and Viet Nam, for example, are expected to grow at a pace above 120 per cent.

Figure 2: Mobile subscriber penetration in GMS countries in the period 2015-2018 (per cent).



Source: TeleGeography, ICT Statistics, Online database. Available at https://www.telegeography.com/login/login?service=https%3a%2f%2fwww.telegeography.com%2fproducts%2fglobalcomms%2f (accessed 4 February 2020), and Ministry of Industry and Information Technology, Ministry's website, online. Available at http://www.miit.gov.cn/n1146312/n1146904/n1648372/index.html (accessed 4 February 2020)

Figure 3: Prediction on the trend of change in mobile subscriber penetration in GMS countries 2020-2022

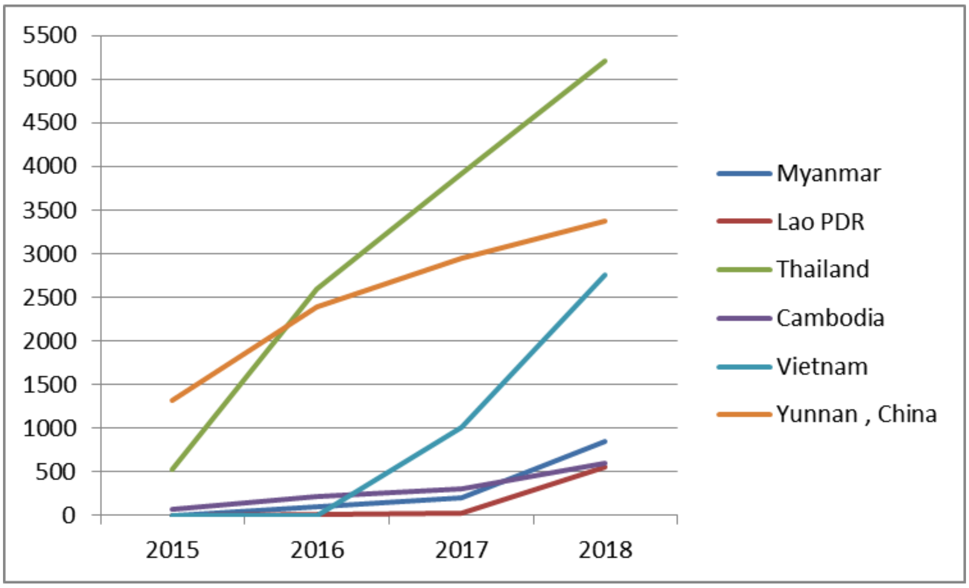


Source: Author's computations.

We extrapolated the future trend, based on the change in 4G mobile subscribers in the GMS countries within the period 2015-2018 as shown in Figure 4. It shows that most GMS countries have witnessed a rapid growth in 4G subscribers during the period. For such a growth pattern, **the quadratic curve prediction method**[23] is proposed to be used for the purpose of this report, based on a trend extrapolation. The detailed explanation of various models is found in Annex 1 at the end of this report.

The countries with better economic performance, such as Thailand and Viet Nam, have more 4G subscribers, while Cambodia and Lao PDR have a smaller subscriber base.

Figure 4: 4G Mobile phone subscribers in GMS countries in the period 2015-2018 (Unit:10,000)



Source: TeleGeography, ICT Statistics, Online database. Available at https://www.telegeography.com/login/login?service=https%3a%2f%2fwww.telegeography.com%2fproducts%2fglobalcomms%2f (accessed 4 February 2020), and Ministry of Industry and Information Technology, Ministry's website, online. Available at http://www.miit.gov.cn/n1146312/n1146904/n1648372/index.html (accessed 4 February 2020)

Figure 5: Prediction on the trend of change in scale of 4G mobile subscribers in GMS countries (2020-2022) (Unit:10,000)

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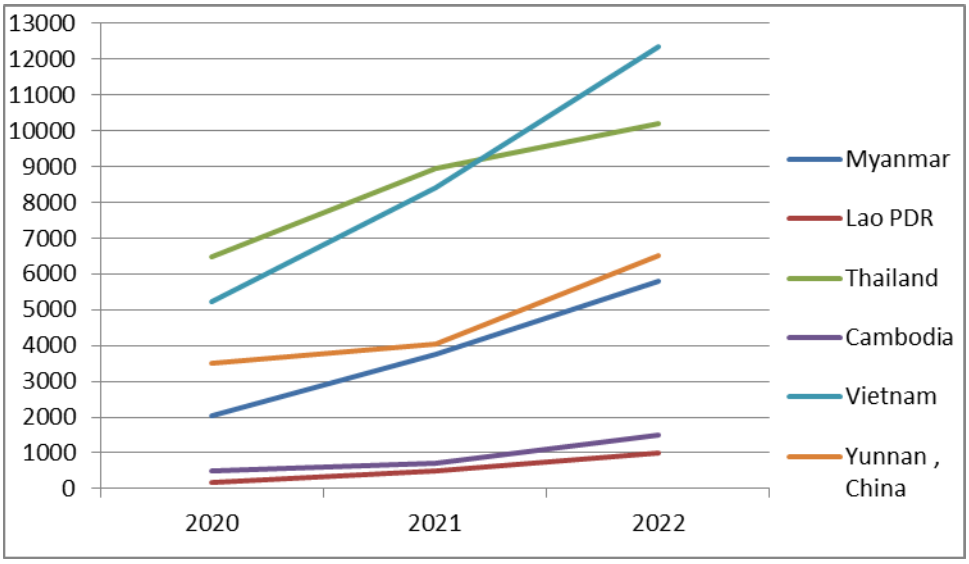
[23] Quadratic curve prediction equation: $y=a+bt+ct^2$, where the prediction object is the dependent variable y, the time t is the independent variable, and a, b, and c are constants.



Source: Author's computation.

3.2.2 Prediction on the broadband subscribers in the GMS

At present, all GMS countries have developed their broadband services. Thailand, Viet Nam and Yunnan Province of China have established expanding Internet markets and realized rapid development in broadband access and services, which resulted in large subscriber bases and high household fixed broadband penetrations. In 2018, the fixed broadband subscribers in Thailand, Viet Nam and Yunnan Province of China reached 9,270, 12,994 and 10,194 (thousand) respectively. Cambodia, Lao PDR and Myanmar only have few fixed broadband subscribers, with a household FBB penetration rate of below 10 per cent each. In 2018, the fixed broadband subscribers in Cambodia, Lao PDR and Myanmar only reached 153, 64 and 10,194 (thousand) respectively (Table 5).

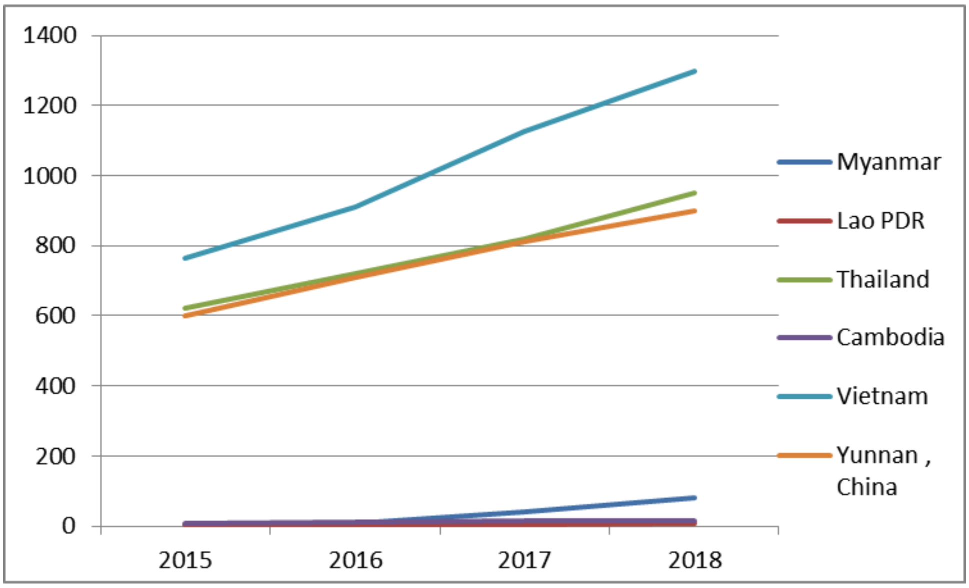
Table 5: FBB subscriber bases in GMS countries (2018)

Country (region)	The number of FBB subscribers (unit: 10,000)	Household FBB penetration (per cent)
Myanmar	82	6.5
Lao PDR	6.4	4.9
Thailand	927	42.9
Cambodia	15.3	4.2
Viet Nam	1299.4	48.1
Yunnan Province, China	1019.43	64.83

Source: Extracted from Table 1.

According to the below Figure 6 on broadband development, the fixed broadband subscribers in the GMS region have maintained a steady and linear growth on the original benchmark. As with the number of mobile subscribers, the linear prediction method[24] is used to predict the change in fixed broadband subscribers in the GMS in the next few years, which is shown below in Figure 7.

Figure 6: Fixed broadband subscribers in GMS countries in the period 2015-2018 (Unit:10,000)



Source: TeleGeography, ICT Statistics, Online database. Available at https://www.telegeography.com/login/login?service=https%3a%2f%2fwww.telegeography.com%2fproducts%2fglobalcomms%2f (accessed 4 February 2020), and Ministry of Industry and Information Technology, Ministry's website, online. Available at http://www.miit.gov.cn/n1146312/n1146904/n1648372/index.html (accessed 4 February 2020)

Note：In the Figure above, the respective FBB subscriber scale in Myanmar, Lao PDR, and Cambodia is 33,000, 25,000, and 85,400 in 2015, and the number in 2018 amounted to 820,000, 63,700, and 153,300. Small, but in a steady growth.

Figure 7: Prediction on the change in fixed broadband subscribers in GMS countries (2020-2022) (Unit: 10,000)

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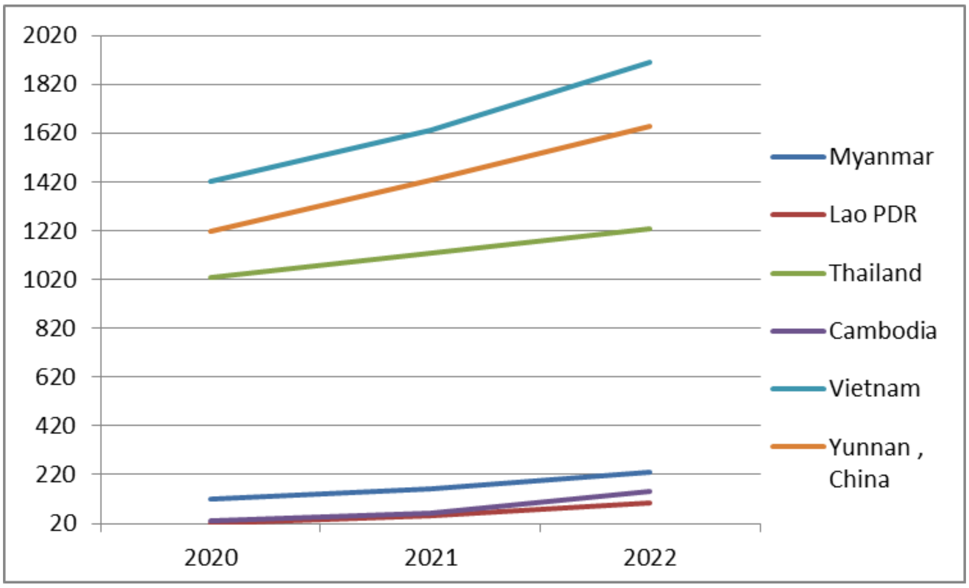
[24] Linear prediction equation: y=a+bt, where the prediction object is the dependent variable y, time is the independent variable t, and a and b are constants



Source: Author's computation.

4. The ICT Infrastructure planning scheme for the GMS Countries

ICT infrastructure facilities in the GMS constitutes an important foundation to develop ICT services. Based on the estimated size of mobile, 4G and fixed broadband subscribers between 2020 and 2022, this section proposes possible solutions to address the challenges posed by insufficient infrastructure and weak regional interconnection as mentioned in Section 3.1. In particular, this section focuses on two aspects; Internet planning and transmission network planning.

4.1. The Internet planning scheme for the GMS countries

4.1.1 Internet planning principle

Based on the previous work and the principles adopted by the Asia-Pacific Information Superhighway (AP-IS), Internet planning may take into account the following recommended principles to be applied in the GMS region:

a) Promote the synergies between network planning and construction among GMS countries. The Internet networks should be planned and constructed to attain consistency between the service strategy, routing strategy, technology selection and network structure.

b) Plan the Internet networks with needs for future upgrades. Since the Internet is a service network, we should take into account the possible advancement of Internet technologies and interconnections from the initial stage to ensure the smooth upgrading of the network, scientific network architecture and gradual evolution of the network.

c) Ensure the network quality of the Internet. In order to meet standards of key services concerning bandwidth, delay, jitter and other transmission-related network performance, multiple node assurance technologies should be adopted to realize the classified control of services.

d) Enhance e-resilience by building a high-reliability service support platform. In order to improve the network security, core node routers should be deployed in two different stations between which there should be at least two interconnection circuits distributed on different optical cable routes.

e) Proactively assess the demand for optimization of ICT network structures. On the basis of maintaining the flat structure and in accordance with the principle of simplicity and efficiency, we should minimize the network layers and gradually introduce the router cluster to optimize the network structure.

4.1.2 Internet planning scheme

Differences in the economic and social development trajectory would impact the way Internet traffic distribution is predicted and planned amongst the countries of the GMS. Currently, the service volume of Internet exchange in the GMS is mostly contributed by China, Thailand and Viet Nam. According to the interconnection service volume in the GMS countries in recent years and the estimated Internet traffic demands of the GMS countries, the interconnection service volume by 2022 is estimated, as shown below in Table 6.

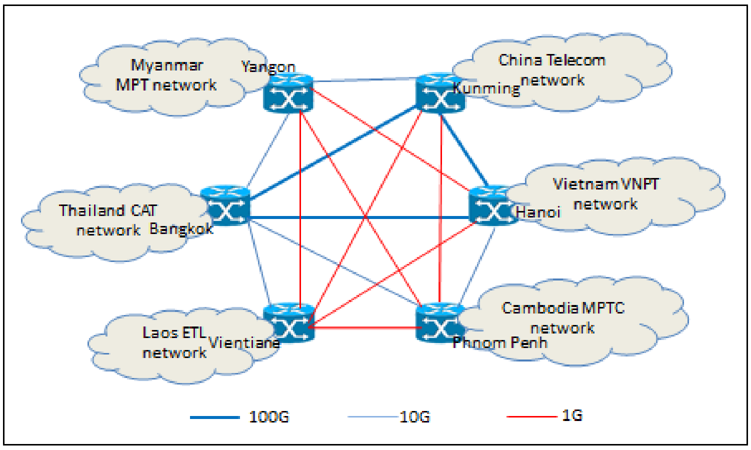
Table 6: Estimated Internet traffic demand among GMS countries by 2022 (Unit: Mbps)

Inflow country/region / Outflow country/region	Cambodia	Lao PDR	Myanmar	Thailand	Viet Nam	Yunnan Province, China
Cambodia	-	200	150	650	800	400
Lao PDR	150	-	120	600	300	200
Myanmar	400	400	-	1700	1050	3600
Thailand	4,200	11,000	1,900	-	28,000	46,300
Viet Nam	2,800	1,500	750	14,000	-	15,000
Yunnan Province, China	2,800	2,100	3,500	32,800	28,000	-

Source: Author’s computation.

According to the afore-mentioned networking principles and the estimation of Internet interconnection service in the GMS countries, the Internet network configuration in the GMS is proposed as follows:

Figure 8: GMS Internet networking structure diagram (Unit: Mbps)



Source: Author's computation.

4.2. The transmission network planning scheme for the GMS

It is crucial to improve the connectivity of the backbone transmission networks in the GMS as it will directly affect the Internet traffic in the subregion. The availability of transmission networks will play a positive role in realizing the implementation of the Greater Mekong Subregion Information Superhighway (GMS-IS) and enhancing cooperation in further developing Internet networks and associated services among the GMS countries.

The below Section on transmission network planning will assess three aspects, namely the planning principles, planning scheme, and capacity assignment of transmission networks, so as to propose the final transmission network planning scheme for the GMS countries.

4.2.1 Transmission network planning principles

Within a broad framework of the Asia-Pacific Information Superhighway (AP-IS), transmission network planning may take into consideration the following recommended principles in the context of the GMS countries:

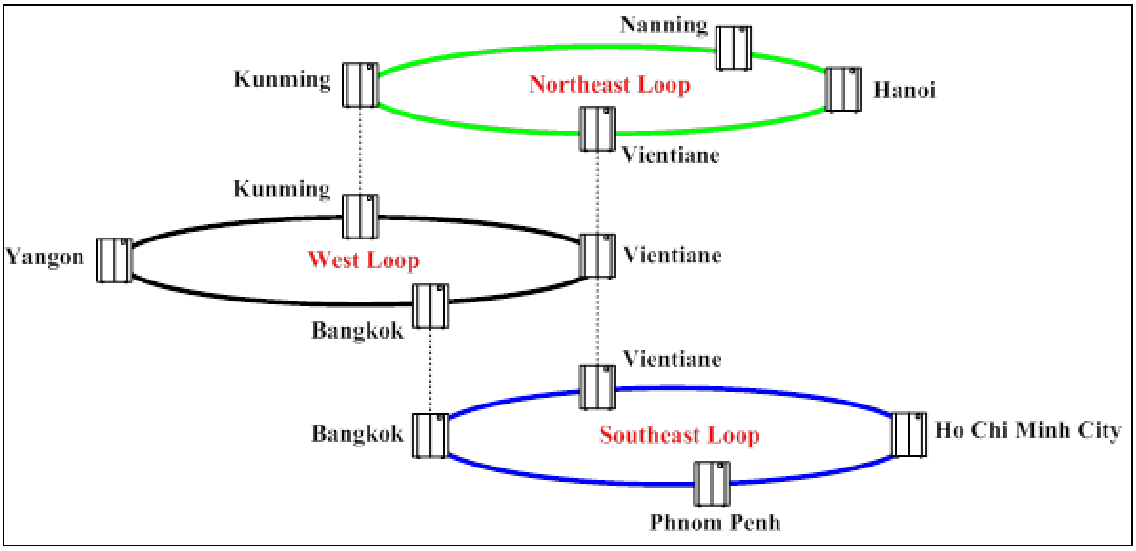
a) The backbone transmission networks in the GMS should cover the capital cities and major cities;
b) In order to reduce the construction cost, the backbone transmission networks in the GMS should make full use of the existing optical fiber resources;
c) Direct optical cable routes should be established as much as possible between two neighbouring countries;

d) In order to ensure the availability, security, resilience and reliability of networks, each country in the GMS should have more than two optical cable routes in place to connect the backbone transmission networks;
e) In order to facilitate the subsequent operation and maintenance, new optical cable lines should select relatively stable routes with the shortest distance possible;
f) The network construction will adopt a step-by-step approach according to the GMS-IS network development demands and AP-IS framework.

4.2.2 Transmission network planning scheme

Taking into consideration the above network planning principles and the current status and projected demands for mobile/broadband traffic in the GMS, we propose to adopt a loop network as the main structure and build three optical fiber transmission loop networks (northeast loop, west loop, and southeast loop) in the GMS (see Figure 9). Having comprehensively considered influencing factors such as geographical locations and business relations, this organizational structure intends to integrate transmission network backbone nodes in the GMS countries into multiple loop networks. Service between nodes in the same loop network is dredged within the ring, while service between nodes in different loop networks needs to be connected through the inter-loop interconnection nodes. The loop network organizational structure requires that the equipment used by the same loop network node should use similar technical standards and that the networking, network management, and operation and maintenance should be carried out in a synchronized manner.

Figure 9: Diagram of loop network organizational structure of optical cable transmission networks in the GMS



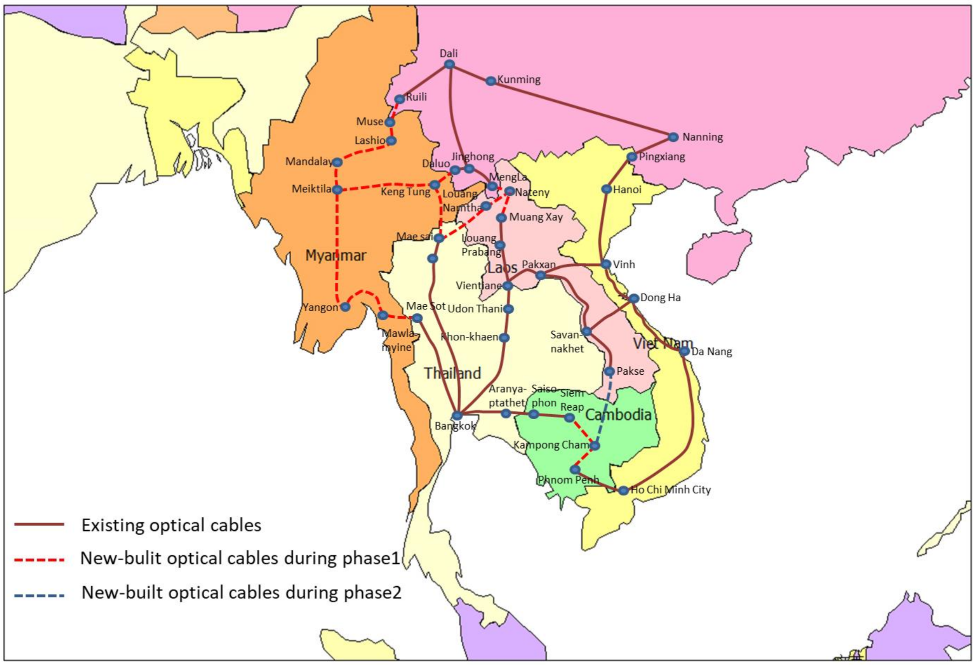
Source: Author's computation.

Its advantages lie in the fact that to a certain extent, it embodies the characteristics of "overall networking” and conveniently supports the dispatch and configuration of transmission circuits; that it can provide better safety precautions; and that it can be managed and can meet the service configuration requirements quickly. The loop network organizational structure will play a positive role in developing the comprehensive capability of the backbone transmission networks in the GMS.

According to the principle of construction, operation and maintenance in a synchronized manner, two interconnected loop network transmission systems should be built to support the interconnection among rings by introducing the loop network organizational structure into the transmission networks in the GMS. The loop network structure should continue to be overlapped with the original point-to-point structure in the GMS. Following the principle of networking, construction, management and operation and maintenance in a synchronized manner, we should strive to realize the interconnection among the GMS countries by means of planning networks in a comprehensive manner. When the loop network structures are completed, the backbone transmission networks in the GMS will form a two-layer structure (new loop network structure and the original point-to-point structure). The network can provide a more flexible transmission circuit organization and dispatching functions, and also provide fast and effective protection for some important services through the loop network structure. As shown in Figure 9, the new loop network structure covers all the GMS countries. After the completion, the loop network will greatly improve the efficiency of cross-border circuit dispatching and network operations in the GMS, provide rapid and effective circuit configuration for the interconnection services among the countries, and ensure the security of transmission.

To realize the loop network structures mentioned above, it is necessary to build part of fiber cable lines, as shown in Figure 10. The fiber cable routing can be built in two stages for improved outcomes: 3,122km for the first stage (marked in red below) to realize the transmission network connection between the GMS countries, and 554km for the second stage (marked in blue below) to lay the foundation for the loop network structures.

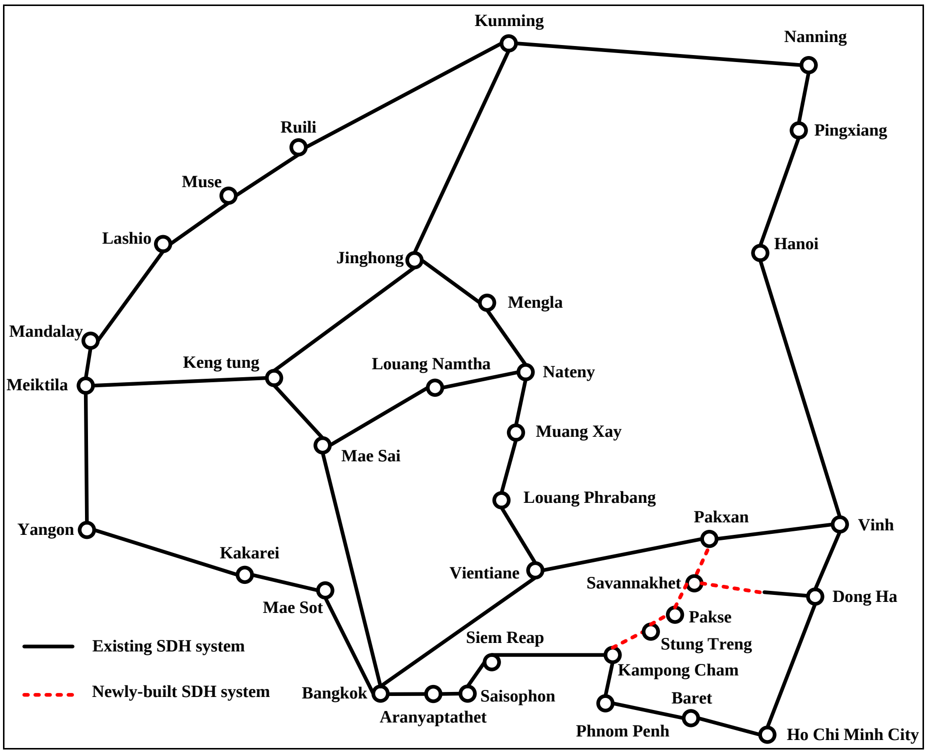
Figure 10: GMS optical cable network networking structure diagram



Source: Author's computation.

In addition, to realize the loop network structure in Figure 9, it is vital that a new point-to-point transmission system of about 1,290km is built on the basis of the original point-to-point organizational structure in the GMS, including about 230 km for the cross-border section system and about 1,060km for the domestic section system, as shown in Figure 11 and Table 7. The completed transmission network system will increase the interconnection with systems in Cambodia, Lao PDR, Thailand and Viet Nam, and support the backup of the existing transmission system.

Figure 11: Diagram of network structure of the point-to-point transmission system of the transmission networks in the GMS



Source: Produced by Xi'An University of Posts and Telecommunications based on data from Ministry of Industry and Information Technology, Ministry's website, online. Available at http://www.miit.gov.cn/n1146312/n1146904/n1648372/index.html (accessed 4 February 2020)

Table 7: New point-to-point transmission system to be built for the transmission networks in the GMS

S/N	New point-to-point system	Type	Length	Remarks
1	Pakse-Stung Treng	Cross-border section	230km	Lao PDR (160km) and Cambodia (70km)
—	Subtotal	—	230km	—
2	Pakxan-Savannakhet-Pakse	Domestic section	491km	Lao PDR (491km)
3	Stung Treng-Kampong Cham	Domestic section	324km	Cambodia (324km)
4	Savannakhet – Lao PDR-Viet Nam border	Domestic section	245km	Lao PDR (245km)
—	Subtotal	—	1,060km	—
—	Total	—	1,290km	—

Source: Author's computation.

The formation of the transmission networks structure (loop network as its main structure) in the GMS is expected to play a positive role to improve the connectivity of infrastructure between the GMS countries so as to realize the concept of Greater Mekong Subregion Information System (GMS-IS) and enhancing cooperation among GMS countries within the framework of the AP-IS.

4.2.3 Capacity assignment scheme

The capacity assignment scheme of the transmission system can refer to the ESCAP research paper[25]. It aims to assign the specified end-to-end channel capacity of multi-national terrestrial optical cable transmission wavelength-division multiplexing (WDM) systems positively correlated with the physical length of the fiber cable contributed by the participant countries.

Table 8: Loop network organizational structure of optical cable transmission networks in the GMS

S/N	Loop name	Loop route (km)	Distance (km)
1	Northeast Loop	Kunming-Nanning-Hanoi-Vientiane-Kunming 985 (China), 580 (China 290/Viet Nam 290), 750 (Viet Nam 210/Lao PDR 540) and 1,245 (Lao PDR 805/China 440)	3,560
2	West Loop	Yangon-Mandalay-Kunming-Vientiane-Bangkok-Yangon 930 (Myanmar), 1,240 (Myanmar 530/China 710), 1,250 (China 475/Lao PDR 775), 870 (Lao PDR 50/Thailand 820) and 930 (Thailand 480/Myanmar 450)	5,220
3	Southeast Loop	Bangkok-Vientiane-Ho Chi Minh City-Phnom Penh-Bangkok 850 (Thailand 810/Lao PDR 40), 1,480(Lao PDR 300/Viet Nam 1,180), 355(Viet Nam 135/Cambodia 220) and 885 (Cambodia 495/Thailand 390)	3,570

Source: Author’s computation.

According to the diagram of Table 8 on Loop Network Organizational Structure of Optical Cable Transmission Networks and routing length of loop networks, the physical length of the optical cable provided by China, Viet Nam and Lao PDR in the Northeast Loop

[25] ESCAP, “The Operation of Cross-Border Terrestrial Fibre-Optic Networks in Asia and the Pacific”, Asia-Pacific Information Superhighway Working Paper Series, (Bangkok, 2019). Available at https://www.unescap.org/resources/operation-cross-border-terrestrial-fibre-optic-networks-asia-and-pacific

(Kunming-Nanning-Hanoi-Vientiane-Kunming) is 1,685km, 520km and 1,355km, respectively. The physical length of the optical cable provided by China, Lao PDR, Thailand and Myanmar in the West Loop (Yangon-Mandalay-Kunming-Vientiane-Bangkok-Yangon) is 1,185km, 825km, 1,300km and 1,910km respectively; and the physical length of the optical cable provided by Thailand, Lao PDR, Viet Nam and Cambodia in the Southeast Loop (Bangkok-Vientiane-Ho Chi Minh City-Phnom Penh-Bangkok) is 1,200km, 340km, 1,315km and 715km respectively. According to the proportion of fibre optic cables in each country, the transmission network capacity assignment among GMS countries is computed as follows in Table 9:

Table 9: System capacity to be available to GMS countries in the loop network structure

Loop circuit	Country	Optical cable's physical length	Proportion (per cent)	Channel capacity (n*100G)[26]
Northeast Loop	China	1,685	47.3	38
	Viet Nam	520	14.6	12
	Lao PDR	1,355	38.1	30
	Total	3,560	100	80
West Loop	China	1,185	22.7	18
	Lao PDR	825	15.8	13
	Thailand	1,300	24.9	20
	Myanmar	1,910	36.6	29
	Total	5,220	100	80
Southeast Loop	Thailand	1,200	33.6	27
	Lao PDR	340	9.6	8
	Viet Nam	1,315	36.8	29
	Cambodia	715	20.0	16
	Total	3,570	100	80

Source: Author's computation.

5. Recommendations

Based on the AP-IS Master Plan and Regional Cooperation Framework Document as well as the associated regional policy discussions, this section offers recommendations on how to implement the network optimization and management in the GMS; including organization, management, construction, operation and maintenance of the proposed networks

[26] "n" represents the number of channels. In this report, "n" is illustrated by taking 80*100G wavelength division system as an example and should be rounded.

The AP-IS platform should be capitalized to promote the implementation of the GMS-IS. A GMS Working Group should be established for the inter-governmental negotiations and the network planning for the GMS region as a subregional implementation of the AP-IS initiative.

In terms of the specific implementation, the GMS Working Group is expected to partner with the respective government authorities in charge of telecommunications in the GMS, and the latter will be responsible for organizing domestic telecommunication operators to form a management implementation group for the specific implementation of the proposed networks.

The six GMS countries may wish to form a GMS-IS Steering Group which is comprised of and led in rotation by the heads of their competent communication authorities. The Steering Group is mainly responsible for coordinating the relevant policies of the six governments with regards to the construction of GMS-IS, communicating with ESCAP over relevant issues, evaluating and approving the reports of the GMS-IS Implementation Group.

The GMS-IS Implementation Group should be also be formed, which would be compromised of and led in rotation by representatives of telecommunication operators from the six GMS countries. The Implementation Group is mainly responsible for the specific implementation of GMS-IS, for formulating a GMS-IS construction plan, for solving issues related to funding, technology, personnel training, and providing a platform for various forms of bilateral and multilateral cooperation among operators from the six GMS countries.

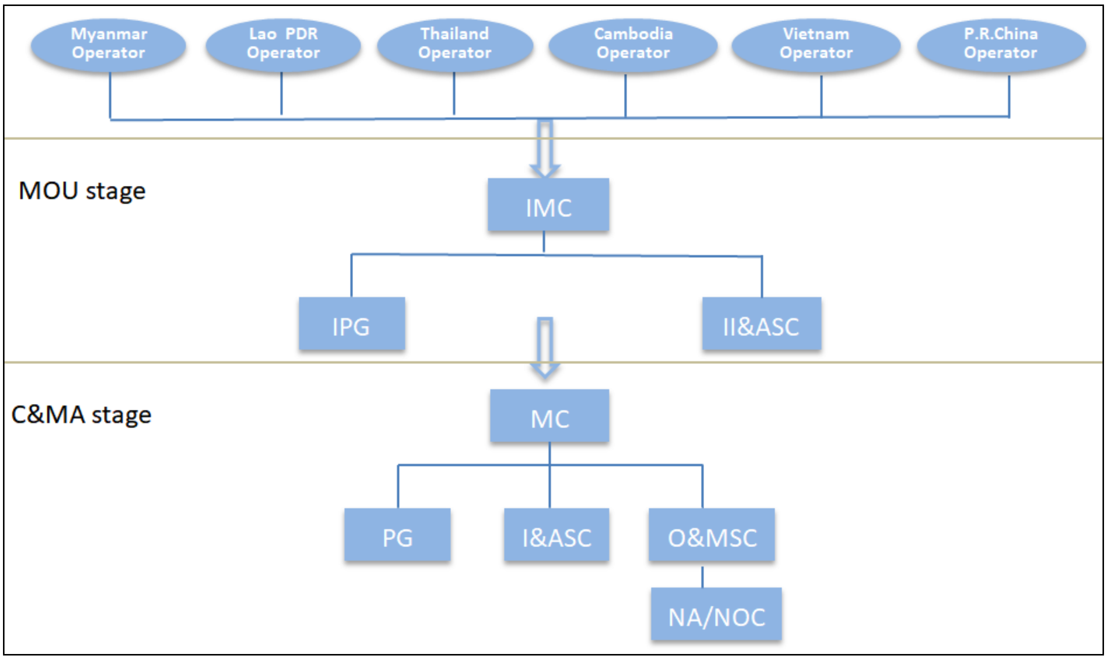
The Implementation Group can be established within the following organizational management framework. In accordance with the basic principle of the transnational optical fibre cable circuit resource sharing mode mentioned earlier, the participating operators in the GMS countries may wish to form a project management committee responsible for the management of the MOU, planning, design, construction, operation and maintenance and other relevant stages. Different frameworks with the corresponding functions are required for MOU, construction and operation:

- *Memorandum of Understanding (MOU)*: The participants may wish to sign a MOU, carry out the relevant preparatory work and establish interim cooperation organizations, including Interim Management Committee (IMC), Initial Procurement Group (IPG) and Initial Investment and Agreement Sub-Committee (II&ASC). (IMC: to carry out overall coordination at the stage of MOU; IPG: to collect the latest technical information and draft supply contracts; and II&ASC: to raise fund, carry out network construction and draft the standard for management of operation and maintenance)

- *Construction and Maintenance stage (C&MA)*: network construction, business operation and other relevant activities should be carried out, and construction as well as operation management organizations should be established, including Management Committee (MC), Procurement Group (PG), Investment and Agreement Sub-Committee (I&ASC), Operations and Maintenance Sub-Committee (O&MSC), Network Administrator/ Network Operation Center (NA/NOC), etc. (MC: to carry out overall coordination at the operational stage; PG: to pursue the activities previously undertaken by the IPG, negotiate with suppliers, determine the procurement price and carry out engineering acceptance; I&ASC: to pursue the activities previously undertaken by the II&ASC; O&MSC: to divide the work of participants in network operations and maintenance; and NA/NOC: to monitor the whole network, have network configuration authority, and assign maintenance tasks to participants)

The proposed organizational structure is shown the below Figure 12:

Figure 12: Diagram of organizational structure of GMS transnational cooperative mechanism



Source: Author's computation.

Notes: (IMC: Interim Management Committee; IPG: Initial Procurement Group, Collect the latest submarine cable technology and draft the Supply Contract etc; II&ASC: Initial Investment and Agreement Sub-Committee, conduct financing, Network Construction, and draft the C&MA etc; MC: Management Committee; PG: Pursue the activities previously undertaken by the IPG; I&ASC: Pursue the activities previously undertaken by the II&ASC; O&MSC: Operations and Maintenance Sub-Committee; NA/ NOC: Network Administrator/ Network Operation Center)

Annex 1:

Prediction method[27] of subscriber scale

At present, the correlation regression prediction technology and time series prediction technology are commonly used for telecommunication service prediction.[28]

Regression prediction

Regression analysis prediction technology is to make prediction by establishing a regression equation based on the relationship among economic variables and historical data. The correlation regression analysis is a quantitative prediction method, which quantitatively reflects the causal relationship between things.

The basic idea of regression analysis prediction is to analyze and study the relationship between the prediction object and the relevant factors, express the aforementioned relationship with appropriate regression prediction models, and then predicting its future status according to mathematical models. Establishing the relevant regression model and estimating the parameters through analysis on a set of data and using that regression model to predict and analyze the study object, this method can provide the basis through which economic decisions can be made. Both the number of factors affecting economic variables and the functional rule are not always the same. Therefore, the regression prediction method can be further divided into several different types. In regression prediction, the prediction object is called dependent variable, and the relevant factor is called independent variable; the regression with only one dependent variable is called unitary regression, and the regression with multiple dependent variables is called multiple regression; and the regression in which there is linear relation between the statistical law of the dependent variable and that of the independent variable is called linear regression, and the regression in which there is curvilinear relation between the statistical law of the dependent variable and that of the independent variable is called non-linear regression.

Time series prediction

Time series is a set of statistical data that is arranged in a chronological order. Time series prediction is to analyze the law of development of statistical data over time and use the historical data on that variable to establish a mathematical model for extrapolation and

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[27] Details about the prediction method can be found in the paper: Analysis on the Telecommunication Prediction Technology, January 2007. Available at http://www.paper.edu.cn/releasepaper/content/200701-266

[28] Analysis on the Telecommunication Prediction Technology, January 2007, http://www.paper.edu.cn/releasepaper/content/200701-266

prediction. It describes all factors affecting the change in dependent variables by “time”. As a quantitative prediction method, this method is mainly based on historical data and the development of telecommunication services in different periods. Time series prediction methods commonly used in the telecommunication industry include trend extrapolation prediction method, growth curve prediction method and smoothing prediction method.

Trend extrapolation prediction method: The statistical data shows that a large number of socioeconomic phenomena is developed step by step and takes on a certain law of development over time, i.e., the future development trend is to some extent consistent with the past one. The statistical trend extrapolation method is to carry out prediction and analysis by means of extrapolation with a trend model on the relationship between time series y and time t. The trend extrapolation method is to use curve to match data series so as to establish a prediction model that can describe the object’s development process. The trend extrapolation method assumes that the future development trend is consistent with the past one, so it is more suitable for short-term prediction than for medium- and long-term prediction.

Growth curve prediction method: Things must go through the growth process of occurrence, development and maturity. When approaching a certain degree, things will no longer grow per the law of exponent or quadratic curve, in which case, the exponential curve and quadratic curve cannot be used to predict the characteristics close to the limit value. As far as the telecommunication service prediction is concerned, when the penetration of fixed line and mobile phone increases above a certain value, it tends to be saturated gradually, instead of simply increasing as per the exponential or linear trend.

As another time series prediction model, the smoothing prediction method is to firstly smooth the statistical data and filter out the fluctuations caused by accidental factors, and then find out the law of development. The moving average method and exponential smoothing prediction method are commonly used for telecommunication service prediction. The moving average method can be further divided into simple moving average method and trend moving average method. As a simple and effective prediction tool, the simple moving average method is only suitable for short-term prediction, provided that the basic trend of the prediction object is fluctuating at a certain level. The exponential smoothing method is developed on the basis of the weighted average method and is an improvement of the moving average method.

Comparative analysis

The regression prediction method has three main advantages: firstly, it can study the relationship between the prediction object and the related factors and grasp the essential reasons for the change in the prediction object, which ensures a credible prediction result; secondly, it can give the confidence interval and confidence coefficient of the prediction result, making the prediction more complete and objective; and thirdly, by considering the correlation and using the relevant mathematical statistics method to test the regression equation, it is able to identify to some extent the turning point of the change in the prediction object.

Mainly used in the traditional service in the telecommunication network with complete historical data, the time series prediction method is characterized by the future prediction based on the historical data. As far as the time series prediction method is concerned, as the fixed network telephone service and the mobile network circuit service have formed a certain scale with subscriber growth having entered a relatively stable growth stage, it is appropriate to use the quadratic curve model for the medium- and long-term (about 5 years) prediction and the growth curve model for long-term (10-15 years or more) prediction.