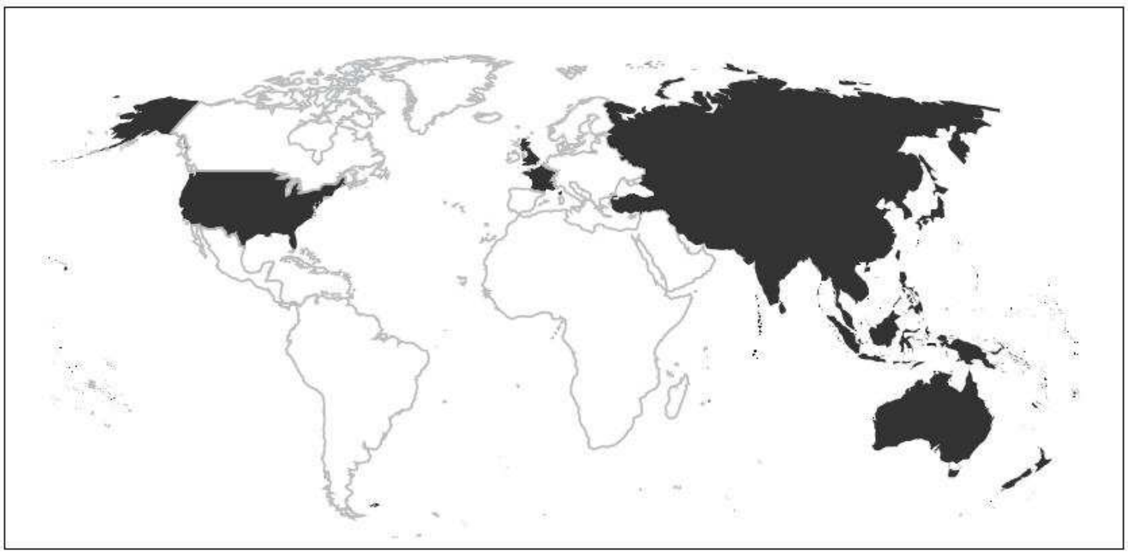
A Study of ICT Connectivity for the Belt and Road Initiative (BRI):

Enhancing the Collaboration in China-Central Asia Corridor

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

Working Paper by the Information and Communications Technology and Disaster Risk Reduction Division

The secretariat of the Economic and Social Commission for Asia and the Pacific (ESCAP) is the regional development arm of the United Nations and serves as the main economic and social development centre for the United Nations in Asia and the Pacific. Its mandate is to foster cooperation among its 53 members and 9 associate members. It provides the strategic link between global and country-level programmes and issues. It supports Governments of countries in the region in consolidating regional positions and advocates regional approaches to meeting the region's unique socioeconomic challenges in a globalizing world. The ESCAP secretariat is in Bangkok. Please visit the ESCAP website at www.unescap.org for further information.



The shaded areas of the map indicate ESCAP members and associate members.

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Executive Summary

The Belt and Road Initiative (BRI) was initially introduced in 2013 in order to enhance connectivity and collaboration among 60 countries and beyond in Asia, Africa and Europe. According to BRI, the Belt refers to Silk Road Economic Belt which is the land routes among these countries, whereas the Road refers to the 21st-Century Maritime Silk Road which is the sea routes, rather than roads, aimed at marine transportation and communications from China's east coast to other countries across the South China Sea and the Indian Ocean.

Through the Asia-Pacific Information Superhighway (AP-IS) initiative, ESCAP is collaborating with the government of the People's Republic of China to promote the BRI to member States along the BRI corridors as well as the wider Asia-Pacific region. The ESCAP-China cooperation could increase inclusiveness among 62 ESCAP member economies to achieve a higher level of ownership and therefore support to the BRI initiative. In addition, the ESCAP-China cooperation strengthens synergies between AP-IS and BRI initiatives respectively to attain mutual benefits, sustainable development, and strengthen economic relations among the ESCAP member countries.

In order to successfully achieve these objectives, information and communications technology (ICT) connectivity is critical to providing fundamental communication channels for global connectivity, infrastructure development, trade and transport and socio-economic collaboration among people, organizations and countries along BRI corridors.

In addition, ICT contributes directly and indirectly to economic, social and environmental aspects of Sustainable Development Goals (SDG). Specific SDG targets and goals include target 9.1 (Develop quality reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all) and 9.c (Significantly increase access to ICT and strive to provide universal and affordable access to the Internet in least developed countries by 2020). Furthermore, under Goal 4 on education, one target requires the member countries to expand educational opportunities in ICT[1]. In the area of gender equality, Goal 5 has the target of "enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women". A goal under SDG 17 further specifies the role of ICT as a means of implementation[2].

[1] "By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries"
[2] "Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology".

In this light, the AP-IS initiative plays an important role in Asia and the Pacific to develop a regional information and communication system among countries in this region in bridging the digital divide and contribute to socio-economic development and SDGs.

To achieve closer cooperation among countries in different regions, six economic corridors are examined for ICT inter- and intra-connectivity under the ESCAP-China cooperation: (1) China-Mongolia-Russia Corridor, (2) New Eurasian Land Bridge Corridor, (3) China-Central Asia-West Asia Corridor, (4) China-Pakistan Corridor, (5) Bangladesh-China-India-Myanmar Corridor and (6) China-Indochina Peninsula Corridor. This study focuses on examining the role of ICT connectivity for BRI in China-Central Asia Corridor, an important gateway to connect countries between Asia and Europe.

The international connectivity of the Landlocked Developing Countries (LLDC) in Central Asia is highly dependent on the ease and costs of connecting to neighboring countries. As a result, LLDCs in Central Asia usually experience inadequate international bandwidth and high transit cost to access international links. Therefore, the strenthening of ICT infrastructure connectivity in Central Asia could result in drastically improving access and affordability in Central Asia but also for other countries along the BRI corridors. The study focuses on China, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

Taking into account the above, the objectives of this study are to (1) examine the status of ICT connectivity in China-Central Asia-West Asia Corridor; (2) design a resilient network topology for both intra- and inter-corridor ICT connectivity in alignment with BRI; (3) specify the challenges and opportunities on ICT connectivity; and (4) recommend ICT strategies and activities under the framework of BRI. To accomplish these objectives, the study analyzes the ICT connectivity between current and future state to identify gaps (i.e. challenges and opportunities). Network topology designs and ICT strategy recommendations were developed to bridge the gaps identified.

The main challenge identified by the study are as follows:

1) *Redundant fiber route is required:* China and Central Asia could enhance ICT connectivity through connection via three cross-border fiber routes (China-Kazakhstan, China-Kyrgyzstan, and China-Tajikistan).
2) *More international bandwidth is required*: In particular for Tajikistan, Turkmenistan and Uzbekistan, which have an average international bandwidth per user lower than 4 kbps.
3) *National ICT infrastructure (domestic backbone networks) is required:* China has low fiber connectivity density in central and western areas. Kyrgyzstan, Tajikistan and Turkmenistan are far below the global average fixed broadband penetration.
4) *Security in ICT infrastructure is required to improve secured connections:* Encryption techniques are adopted in a small number of servers. The average number of secure servers in this region is less than 18 whereas the world average is 209.
5) *Broadband pricing must be reduced to be affordable:* Broadband price in terms of percentage of GNI per capita is more than 5 per cent in some countries.

6) *International cooperation or policy coordination among countries is required for the effective implementation and operation of networks*: Since networks are often operated by multiple operators, there is difficulty and complexity in building uniform quality of services between endpoints to guarantee traffic delivery and ensure low transit cost.

Based on the challenges identified, the study designed and recommended ICT strategies for a network topology by comparing major cities' geographical location, intra-corridor connectivity (China-Central Asia-West Asia connectivity) and international connectivity criteria. The ICT strategy identified a hybrid network with new nodes proposed to ensure efficient ICT connectivity along the China-Central Asia-West Asia Corridor.

This report aims to contribute to the ESCAP approach to BRI - smart and green connectivity for sustainable development – which capitalizes on ESCAP's unique intergovernmental platform and multi-displinary approach in promoting regional connectivity for inclusive and sustainable development. The support ICT can provide in an ICT Corridor would be an integral part of overall regional connectivity, as energy, trade facilitation and transport connectivity depend on ICT and vice versa.

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Acronyms

3G	Third Generation
AAE-1	The Asia-Africa-Europe-1
ADB	Asian Development Bank
APCN-2	The Asia Pacific Cable Network - 2
AP-IS	Asian-Pacific information Superhighway
APG	Asia Pacific Gateway
APNIC	Asia Pacific Network Information Centre
ASEAN	Association of Southeast Asian Nations
B2B	Business to Business
BRI	Belt and Road Initiative
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CAT	Communication Authority of Thailand
CERT	Computer Emergency Response Team
CHN-IX	China Internet Exchange point
CHUS	China-U.S. Cable Network
CNNIC	China Internet Network Information Center
CNPC	China National Petroleum Corporation
CoE	Center of Excellence
DDoS	Distributed Denial of Service
DoS	Denial of Service
DREAM	Diverse Route for European and Asian Markets
DWDM	Dense Wavelength Division Multiplexing
E	Edges or links
EGDI	E-Government Development Index (EGDI)
ESCAP	Economic and Social Commission for Asia and the Pacific
ETSI	European Telecommunications Standards Institute
FEA	FLAG Europe-Asia
FinTech	Financial Technology
GB	Gigabytes
Gbps	Gigabits per second
GDP	Gross Domestic Product
GMS	Greater Mekong Subregion
GNI	Gross National Income
HKTDC	Hong Kong Trade Development Council
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMF	International Monetary Fund
IoE	Internet of Everything
IoT	Internet of Thing

IP	Internet Protocol
IPB	ICT Price Basket
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
ISO	International Organization for Standardization
ISOC	Internet Society
ITC	Information Technology and Communication
ITS	Intelligent Transportation System
ITU	International Telecommunication Union
IX	Internet Exchange
IXP	Internet Exchange Point
KAS-IX	Kazakstan Internet Exchange
Kbps	Kilobits per second
Km	Kilometer
KMG	KazMunayGas
LBS	Location Based Services
LDCs	Least developed countries
LLDC	Landlocked developing countries
LTE	Long-Term Evolution
MB	Megabytes
Mbps	Megabits per second
MCT	Malaysia-Cambodia-Thailand
MPLS-TP	Multiprotocol Label Switching - Transport Profile
NAT	Network Address Translation
NCP	New Cross Pacific
NDRC	National Development and Reform Commission
NSRC	Network Startup Resource Center
OAM	Operations, Administration and Maintenance
OBOR	One Belt One Road
OPEX	Operating Expenditure
OTN	Optical Transport Network
PB	Petabytes
POPs	Point of Presence
PSTN	Public Switched Telephone Network
QoS	Quality of Service
R&D	Research and Development
RFC	Request for Comments
RIPE NCC	Réseaux IP Européens Network Coordination Centre
SDGs	Sustainable Development Goals
SDH	Synchronous Digital Hierarchy
SEA-ME-WE	Southeast Asia, the Middle East and Western Europe
SIDs	Small Island Developing States
SJC	Southeast Asia Japan Cable
SRG1	Silk Road Gateway 1

SR-IS	Silk Road Information Superhighway
TAE	Trans Asia-Europe
TASIM	Trans-Eurasian Information Super Highway
TAS-IX	Uzbekistan Internet Exchange
TB	Terabytes
Tbps	Terabits per second
TPE	Trans-Pacific Express
TSE-1	Taiwan Strait Express-1
TV	Television
TW1	Transworld-1
TWA	TransWorld Associates
UAE	United Arab Emirates
UNPAN	United Nations Public Administration Network
UPS	Uninterruptible power supply
USD	US Dollar or American dollar
V	Vertices or nodes
VNI	Visual Networking Index
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
WSIS	World Summit on the Information Society

1. INTRODUCTION

This document presents the results of the study and comparative analysis of ICT connectivity for the Belt and Road Initiative (BRI) in China-Central Asia-West Asia Corridor.

1.1 Objectives

The main objective of this report is to analyze the benefits and challenges offered by ICT connectivity for BRI in China-Central Asia-West Asia Corridor, which contains the following main areas: (1) current status of ICT infrastructure and use of ICT application in the corridor in Central Asia; (2) design network topology of inter-corridor and intra-corridor ICT connectivity, in particular from the perspective of connecting missing links and setting Internet Exchange Points (IXPs); (3) specific challenges, barriers and issues of each BRI corridor on ICT connectivity; (4) strategies for moving forward with the proposed corridor connectivity activies within the framework of BRI and the Asia-Pacific Information Superhighway (AP-IS) as described below.

1.2 Background

ESCAP is collaborating with the government of the People's Republic of China in understanding clear development benefits of the BRI initiative among ESCAP member States that could lead to a higher level of ownership of the initiative, enhanced cooperation and connectivity in and beyond the Asia Pacific region. The objectives of BRI focus on realizing and building five linkages between countries along the BRI corridors: (1) To enhance policy coordination; (2) To improve infrastructure connectivity; (3) To reinforce trade and investment cooperation; (4) To move forward with financial integration; and (5) To support people-to-people collaboration.

The BRI initiative strongly focuses on improving and creating new connectivity and collaboration among six international economic corridors which are (1) China-Mongolia-Russia Corridor; (2) New Eurasian Land Bridge corridor; (3) China-Central Asia-West Asia Corridor; (4) China-Pakistan Corridor; (5) Bangladesh-China-India-Myanmar Corridor, and (6) China-Indochina Peninsula Corridor. In addition, ESCAP-China cooperation on BRI covers four main sectors including (a) Transport; (b) Trade and Investment; (c) Information and Communications Technology (ICT); and (d) Energy.

The ICT sector is essential for the BRI initiative in providing digital communicationchannels. In order to effectively provide connectivity the Asia-Pacific Information Superhighway (AP-IS) plays an important. The AP-IS initiative is aimed at achieving high availability and affordability of Internet and broadband networks by strengthening network infrastructure in Asia and the Pacific. In addition, AP-IS also provides seamless integration among these networks to develop a regional information and communication system. This could lead to the development of digital inclusion, and achievement of Sustainable Development Goals (SDGs) and World Summit on the Information Society (WSIS) Action Lines.

Furthermore, the AP-IS supports cross-sectoral synergies with transport, energy and trade within an overall objective of promoting regional economic connectivity and facilitating the movement of people, goods, information, knowledge and money. ICT is a growth sector on its own but it also serves as the critical infrastructure to other sectors and enables various applications, such as intelligent transport systems, single windows, paperless trade and smart grid to name a few, thus making ICT connectivity a strategic initiative which shapes the future of the region.

Enhanced fibre-optic connectivity between ESCAP members provides positive externalities to other sectors of the economy. For instance, there is a strong positive correlation between broadband connectivity and international trade (e-commerce in particular) in the Asia-Pacific region. Therefore, enhanced cross-border fibre-optic connectivity not only bridges the digital divide in ESCAP countries that need it the most (such as LLDCs, LDCs and SIDS), but also facilitate trade exports contributing to the achievements of the Sustainable Development Goals.

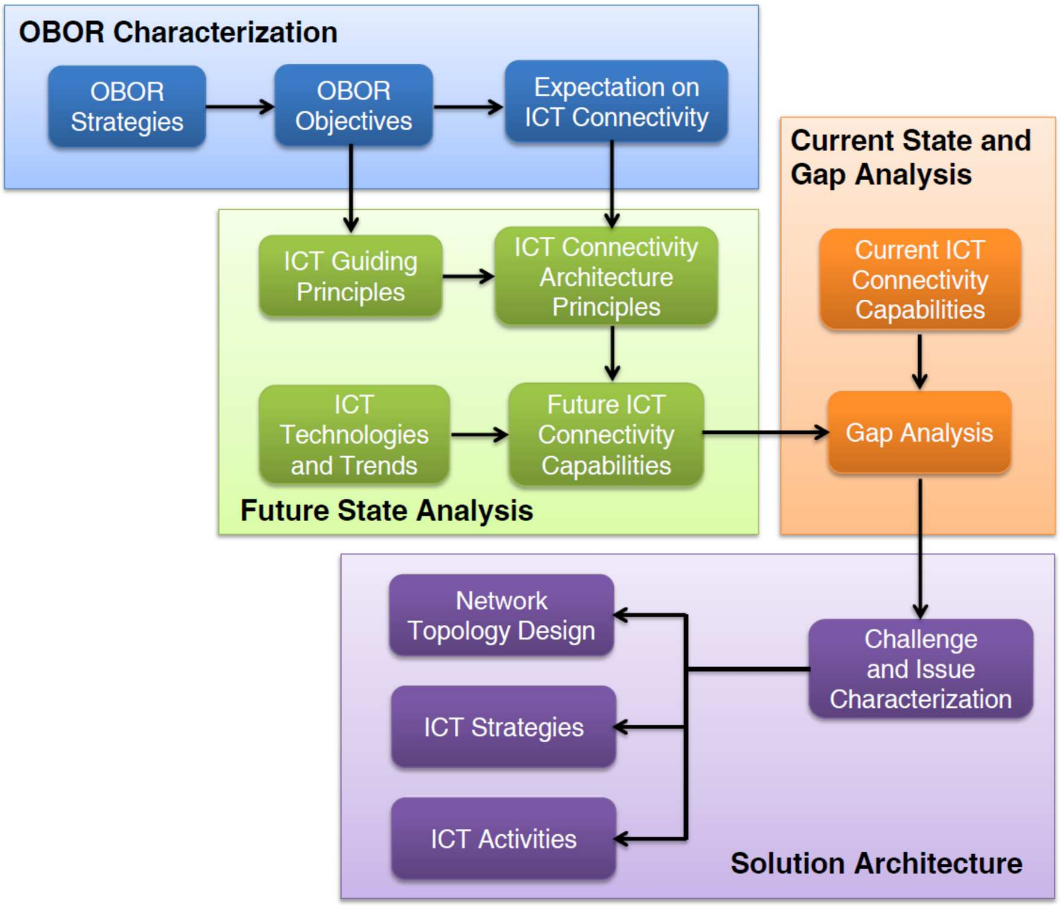
At the same time, ICT infrastructure also benefits from cross-sectoral synergies. As an AP-IS follow-up action initiated by the Government of Bangladesh, a request for the amendments to the Asian Highway and Railway Agreements was submitted to the ESCAP Secretariat. The amendments would facilitate the co-deployment of fibre-optic cables along highways and railways, thereby significantly reducing time and costs in developing broadband infrastructure.

To develop a single uniform ICT network and system across various counties associated with BRI, this study focuses first on ICT connectivity in all 6 Corridors and then narrows the focus to the China-Central Asia-West Asia Corridor. This study also provides the specific challenges and issues of ICT connectivity for BRI, and recommends ICT strategies/plans to fully support BRI initiative and ICT activities within the framework of BRI.

1.3 Approach and Methodology

The main approach used to study and analyze ICT Connectivity is the “Gap Analysis”. Gap analysis typically involves the comparative analysis between current state (As-Is) and future state (To-Be). For the purpose of this study, gaps between ICT connectivity will be identified, which could consequently lead to effective ICT strategic planning and network topology design. The methodology used to accomplish this work is divided into four major stages i.e. (1) BRI Characterization; (2) Future State Analysis; (3) Current State and Gap Analysis; and (4) Solution Architecture, as depicted in Figure 1-1.

Figure 1-1: Approach and Methodology



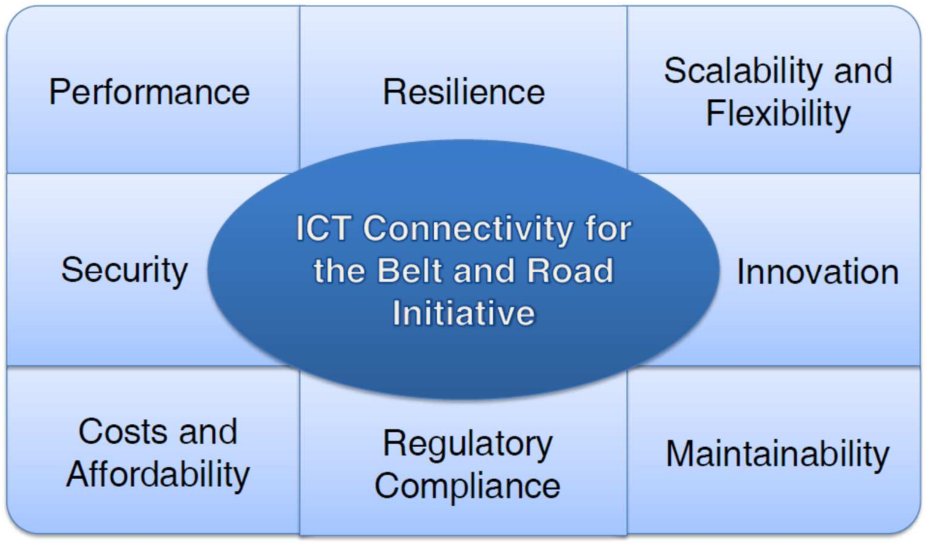
The first stage is intended to study and characterize the Belt and Road Initiative in order to understand both requirements and expectations on ICT connectivity for BRI itself. After all, the basic information with regard to the BRI initiative must be collected and studied in detail in order to clearly understand its strategies, objectives and expectations on ICT to effectively support the BRI initiative. This stage is essential stage to determine the future state of ICT connectivity for BRI in China-Central Asia corridor.

Once the requirements and expectations on ICT connectivity are obtained, the new/current ICT trends and technologies (including recommendations and best practices) are studied to identify the future ICT infrastructure and operation capabilities. These technologies/trends include (1) ICT infrastructure technologies to be used for inter- and intra-corridors ICT connectivity and (2) electronic application trends (e.g. e-government, e-commerce and so on) to be supported on top of ICT infrastructure.

The third stage is the system assessment to obtain the current state of ICT connectivity for BRI. All relevant documents or information required in this stage must be collected. Some examples include broadband penetration, Internet penetration, Internet prices, international links, cross-border fibre-optic cable, and so on.

Once both future and current states of ICT connectivity are clearly characterized, gap analysis could be applied to identify the gaps between the requirements/expectations on ICT connectivity and the results obtained from current state analysis. The framework for the main areas to be considered in studying of ICT connectivity for BRI is carefully developed, as shown in Figure 1-2. Thus, in this stage, challenges and issues on ICT connectivity among each economic corridor can also be clearly revealed.

Figure 1-2: Main areas in studying of ICT connectivity for BRI



After gap analysis is successfully carried out, the results obtained from this stage could be potentially used as baseline in the last stage (solution architecture) to formulate effective solutions for high-level architecture and technologies that meet and fulfill those requirements, and also bridge gaps between the current state and future state. This typically includes ICT strategies and activities which must be taken into account to successfully strengthen ICT connectivity for BRI.

2. ICT CORRIDORS UNDER BELT AND ROAD CHARACTERIZATION

2.1 ICT Corridor Overviews

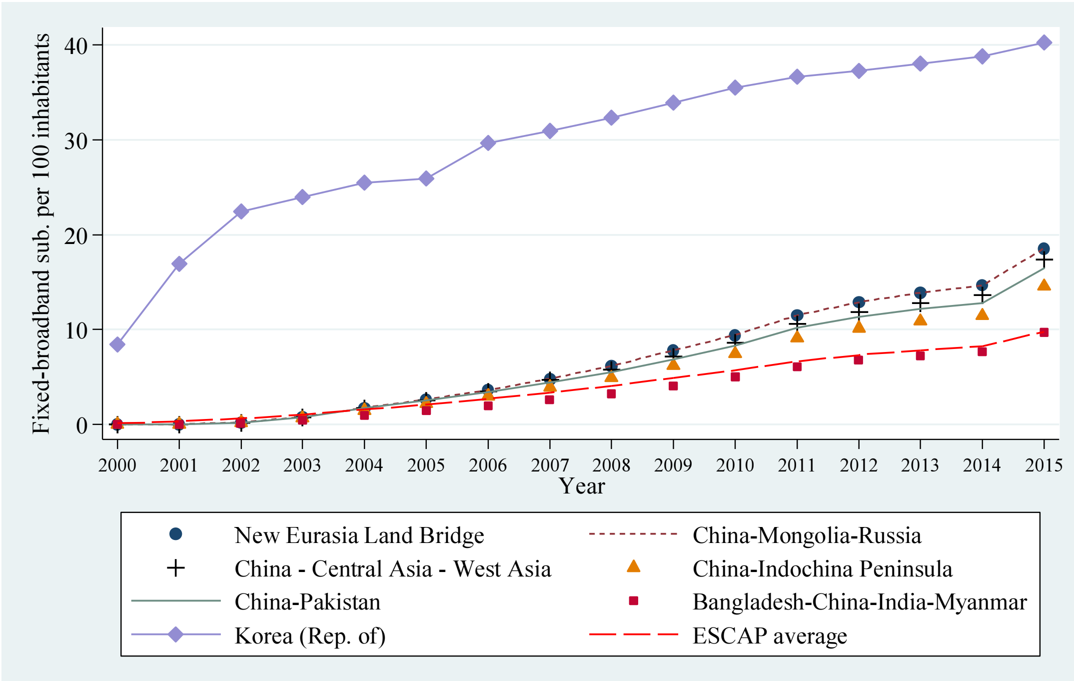
This chapter will review the characteristics of each corridor based on the latest ITU data for fixed broadband subscription and on the broadband growth projection developed by Terabit Consulting for an ESCAP report[3] in 2016, as an indication for broadband market size in the future and as a basis for this report's focus on the Central Asia-West Asia Corridor in the following chapters.

Figure 2-1 below demonstrates the current level of fixed broadband usage among countries along the 6 corridors, together with the ESCAP average and one for the Republic of Korea. While almost all the corridors appear above the ESCAP average, Figure 2-2 reveals that

[3] ESCAP (2016) Updated Analysis of the Broadband Infrastructure in Asia Pacific, ESCAP working paper series

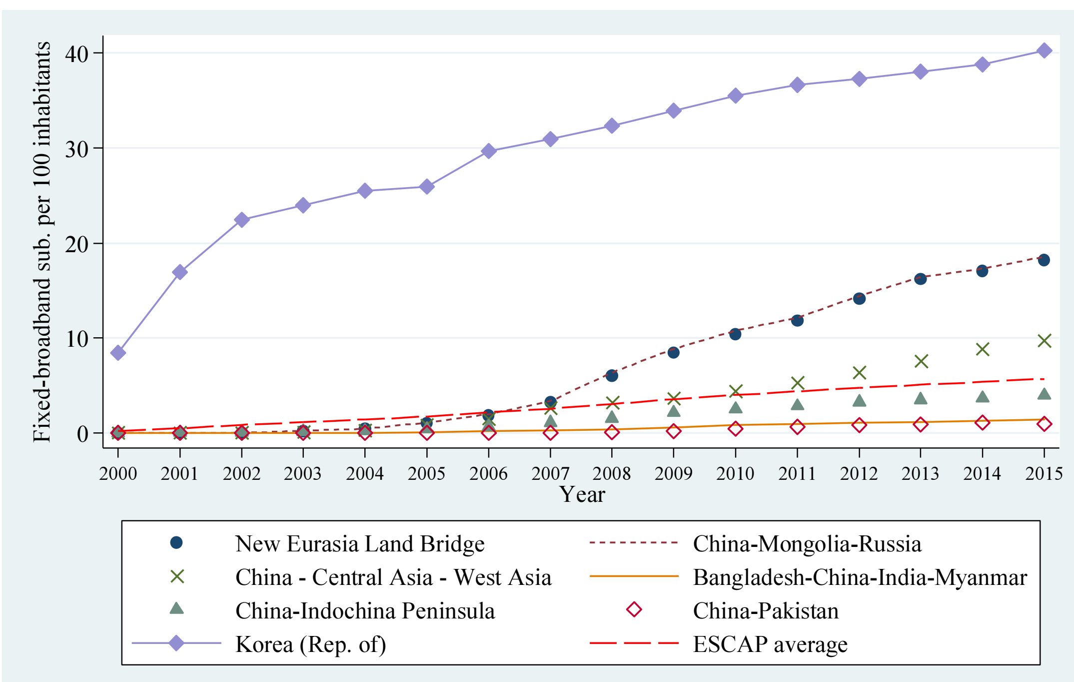
the the numbers have increased due to the growth in China and when China is excluded from the analysis, several corridors fall further below the ESCAP average.

Figure 2-1: Population weighted trends, by corridor (ESCAP countries only)



Source: ESCAP, based on ITU.

Figure 2-2: Population weighted trends, by corridor (ESCAP countries only, excluding China PR)



Source: ESCAP, based on ITU (2016)

According to the historical data and estimates by Terabit Consulting, international bandwidth[4] demand is expected to grow exponentially, which underlines the urgent need for building broadband connectivity along the 6 corridors. Table 2-1 below also demonstrates that some corridors, such as the China-Mongolia-Russia Corridor and New Eurasia Land Bridge Corridor, are expected to have higher corporate data[5] requirements than the other corridors.

Table 2-1: Medium-term international bandwidth demand projections[6] (2016-2020), by corridor

	Projected annual growth in international bandwidth demand 2016-2020	Projected Total growth in international bandwidth demand 2016-2020	Share of corporate data in international bandwidth demand 2016	Share of corporate data in international bandwidth demand 2020	Share of Internet in international bandwidth demand 2016	Share of Internet in international bandwidth demand 2020
China-Mongolia-Russia Corridor	+40.4 per cent	+286.3 per cent	31.4 per cent	35.0 per cent	68.2 per cent	64.8 per cent
New Eurasia Land Bridge Corridor	+38.3 per cent	+264.4 per cent	34.2 per cent	39.8 per cent	65.4 per cent	60.0 per cent
China-Central West-Asia Corridor	+47.1 per cent	+364.8 per cent	17.5 per cent	17.5 per cent	82.2 per cent	82.4 per cent
China-Pakistan Corridor	+40.1 per cent	+281.5 per cent	11.8 per cent	12.7 per cent	87.9 per cent	87.1 per cent
Bangladesh-China-India-Myanmar Corridor	+43.5 per cent	+341.9 per cent	12.5 per cent	12.5 per cent	86.9 per cent	87.2 per cent
China Indonesia Corridor	+46.3 per cent	+361.6 per cent	17.2 per cent	17.6 per cent	81.7 per cent	81.9 per cent

Source: ESCAP 2016

Broadband connectivity is a critical component for integration into the global value chain and online trade among other economic activities. Based on analysis conducted on available data on e-commerce, access to fixed broadband connectivity is found to be strongly correlated with e-commerce. Using UNCTAD's 2016 E-Commerce Index, it can be observed that e-commerce is strongly correlated (0.90) with access to fixed broadband connectivity (see

[4] Terabit Consulting defines international Internet bandwidth as activated downstream capacity carying Internet traffic. For example, if an operator or ISP activates a 10 Gbps link between Bangkok and Amsterdam for public IP transport, then it would be counted as a full 10 Gbps, even if the total traffic on it is only 6 Gbps during peak hour.

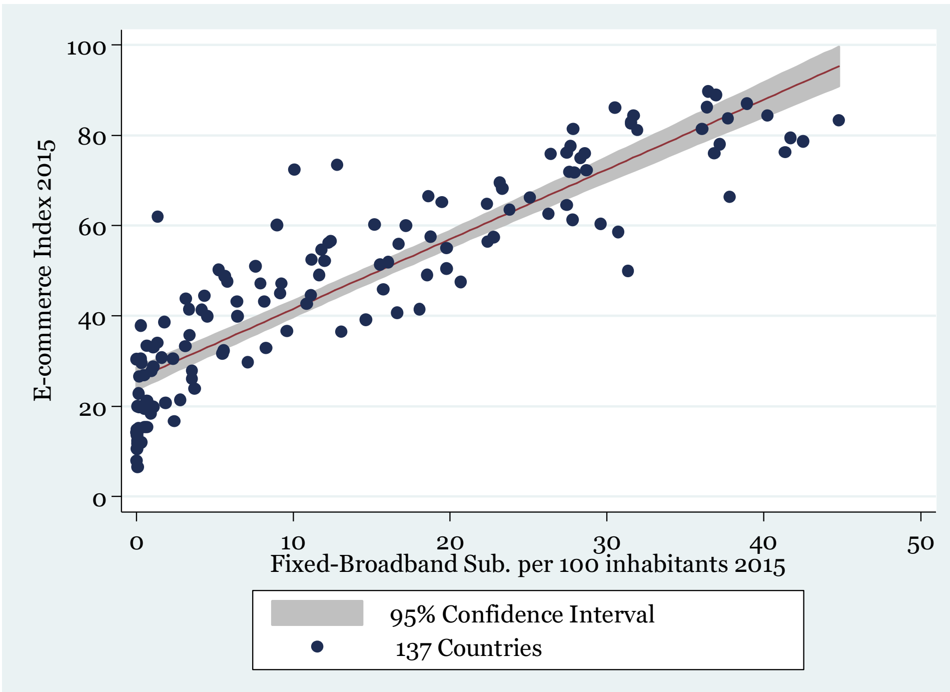
[5] This report follows the classification of data transmission type in the report entitled "Updated Analysis of the Broadband Infrastructure in Asia Pacific" for consistency purposes. The report is available at http://www.unescap.org/sites/default/files/Updated%20Analysis%20of%20Broadband%20Infrastructure%20in%20AP.pdf

[6] The details on international bandwidth estimation per country are found in the above mentioned report.

Figure 2-3), while the correlation between e-commerce and mobile broadband connectivity is less obvious.

This means that enhancing the ICT infrastructure connectivity will very likely increase B2B trade and e-commerce in Asia-Pacific countries. Moreover, smaller businesses stand to gain from the opportunities provided by e-commerce, such as a potentially global customer base.

Figure 2-3: E-commerce versus fixed broadband access, 2015

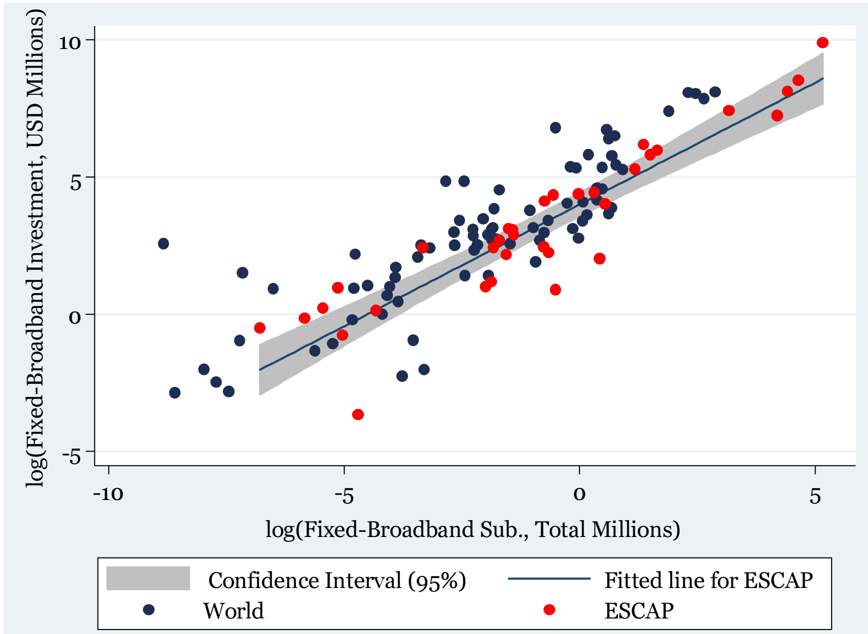


Sources: ESCAP estimates; UNCTAD B2C E-Commerce Index 2016; and fixed broadband per 100 sourced from ITU.

Using a panel dataset for the world with available data on investment and access between 2000 and 2015, a positive relationship is found for fixed broadband and mobile broadband, demonstrating the critical role of investment in infrastructure on increasing access to ICT. The positive correlation however, is stronger for the role of investment in fixed broadband subscriptions with a coefficient of (0.87) , statistically significant at $p<0.01$, more so than for mobile broadband, as illustrated in Figure 2-4.

The stronger and statistically positive relationship between investment and fixed broadband subscription provides support towards the important role of investing in costlier physical ICT infrastructure for fixed broadband networks, whereas mobile broadband in comparison might not require an equal level of infrastructure investment. The positive relationship between investment in the ICT infrastructure (fixed broadband and mobile broadband) and access is important in all countries of different income groups. While these trends highlight the important role of investing in ICT infrastructures to improve access, conducive government policies and regulations will continue to influence private telecom operators' investment in the ICT infrastructure.

Figure 2-4: The relationship between telecommunications investment and total fixed broadband subscriptions in 2000-2015.

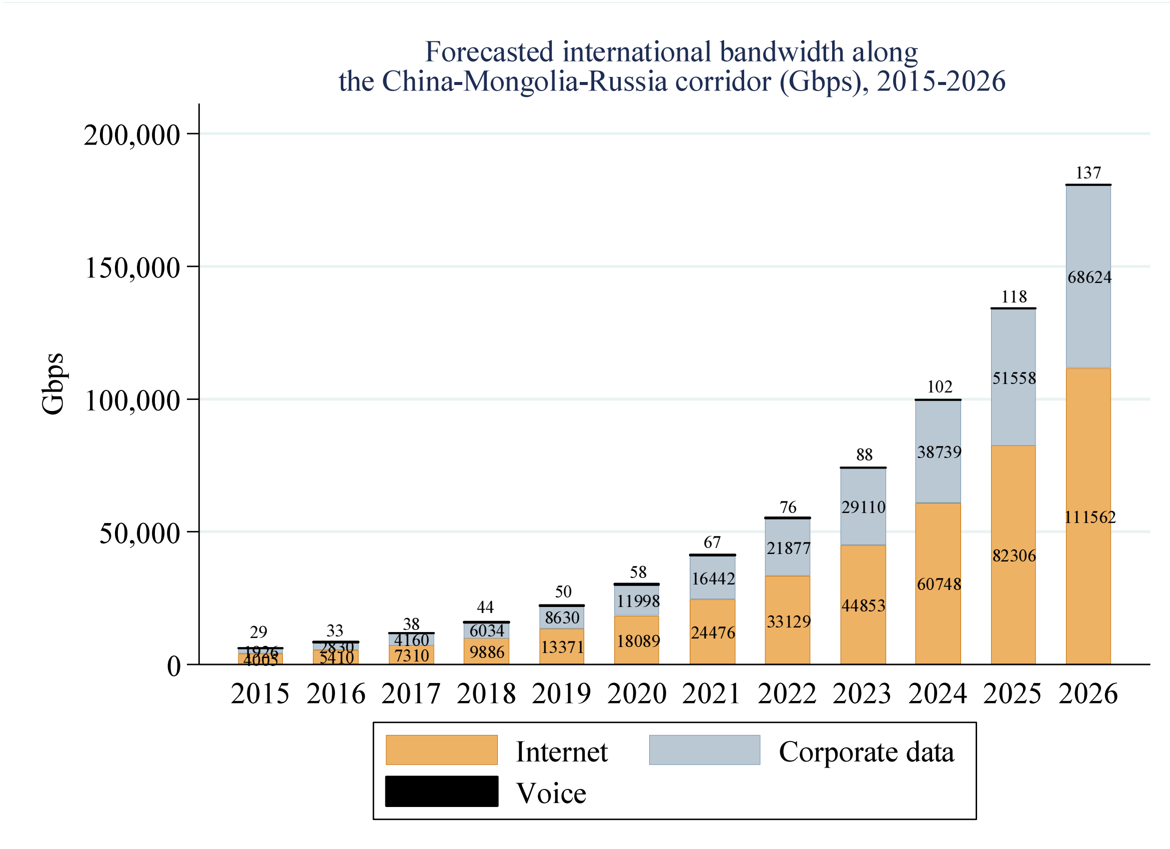


Source: Produced by ESCAP, based on data sourced from ITU World Telecommunications/ICT Indicators Database (accessed July 2016).

2.1.1. China-Mongolia-Russia Corridor

The international bandwidth demand is expected to grow from 33Gbps in 2016 to 58Gbps in 2020 – representing a 262 per cent increase - along the China-Mongolia-Russia Corridor (see Figure 2-5). The relative weight of corporate data in international bandwidth will also increase from 34.2 per cent in 2016 to 39.8 per cent in 2020.

Figure 2-5: Forecasted international bandwidth along the China-Mongolia-Russia corridor (Gbps), 2015-2026



Source: ESCAP (2016)

Table 2-2 below shows affordability as a percentage of GNI per capita using 2014 data for fixed telephone, mobile cellular and fixed broadband services among the countries along this corridor.

Table 2-2: China-Mongolia-Russia Corridor[7]

Country	IPB 2014[8]	Fixed telephone sub-basket as per cent of GNI per capita, 2014[9]	Mobile-cellular sub-basket as per cent of GNI per capita, 2014[10]	Fixed broadband sub-basket as per cent of GNI per capita, 2014[11]	GNI per capita, USD, 2014*	Rank[12]
China	1.7	0.9	0.7	3.6	6 553	67
Mongolia	1.6	1.5	1.0	2.3	3 766	61
Russian Federation	0.5	0.3	0.5	0.7	13 836	10

Source: ESCAP analysis based on the figures from "Measuring the Information Society Report 2015" published by ITU and the data for GNI in the World Development Indicators (2015).

In this background, various fibre-optic network projects have been in place along this corridor. One notable initiative that could support the availability of broadband services and increase the affordability is the Okha-Ust-Bolsheretsk cable. The first stage of the network went live in May 2016 and involved the deployment of 930km of fibre-optic cabling between Ola in Magadan and Okha (Sakhalin) in the Russian Federation. The whole system – which is now scheduled to enter into commercial operation in Q1 2017 – will span 2,000km and have a total capacity of 400Gbps, with the option to expand to up to 8Tbps in the future[13].

2.1.2. New Eurasia Land Bridge Corridor

The New Eurasia Land Bridge Corridor is expected to experience an exponential increase in international bandwidth as illustrated in Figure 2-6, which presents forecasted trends based on historical data. The demand is expected to grow at an annual rate of 40.4 per cent on average from 2016 to 2020. The share of corporate data in total international bandwidth will also grow from 19.5 per cent in 2016 to 35 per cent in 2020.

[7] Definitions are found at http://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2015/MISR2015-w5.pdf

[8] The ICT Price Basket (IPB) represents a composite basket that includes three price sets, fixed-telephone, mobile-cellular and fixed-broadband sub-baskets, calculated from the sum of the price of each sub-basket as a % of a country's monthly GNI p.c., divided by three.

[9] The fixed-telephone sub-basket is a monthly price charged for subscribing to the public switched telephone network (PSTN), plus the cost of 30 three-minute local calls to the same network (15 peak and 15 offpeak calls), calculated as a % of a country's average monthly GNI p.c..

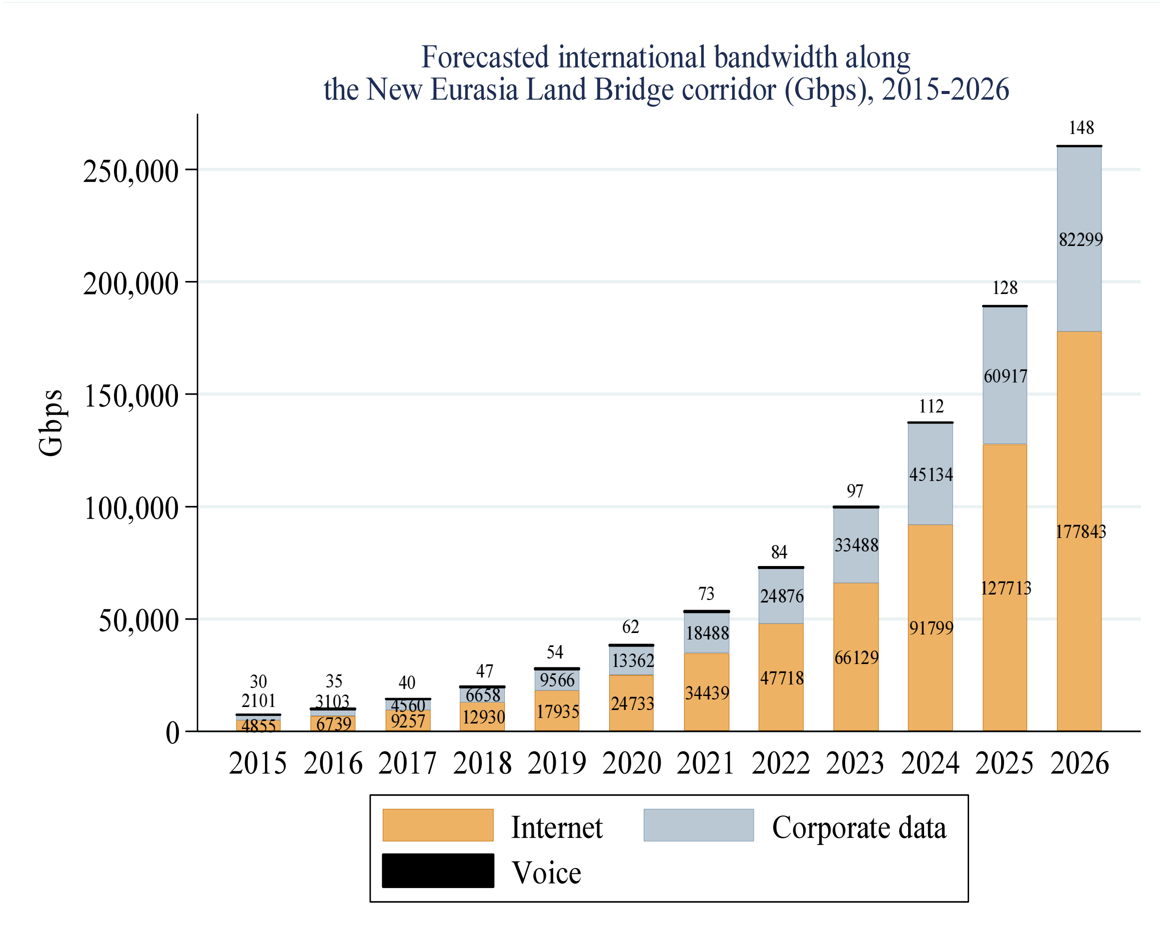
[10] The mobile-cellular sub-basket is the price of a standard basket of mobile monthly usage for 30 outgoing calls per month and 100 SMS messages, calculated as a % of a country's average monthly GNI p.c.

[11] The fixed-broadband sub-basket is the price of a monthly subscription to an entry level fixed-broadband plan, calculated as a % of a country's average monthly GNI p.c.

[12] From "Measuring the Information Society Report 2015", p.140.

[13] TeleGeogrpahy (2016, June). Available from: https://www.telegeography.com/products/commsupdate/articles/2016/06/10/cable-compendium-a-guide-to-the-weeks-submarine-and-terrestrial-developments/

Figure 2-6: Forecasted international bandwidth along the New Eurasia Land Bridge corridor (Gbps), 2015-2026[14]



Source: ESCAP (2016)

The affordability of various telecommunication services along this corridor is shown in the Table 2-3.

Table 2-3: New Eurasia Land Bridge Corridor

Country	IPB 2014	Fixed telephone sub-basket as per cent of GNI per capita, 2014	Mobile-cellular sub-basket as per cent of GNI per capita, 2014	Fixed broadband sub-basket as per cent of GNI per capita, 2014	GNI per capita, USD, 2014*	Rank
China	1.7	0.9	0.7	3.6	6 553	67
Kazakhstan	0.8	0.3	0.9	1.1	11 538	23
Russian Federation	0.5	0.3	0.5	0.7	13 836	10
Belarus			non ESCAP member			
Germany			non ESCAP member			
Poland			non ESCAP member			
EU			non ESCAP member			

[14] Excludes Germany (+ EU), Belarus and China PR

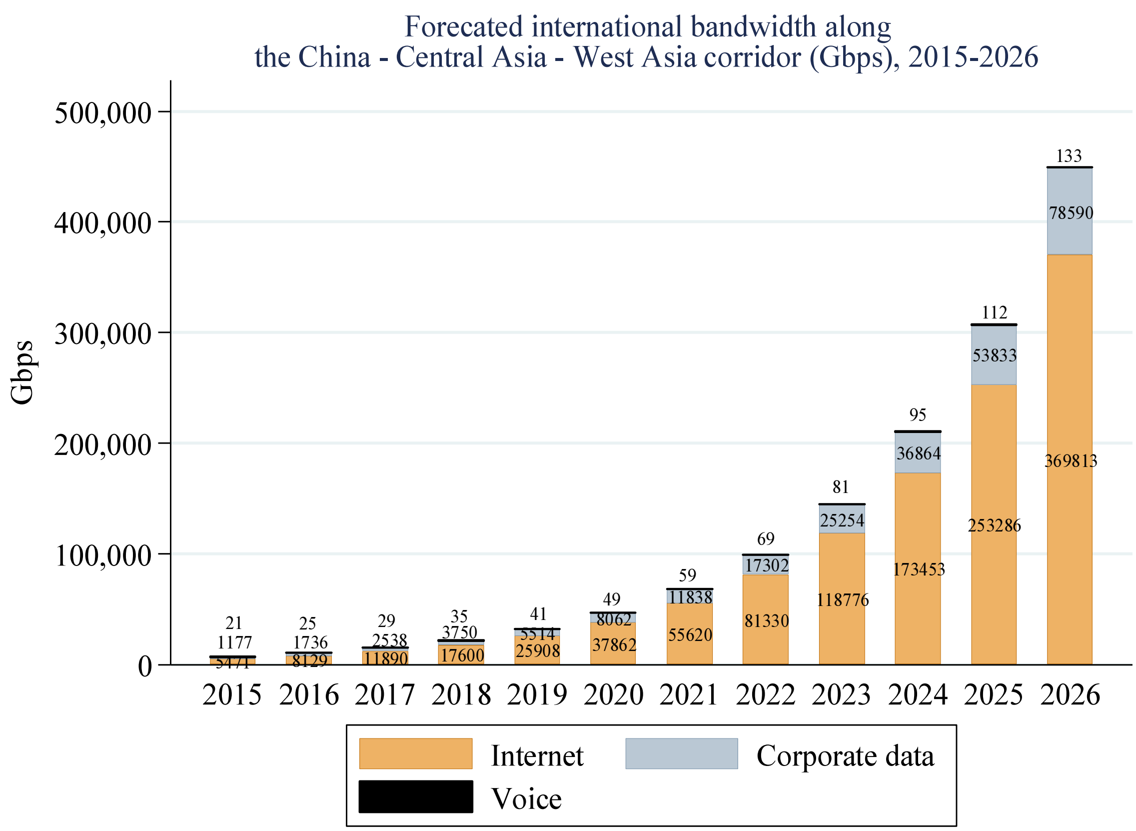
Source: ESCAP analysis based on the figures from "Measuring the Information Society Report 2015" published by ITU and the data for GNI in the World Development Indicators (2015).

Some of the major terrestrial infrastructure initiatives are highlighted below under the China-Central Asia-West Asia Corridor.

2.1.3. China-Central Asia-West Asia Corridor

A forecasted increase in international bandwidth is also expected in the China-Central-Asia-West Asia Corridor. International bandwidth in Gbps is expected to grow by 364.5 per cent from 2016 to 2020 (see Figure 2-7). Corporate data is forecasted to account for approximately 17.5 per cent of total international bandwidth for the period 2016-2020, while the rest will be Internet bandwidth.

Figure 2-7: Forecasted international bandwidth along the China-Central Asia-West Asia Corridor (Gbps), 2015-2026



Source: ESCAP (2016)

Table 2-4 shows that Central Asian countries are estimated to have lower affordability in various telecommunications services than in countries of other corridors, although the comparative figures are not available for Tajikistan, Uzbekistan and Turkmenistan.

Table 2-4: China-Central West-Asia Corridor

Country	IPB 2014	Fixed telephone sub-basket as per cent of GNI per capita, 2014	Mobile-cellular sub-basket as per cent of GNI per capita, 2014	Fixed broadband sub-basket as per cent of GNI per capita, 2014	GNI per capita, USD, 2014*	Rank
China	1.7	0.9	0.7	3.6	6 553	67
Kazakhstan	0.8	0.3	0.9	1.1	11 538	23
Kyrgyzstan	5.6	1.2	4.9	10.7	1 209	117
Tajikistan	Not included in the dataset					
Uzbekistan	Not included in the dataset					
Turkmenistan	Not included in the dataset					
Iran	0.5	0.1	0.4	0.9	5 774	7
Turkey	1.6	1.2	2.5	1.1	10 959	63
Greece	non ESCAP member					
EU	non ESCAP member					

Source: ESCAP analysis based on the figures from "Measuring the Information Society Report 2015" published by ITU and the data for GNI in the World Development Indicators (2015).

In order to increase availability and affordability of telecommunication services, various fibre-optic cable networks have been planned and implemented along this corridor as highlighted below in Table 2-5.

Table 2-5: Main fibre-optic network projects along the China-Central Asia-West Asia Corridor

Title	Description	Type	ESCAP Countries	Completion
Turkmenistan deployed new national backbone network	The Ministry of Communications of Turkmenistan has deployed a new national backbone network that connects all major cities of Turkmenistan with cross-border transit and subsea transmission links. The network has a total system capacity of up to 9.6Tbps per fibre pair[15]. The new network deployment is expected to support the growing demand for backbone capacity driven by high-bandwidth end-user services and applications, including LTE, mobile backhaul, e-government and residential Internet access.	Terrestrial	*Turkmenistan*	July 2016

[15] TeleGeography (2016, July). Available from: https://www.telegeography.com/products/commsupdate/articles/2016/07/15/cable-compendium-a-guide-to-the-weeks-submarine-and-terrestrial-developments/

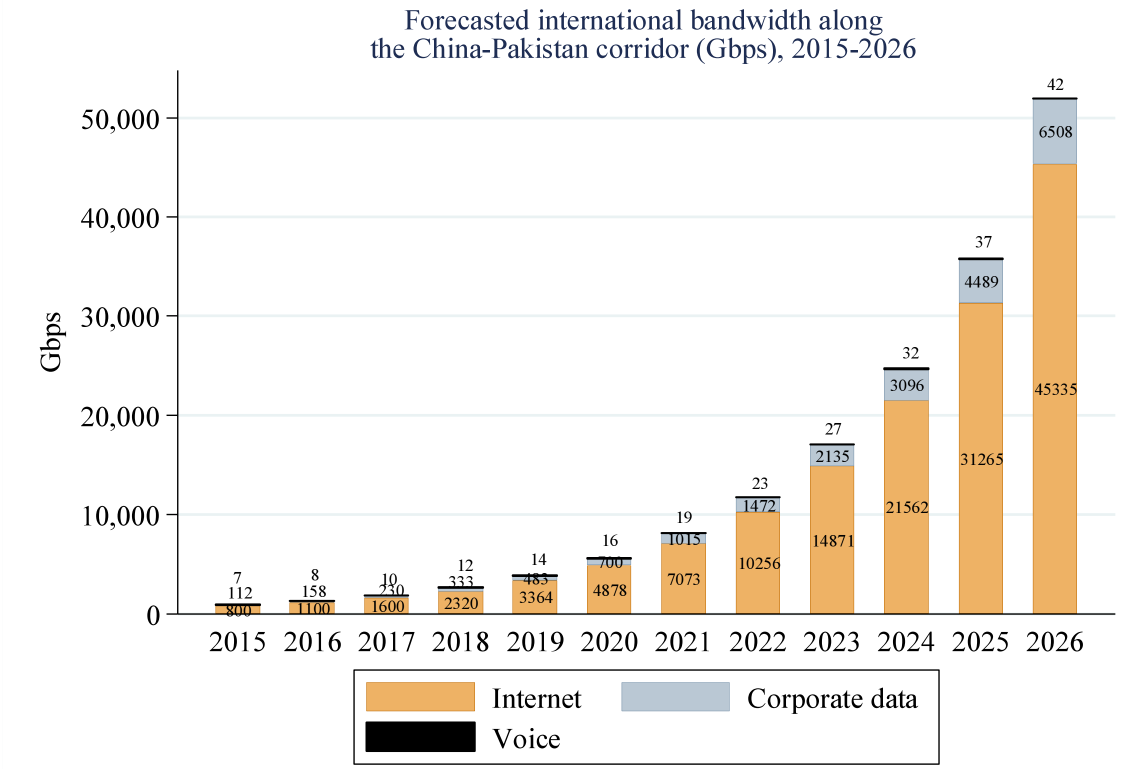
Silk Road Gateway 1 cable system linking Pakistan and Oman to be ready in 2017	Telecommunications companies Omantel and Multinet Pakistan announced that they are working on a 20Tbps submarine cable network linking Pakistan and Oman[16]. The network will connect Karachi with Muscat (with a planned future extension to Gwadar in Pakistan) and titled Silk Route Gateway 1 (SRG1). After completion, Pakistan would get around 200Gbps of extra bandwidth. The 1030km 20Tbps SRG1 is said to have onwards connectivity to Afghanistan, China, Iran, Turkmenistan and Tajikistan[17].	Submarine	*Pakistan, Afghanistan, China, Iran (I.R.), Turkmenistan, Tajikistan*	Q4 2017
Construction of terrestrial link between Kyrgyz Republic and China completed	The chairman of Kyrgyzstan's State Committee for ITC has revealed that construction work on an alternative fibre-optic route linking Kyrgyzstan and China has been completed. The Naryn-Torugart network is the second alternative route build by RTC and China Telecom, in addition to the in-operation Bishkek-Osh route. The two companies are understood to now be planning to deploy a third diverse fibre-optic route, linking Balykchy and Naryn[18].	Terrestrial	*China, Kyrgyz Republic*	Not disclosed

2.1.4. China-Pakistan Corridor

As far as the China-Pakistan Corridor is concerned, the total international bandwidth is projected to grow at 43.5 per cent on average each year between 2016 and 2020 (see Figure 2-8). The percentage of corporate data in international bandwidth will remain around 12.5 per cent during the same period.

[16] Capacity Media (2016, May). Available from: http://www.capacitymedia.com/Article/3552917/Omantel-and-Multinet-Pakistan-announce-Silk-Route-Gateway.html
[17] Times of Oman (2016, November). Available from: http://timesofoman.com/article/95534/Business/Omantel-connects-Africa-to-Asia-with-subsea-cable-systems
[18] TeleGeography (2017, January). Available from: https://www.telegeography.com/products/commsupdate/articles/2017/01/13/cable-compendium-a-guide-to-the-weeks-submarine-and-terrestrial-developments/

Figure 2-8: Forecasted international bandwidth along the China-Pakistan Corridor (Gbps), 2015-2026[19]



Source: ESCAP (2016)

Table 2-6: China-Pakistan Corridor

Country	IPB 2014	Fixed telephone sub-basket as a per cent of GNI per capita, 2014	Mobile-cellular sub-basket as per cent of GNI per capita, 2014	Fixed broadband sub-basket as a per cent of GNI per capita, 2014	GNI per capita, USD, 2014*	Rank
China	1.7	0.9	0.7	3.6	6 553	67
Pakistan	3.8	5.2	1.9	4.4	1 359	105

Source: ESCAP analysis based on the figures from "Measuring the Information Society Report 2015" published by ITU and the data for GNI in the World Development Indicators (2015).

Pakistan is projected to benefit from the below mentioned submarine cable projects, in addition to the terrestrial cable networks being extended from China.

[19] Excludes China

Table 2-7: Main fibre-optic network projects along the China-Pakistan Corridor

Title	Description	Type	ESCAP Countries	Completion
SEA-ME-WE-5 submarine cable completed connecting 18 countries	Developed by a consortium comprising of telcos from 18 countries throughout South-East Asia, Middle East and Western Europe, the SEA-ME-WE 5 project launch event was held in January 2017, after finalizing completion in late 2016. The 20,000km cable system uses 100Gbps technology and has a design capacity of 24Tbps, addressing the heightened demand between Asia and Europe[20]. Construction began in 2014 and the system is said to provide a sevenfold capacity increase along the corridor connecting Southeast Asia, the Middle East and Western Europe[21].	Submarine	*Singapore, Malaysia, Indonesia, Myanmar, Sri Lanka, Pakistan*	January 2017
Silk Road Gateway 1 cable system linking Pakistan and Oman to be ready in 2017	Telecommunications companies Omantel and Multinet Pakistan announced that they are working on a 20Tbps submarine cable network linking Pakistan and Oman[22]. The network will be connecting Karachi with Muscat (with a planned future extension to Gwadar in Pakistan) and titled Silk Route Gateway 1 (SRG1). After the completion, Pakistan would get around 200Gbps of extra bandwidth. The 1030km 20Tbps SRG1 is said to have onwards connectivity to Afghanistan, China, Iran, Turkmenistan and Tajikistan[23].	Submarine	*Pakistan, Afghanistan, China, Iran (I.R.), Turkmenistan, Tajikistan*	Q4 2017
Pakistan upgraded Transworld (TW1) submarine cable connecting to UAE and Oman	In April 2016, Pakistani connectivity provider TransWorld Associates (TWA) has contracted equipment vendor Huawei Marine to upgrade its 1,300km Transworld (TW1) submarine cable connecting Pakistan with United Arab Emirates (UAE) and Oman. It is a 100G upgrade and enables a future upgrade to 400G or 1TB[24]. In July 2016, TWA has	Submarine	*Pakistan*	July 2016

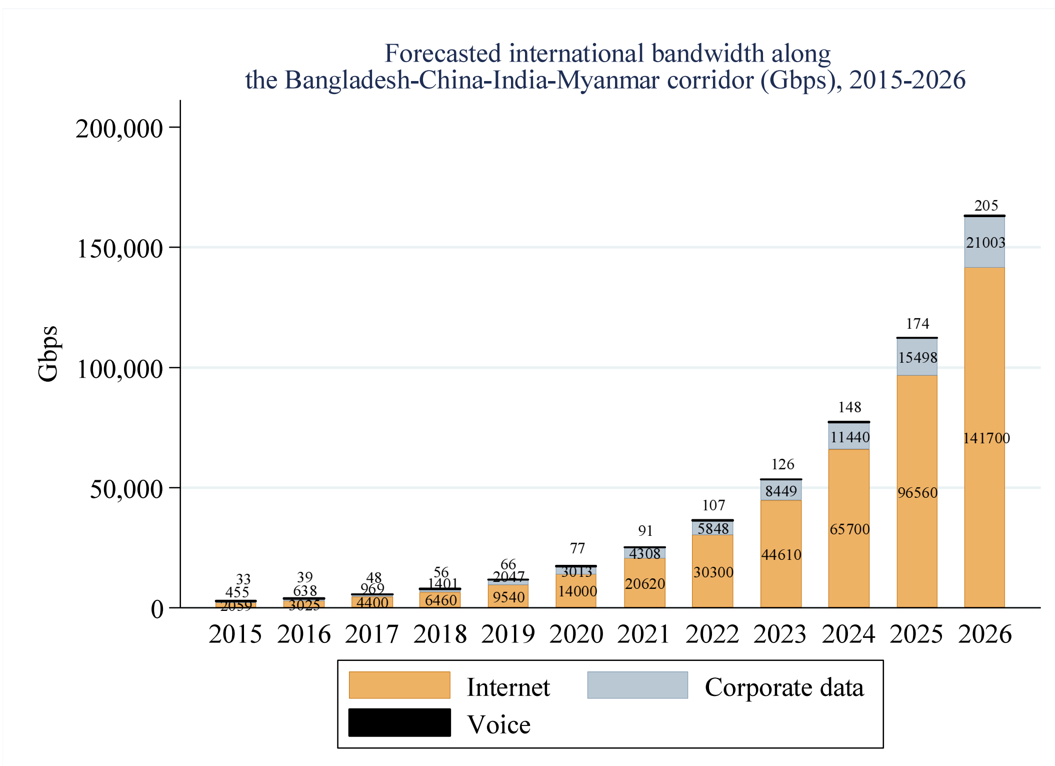
[20] Digital News Asia (2017, January). Available from: https://www.digitalnewsasia.com/digital-economy/south-east-asia%E2%80%93middle-east%E2%80%93western-europe-5-consortium-completes-submarine-cable
[21] Channel News Asia (2016, March). Available from: http://www.channelnewsasia.com/news/business/singapore/singtel-completes-landing/2590174.html
[22] Capacity Media (2016, May). Available from: http://www.capacitymedia.com/Article/3552917/Omantel-and-Multinet-Pakistan-announce-Silk-Route-Gateway.html
[23] Times of Oman (2016, November). Available from: http://timesofoman.com/article/95534/Business/Omantel-connects-Africa-to-Asia-with-subsea-cable-systems
[24] Subtel Forum (2016, April). Available from https://subtelforum.com/articles/technology-upgrades/twa-contracts-huawei-marine-for-100g-upgrade-on-tw1.html

reportedly completed the 100G upgrade of the undersea cable TW1[25].

2.1.5. Bangladesh-China-India-Myanmar Corridor

The Bangladesh-China-India-Myanmar Corridor is expected to experience a dramatic increase in international bandwidth requirements in the coming years. On average, the annual growth rate is projected to be 46.3 per cent from 2016 to 2020. In other words, international bandwidth expressed in Gbps is expected to be 4.7 times higher in 2020 compared to 2016 (see Figure 2-9). The share of corporate data in international bandwidth is forecasted to modestly increase from 17.2 per cent in 2016 to 17.8 per cent in 2020.

Figure 2-9: Forecasted international bandwidth along the Bangladesh-China-India-Myanmar Corridor (Gbps), 2015-2026[26]



Source: ESCAP (2016)

[25] Propakistani (2016, July). Available from https://propakistani.pk/2016/07/01/transworld-completes-100g-upgrade-of-its-tw1-undersea-cable/

[26] Excludes China

Besides innovative national initiatives, such as Digital Bangladesh, the countries along the corridor will benefit from additional fibre-optic network investment to increase availability and affordability of broadband services.

Table 2-8: Bangladesh-China-India-Myanmar Corridor

Country	IPB 2014	Fixed telephone sub-basket as a per cent of GNI per capita, 2014	Mobile-cellular sub-basket as per cent of GNI per capita, 2014	Fixed broadband sub-basket as a per cent of GNI per capita, 2014	GNI per capita, USD, 2014*	Rank
China	1.7	0.9	0.7	3.6	6 553	67
Bangladesh	3.3	3.0	1.7	5.3	1 009	98
India	3.1	1.9	2.1	5.3	1 568	97
Myanmar	*Not included in the dataset*					

Source: ESCAP analysis based on the figures from "Measuring the Information Society Report 2015" published by ITU and the data for GNI in the World Development Indicators (2015).

Table 2-9: Main fibre-optic network projects along the China-Bangladesh-India-Myanmar Corridor

Title	Description	Type	ESCAP Countries	Completion
Thailand CAT Telecom and Indian Tata Communications sign MoU for submarine cable partnership	In June 2016 it was announced that CAT Telecom and Indian telecom giant Tata Communication will sign a memorandum of understanding for a submarine cable partnership. CAT plans to expand its international coverage and capacity to support its business and promote the development of the digital economy in Thailand, while Tata wants cost effective scalable solutions for connectivity between Thailand and neighboring countries[27].	Submarine and general cooperation	*Thailand, India*	Not applicable
Investment in terrestrial cable between India and Myanmar	Indian operator Bharti Airtel has announced that a terrestrial fibre-optic cable link between India and Myanmar has gone live[28]. The telco has invested an undisclosed sum in the 6,500km (route km) terrestrial fibre-optic cable, which is reportedly connected to Airtel's landing stations in Chennai and Mumbai[29].	Terrestrial	*India, Myanmar*	December 2016

[27] The Nation (2016, June). Available from http://www.nationmultimedia.com/news/business/corporate/30288354

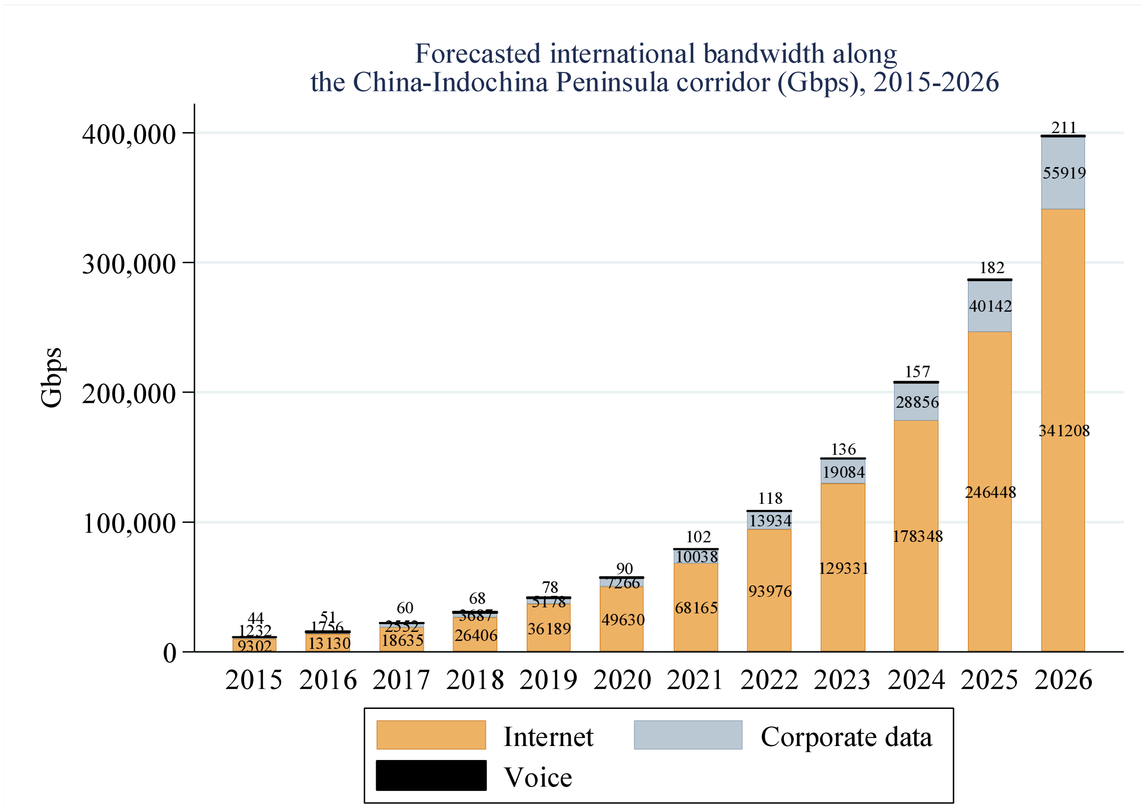
[28] Bharti Airtel (2016, December). Available from: http://www.airtel.in/about-bharti/media-centre/bharti-airtel-news/enterprise/airtel+s+india-myanmar+terrestrial+fiber+link+goes+live

[29] The Economic Times (2016, December). Available from http://economictimes.indiatimes.com/tech/internet/airtel-starts-india-myanmar-fibre-optic-link/articleshow/55882695.cms

2.1.6. China-Indochina Corridor

From 2016 to 2020, international bandwidth demand is forecasted to increase by 281.5 per cent in the China-Indochina Peninsula Corridor, which represents a 40.1 per cent average annual increase (see Figure 2-10). The percentage of corporate data in international bandwidth is expected to remain at a stable level for the period 2016-2020, fluctuating between 11.8 per cent and 12.8 per cent.

Figure 2-10: Forecasted international bandwidth along the China-Indochina Peninsula Corridor (Gbps), 2015-2026[30]



Source: ESCAP (2016)

The Corridor is also characterized by a digital divide among countries as illustrated in Table 2-10. Some countries such as Singapore enjoy affordable telecommunications services, while Cambodia and Lao PDR may need further investment in fibre-optic networks.

[30]Excludes China

Table 2-10: China Indonesia Corridor

Country	IPB 2014	Fixed telephone sub-basket as per cent of GNI per capita, 2014	Mobile-cellular sub-basket as per cent of GNI per capita, 2014	Fixed broadband sub-basket as per cent of GNI per capita, 2014	GNI per capita, USD, 2014*	Rank
China	1.7	0.9	0.7	3.6	6 553	67
Thailand	2.2	1.3	1.8	3.6	5 335	79
Viet Nam	2.1	1.2	3.1	2.0	1 738	75
Lao PDR	6.3	3.9	3.1	11.8	1 449	122
Cambodia	8.7	4.8	8.6	12.6	949	134
Myanmar			*Not included in the dataset*			
Malaysia	1.6	1.0	0.7	3.1	10 420	62
Singapore	0.4	0.2	0.2	0.7	53 986	3
Indonesia	2.0	1.2	1.7	3.1	3 576	72

Source: ESCAP analysis based on the figures from "Measuring the Information Society Report 2015" published by ITU and the data for GNI in the World Development Indicators (2015).

The major initiatives identified for this Corridor are submarine based networks. However, in order to address the aforementioned disparities in availability and affordability of broadband services, terrestrial networks would be required.

Table 2-11: Main fibre-optic network projects along the China-Indochina Corridor

Title	Description	Type	ESCAP Countries	Completio n
The Asia-Africa-Europe-1 (AAE-1) subsea cable system nearing completion	The 25,000km network with a design capacity of 40Tbps will connect Asia, the Middle East, East Africa and Europe. The Asia Africa Europe-1 (AAE-1) consortium has confirmed 19,000km has already been laid and 15 shore-end landings installed and is in the last phase of construction[31]. AAE-1 will connect Hong Kong, Vietnam, Cambodia, Malaysia, Singapore, Thailand, Myanmar, India, Pakistan, Oman, UAE, Qatar, Yemen, Djibouti, Saudi Arabia, Egypt, Greece, Italy and France. It has two diversified points of presence (PoPs) in Asia (terminating in Hong Kong and Singapore at carrier neutral data centers) and three onward connectivity options in Europe via Greece, Italy and France.	Submarine	*Hong Kong (China), Viet Nam, Cambodia, Thailand, Malaysia, Singapore, Myanmar, India, Pakistan*	Q1 2017

[31] Capacity Media (2016, October). Available from: http://www.capacitymedia.com/Article/3593859/Europe/AAE-1-enters-last-phase-ahead-of-2017-launch.html

Backbone ring throughout Greater China's major cities established	DYXnet Group has established a 10Gbps backbone ring throughout Greater China's major cities including Beijing, Guangzhou, Hong Kong, Shanghai and Taipei. The carrier-neutral network service now has more than 200 points of presence in 57 cities throughout Greater China, Singapore, and Vietnam[32]. Two other points of presence are planned for Silicon Valley in the US and Frankfurt in Germany in the next 6 to 12 months (after July 2016).	Terrestrial	*Hong Kong (China), China, Singapore, Viet Nam*	July 2016
Asia-Pacific Gateway submarine cable in operation	The Asia Pacific Gateway (APG) began operations in late December 2016 and was officially launched in January 2017 after four years of construction. The APG boasts a capacity of 54Tbps and has a total length of 10,400km connecting mainland China, Hong Kong, Taiwan, Japan, the Republic of Korea, Malaysia, Singapore, Thailand and Viet Nam[33].	Submarine	*Viet Nam, Japan, Hong Kong (China), China, Singapore, Malaysia, Taiwan (China), Republic of Korea, Thailand*	January 2017
Malaysia-Cambodia-Thailand (MCT) cable system to be operational in Q1 2017	The 1,300km Malaysia-Cambodia-Thailand (MCT) subsea cable system with an initial design capacity of 1.5Tbps is expected to be completed and in service by Q1 2017[34]. The cable system consists of three fiber pairs which will link all three countries at their respective cable landing stations at Cherating, Malaysia, Rayong, Thailand, and Sihanoukville in Cambodia.	Submarine	*Malaysia, Cambodia, Thailand*	Q1 2017

As illustrated above, each Corridor has a different combination of attributes. The Pakistan-China Corridor has attracted several planned and onoing ICT connectivity projects and investments, while the China-Mongolia-Russian Federation Corridor as well as the New Eurasia Land Bridge Corridor have benefitted from better affordability. The China-Indochina Corridor is also supported through various ASEAN connectivity initiatives and regional cooperation. When comparing the China-Central Asia-West Asia Corridor and the Bangladesh-China-India-Myanmar Corridor, it is clear that the former needs more systematic support in the

[32] Global Telecoms Business (2016, July). Available from: http://www.globaltelecomsbusiness.com/article/3573421/DYXnet-establishes-10Gbps-backbone.html#/.WKK3lfJH6Lc
[33] Vietnam Net (2017, January). Available from: http://english.vietnamnet.vn/fms/science-it/170820/submarine-internet-link-completed.html
[34] Capacity Media (2016, December). Available from: http://www.capacitymedia.com/Article/3648466/Infrastructure-and-Networks/MCT-cable-system-to-be-in-service-by-Q1-2017.html

number and capacity of new ICT connectivity initiatives as well as the need for increased affordability. In this context, this report focuses on proposed support BRI can render to the China-Central Asia-West Asia Corridor with the aim to improve ICT connectivity in China, Central Asia and West Asia to Europe, thus providing redundancy and alternative routes to trans-Pacific submarine cable systems. In addition, this report also considers inter-corridor aspects with neighboring corridors in designing network topology in China-Central Asia-West Asia.

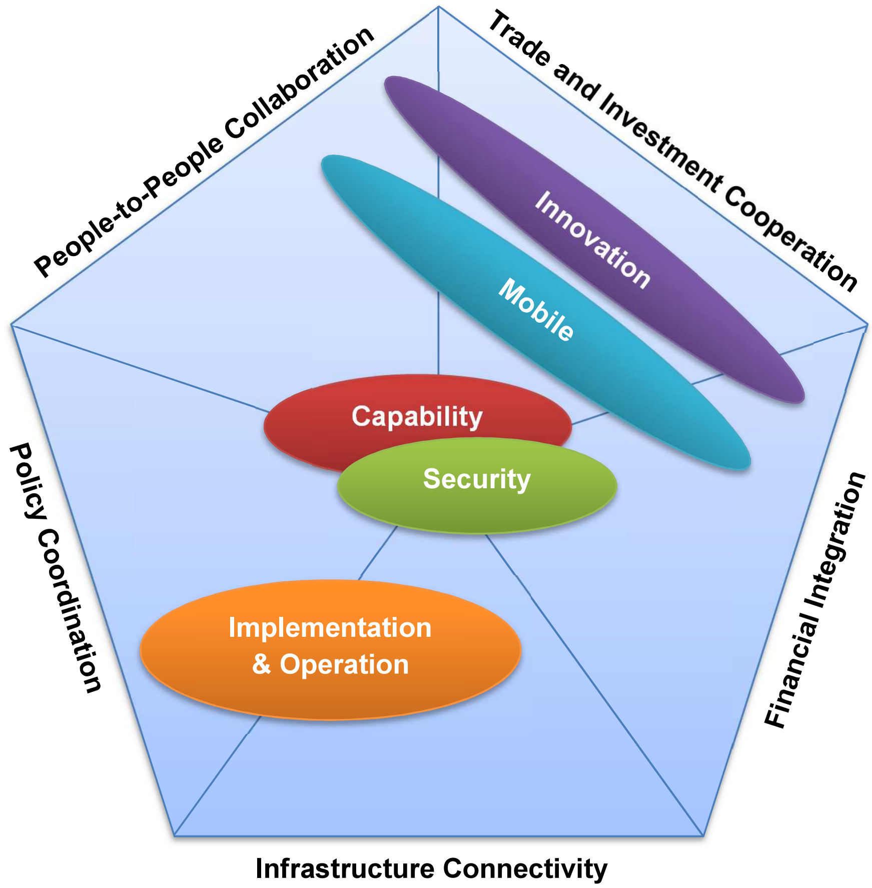
2.3 Expectations on ICT to Support BRI

This BRI initiative is aimed at creating and maintaining connectivity and collaboration among countries along the Belt and Road. Furthermore, to effectively study and conduct comparative analysis on ICT connectivity for BRI especially in the China-Central Asia corridor, its vision and objectives should be firstly characterized as discussed in the following.

To obtain the principles for ICT architecture design solutions for the BRI in China-Central Asia corridor, expectations of ICT should be clearly defined to understand the requirements and technical goals for ICT connectivity to fully support BRIFor the sake of simplicity, the key ICT areas considered in this study (see Figure 1-2) are regrouped into five areas which are capability (performance, resilience, and scalability), security, innovation, mobile (flexibility), and implementation and operation (maintainability, cost and affordability, and regulatory compliance).

Subsequently, Figure 2-11 depicts the ICT areas that must be considered in order to achieve BRI objectives. To accomplish each objective, efficient information sharing and effective communications among people/organizations/countries are required. Hence, both ICT capability and ICT security are fundamental areas for creating trust and allowing people (both consumers and business users) and organizations to effectively exchange valuable information. Innovation and technologiesare also required to bring the new form of communications to support and facilitate people, trade and investment, and financial collaborations; whereas implementation and operation are also the important keys to maintain infrastructure connectivity and policy coordination.

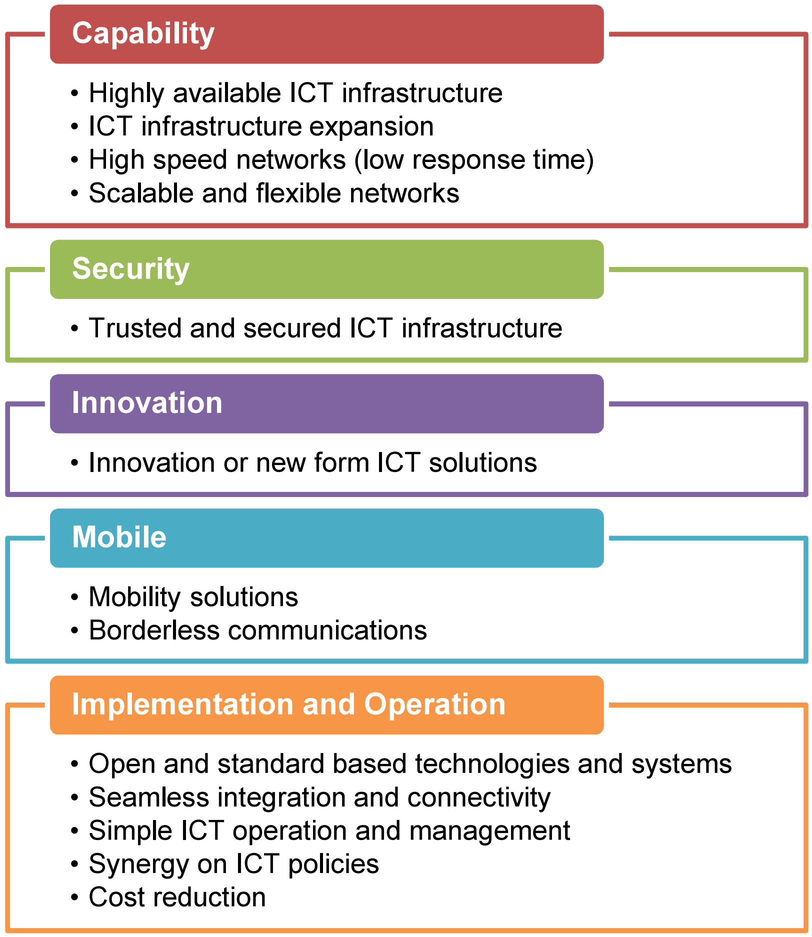
Figure 2-11: Relationship between BRI objectives and ICT areas



From the five key areas identified above, the expectations on ICT connectivity or technical goals in ICT connectivity can be carefully extracted to fully support the BRI initiative and effectively fulfill its objectives as discussed in the Figure 2-12 and Annex.

In addition, fulfilling expectations on ICT connectivity in these five key ICT domains (i.e. capability, security, innovation, mobile, and implementation and operation) could effectively bring economic and sustainable development to each country along the Belt and Road in Asia, Africa and Europe, bridge the global digital divide, and finally enhance cooperation among countries.

Figure 2-12: Expectations on ICT Connectivity



3. CURRENT STATUS OF ICT CONNECTIVITY IN CHINA AND CENTRAL ASIA

One of the BRI objectives is to improve infrastructure connectivity, which usually refers to transport, energy and ICT infrastructure. These infrastructures are closely related and effectively support each other; thus, the mutual reinforcement among them is necessary. It is more efficient and effective to implement ICT infrastructure along with transport and energy infrastructure . ICT infrastructure or ICT connectivity typically requires continuous energy supplied from energy infrastructure to increase availability to support collaborations among people and countries. In the same way, ICT infrastructure can be used to effectively support transport infrastructure such as Intelligent Transportation Systems (ITS), road safety,traffic management, and so on.

To successfully enhance the five linkages on policy, infrastructure, trade and investment, finance, and people among countries along the Belt and Road, ICT connectivity typically plays an important role in allowing effective communications among them. In this study, the comparative analysis on ICT connectivity is conducted in the China-Central Asia corridor which is an integral part to form the China-Central Asia-West Asia corridor and also provides connectivity to other countries in this region. Hence, it is essential to be aware of the current status of countries in the China-Central Asia Corridor including economic and ICT aspects. The countries which are taken into account in this study are (1) China, (2) Kazakhstan, (3) Kyrgyzstan, (4) Tajikistan, (5) Turkmenistan, and (6) Uzbekistan. Their current states are discussed as follows.

3.1 Demographic and Economic Statuses

Because the BRI initiative has beneficial impacts in many regions including Asia, Africa and Europe, it is vital to be aware of their demographic and economic indicators as listed in Tables 3-1 and 3-2. The population in East Asia and the Pacific is about 2.28 billion people or 31 per cent of total world population, making it the largest region by population size. The region with the second largest population is South Asia where there are 1.74 billion people; whereas Europe & Central Asia and Middle East & North Africa have population sizes of around 908 and 424 million people (0.908 and 0.424 billion people), respectively.

By focusing on the demographic status of China and countries in Central Asia as the main region considered in this study, as illustrated in Table 3-1, China not only has the largest population (about 1.37 billion people) in this region but is also the most populous country in the world. Considering that the world's population is about 7.35 billion people, China's population size represents around 18.66 per cent of the global population. Since communications and policies directly or indirectly applied to China affect a lot of people, the connectivity between China and other countries is vital Moreover, the total population in Central Asia is about 68.66 million which corresponds to nearly one per cent of total world population. In the Central Asian countries studied, Uzbekistan has the largest population (about 31.3 million), while Turkmenistan has the lowest population (around 5.37 million).

Table 3-1: Demographic and Economic Indicators in Different Regions and Countries

Economy	Population (Thousand)	Population Density (People per square km. of land area)	Urban Population (per cent of total population)
World	7 346 633	57	54
East Asia & Pacific	2 279 186	94	58
Europe & Central Asia	907 944	33	71
Middle East & North Africa	424 065	39	65
South Asia	1 744 161	370	33
China	1 378 665	147	57
Kazakhstan	17 797	7	53
Kyrgyzstan	6 083	32	36
Tajikistan	8 735	63	27
Turkmenistan	5 663	12	50
Uzbekistan	31 848	75	36

Source: "World Development Indicators" by World Bank, 2017

Since social and economic developments are being discussed, it is important to be aware that there is a wide variety of economic indicators used to characterize and compare countries. Gross Domestic Product (GDP) and GDP per capita are frequently used indicators. Another method used to classify countries is income level, which is typically characterized by Gross National Income (GNI) and GNI per capita. These indicators in different regions and countries associated with BRI are illustrated in Table 3-2.

It follows that East Asia & the Pacific has the highest GDP at 22,477,425 million US Dollars, whereas the region that has the lowest GDP is South Asia at $2,896,361 million. However, by concentrating on GDP per capita, the region with the highest GDP per capita is Europe & Central Asia at about $22,108, while East Asia & Pacific and Middle East & North Africa have a GDP per capita at $9,786 and $7,124 respectively. South Asia has a GDP per capita far below the world average at around $1,639. Moreover, most regions have an annual GDP growth higher than average except Europe & Central Asia, which has GDP growth at only 1.7 per cent. The region with highest annual GDP growth is South Asia at 6.8 per cent.

Table 3-2: Economic Indicators in Different Regions and Countries

Economy	GDP (USD Millions)	GDP per capita (USD)	GDP Growth (Annual per cent)	GNI (USD Millions)	GNI per capita (USD)
World	75 543 543	10 151	2.4	75 585 260	10 299
East Asia & Pacific	22 477 425	9 786	4.1	22 592 686	9 868
Europe & Central Asia	20 162 858	22 109	1.7	20 098 984	23 109
Middle East & North Africa	3 111 499	7 125	3.3	3 126 283	7 800
South Asia	2 896 361	1 640	6.8	2 896 599	1 616
China	11 119 145	8 123	6.7	11 172 428	8 260
Kazakhstan	133 657	7 510	1.0	121 180	8 710
Kyrgyzstan	6 551	1 077	3.8	6 288	1 100
Tajikistan	6 952	796	6.9	8 165	1 110
Turkmenistan	36 180	6 389	6.2	34 426	6 670
Uzbekistan	67 220	2 111	7.8	68 547	2 220

Source: World Development Indicators database, World Bank, 17 April 2017
http://databank.worldbank.org/data/download/GDP.pdf

By specifically focusing on th China-Central Asia corridor, according to the GDP world ranking in 2015 by World Bank, GDP of China is $11,199,145, thereby ranked second in the list, while GDP of Kazakhstan is $133,657 million USD, thereby ranked 55th. As found in table 3.2, all the Central Asian countries listed all fall below the world average in terms of GDP per capita at $10,151.

Moreover, China, Kazakhstan and Turkmenistan are categorized as upper-middle income countries[35], while Kyrgyzstan, Tajikistan and Uzbekistan are categorized as lower-middle income countries. The main indicator used to characterize the income levels is GNI per capita, of which the world average is $10,299. All the countries listed in in table 3-2 fall below the GNI per capita in the region.

Trade, especially international trade, is one of the key factors that directly drives economic development in each country. China and Kazakhstan have the largest trade relationship in this region, characterized by the export and import statistics at $8,273 million in exports and $4,793 million in imports in 2016. This trade relationship is ranked 38th in exports and 44th in imports from China's perspective. By focusing on exports, Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan are the important trading partners of China in Central Asia, and they are among China's top 90 export partners. Furthermore, China's main import partners among these countries are Turkmenistan, Kazakhstan and Uzbekistan which are ranked 39th, 44th and 66th, respectively.[36]

China is also the key trading partner in Central Asia: more than 40 per cent of total trade in Kyrgyzstan, Tajikistan and Turkmenistan is with China. In addition, China is ranked number one in exports in Turkmenistan, and China is also the first ranked country in imports to Kyrgyzstan and Uzbekistan. This trade relationship between China and Central Asia clearly illustrates the strong connectivity and collaboration between these nations. In addition, with regard to energy, China has imported oil and gas from Central Asia for decades. There is a Kazakhstan-China oil pipeline which has agreements for field development and construction between the two countries since 1997. In addition, this cross-border oil pipeline was continuously developed by the China National Petroleum Corporation (CNPC) and the KazMunayGas (KMG) and reached its full capacity in 2014[37].

In addition to the oil pipeline, the gas pipeline running from Central Asia to China is also depicted in Figure 3-1.

[35] The income levels by country used in this study are categorized by World Bank, and there are four groupings: low, lower-middle, upper-middle, and high. The details can be found at http://data.worldbank.org/country.

[36] More information about trade relationship between China and Central Asia can be found from Direction of Trade Statistics database, IMF.

[37] The details of Kazakhstan-China oil pipeline can be found from KazMunayGas (KMG) at http://www.kmg.kz/en/manufacturing/oil/kazakhstan_china.

Figure 3-1: Gas pipelines in Central Asia

Source: "Map: Connecting Central Asia" by Financial Times, 2016

China also imports natural gas from Central Asia with the Central Asia-China Gas Pipelines starting from the Turkmenistan-Uzbekistan border to China as depicted in Figure 3-2. There are currently three gas pipelines (lines A, B and C) running in parallel with the length of each line at 1,830 km[38] and costing $7.3 billion[39]. China also signed an inter-governmental agreement with Tajikistan, Kyrgyzstan and Uzbekistan on a new Central Asia-China pipeline line D project in 2014, with an estimated project investment of about $6.7 billion[40]. In addition, these oil and gas pipelines do not just import energy from Central Asia to supply China but also strenghten and form the backbone infrastructure connections between them.

3.2 ICT Connectivity Status

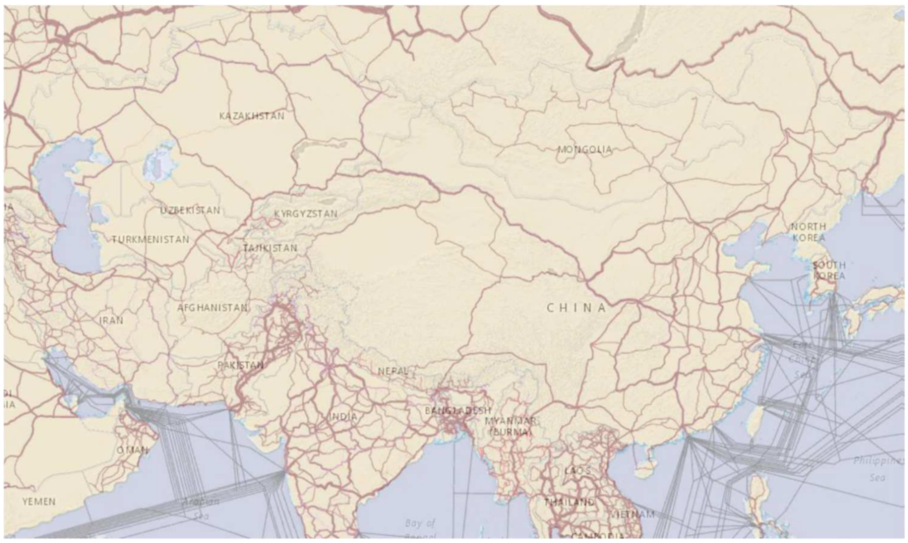
To conduct comparative analysis in ICT connectivity of China and countries in Central Asia, it is important to carefully study and assess its current state. Figure 3-3 depicts ICT infrastructure in terms of both terrestrial and submarine cables in China and Central Asia. It clearly illustrates that China has submarine routes to digitally interconnect with other countries, whereas countries in Central Asia are largely classified as Landlocked Developing Countries (LLDC) due to a lack of territorial access to the sea. Hence, international connectivity is highly dependent on their neighboring countries, and these international links are typically costly and limited by low-capacity cross-border fibre-optic links. Thus, most countries in Central Asia

[38] The details of Central-Asia gas pipeline can be found from "Flow of natural gas from Central Asia" by China National Petroleum Corporation (CNPC).
[39] The details of road, rail and energy projects can be found from "Map: Connecting Central Asia" by Financial Times.
[40] The details about project investment in Central Asia can be found from "One Belt, One Road: An Economic Roadmap" by The Economist Corporate Network.

usually experience inadequate international bandwidth and high transit cost to access international links.

In addition, due to desert and/or mountainous terrain, together with low populations scattered over large distances, difficulties emerge for countries in Central Asia to develop ICT infrastructure to serve people in remote and rural areas (low fiber density in parts of China and Central Asia as shown in Figure 3-2)[41]. These are the main reasons why countries in Central Asia particularly face a large digital divide. Thus, Central Asia could gain significantly from the reinforcement of ICT infrastructure connectivity in the undertaking of the BRI initiative. Moreover, the current status of ICT connectivity is discussed as follows.

Figure 3-2: Landline and Submarine Cables in China and Central Asia



Source: Adapted from "ITU Interactive Transmission Map" and "National Geographic Mapmaker Interactive"

3.2.1 E-Government Development Index (EGDI)

The index discussed in this sub-section is the E-Government Development Index (EGDI) as listed in Table 3-3. EGDI is usually used by the United Nations to measure the willingness and readiness of countries to use e-government and ICT. Moreover, it is the composite value which can be effectively calculated based on the combination of three components or sub-indexes: (1) Online-Service sub-index (i.e., availability of online services and contents); (2) Telecommunications Infrastructure sub-index (i.e., sufficiency of ICT infrastructure); and (3) Human Capacity sub-index (i.e., ability of people to be ready to use ICT).

[41] More ICT issues and challenges in Central Asia can also be found from "Improving Broadband Access in Southeast & Central Asia" by ISOC.

In EGDI, China, Kazakhstan and Uzbekistan are categorized at a high EGDI level[42], as their EGDI are equal to 0.61, 0.73 and 0.54, respectively, which are above the world average as illustrated in Figure 3-4; whereas Kyrgyzstan, Tajikistan and Turkmenistan are falling into medium EGDI level. By looking at online sub-indexes of EGDI, China and Kazakhstan have very high values at about 0.77, which indicate the high provision of online services; while Tajikistan and Turkmenistan are categorized into low level online service sub-index, due to a lack of readiness to provide public online services to their citizens.

Table 3-3: EGDI and EPI in China and Central Asia

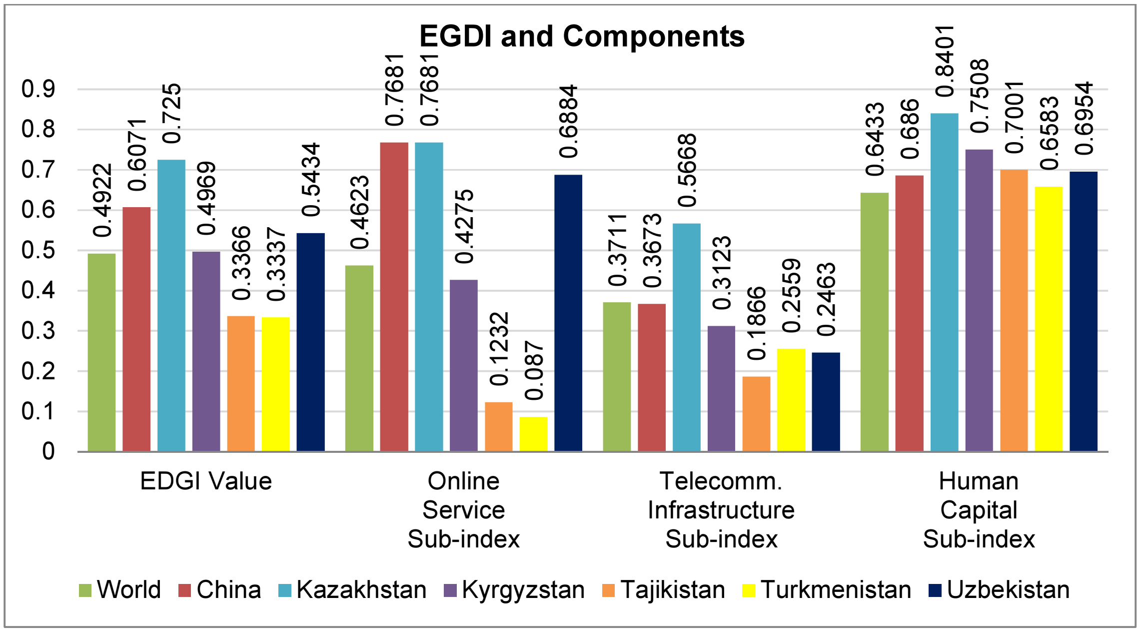
Economy	EGDI Rank	EGDI Level
World	-	-
China	63	High
Kazakhstan	33	High
Kyrgyzstan	97	Medium
Tajikistan	139	Medium
Turkmenistan	140	Medium
Uzbekistan	80	High

Source: "United Nations E-Government Survey", 2016

According to the telecommunication infrastructure sub-index, Kazakhstan has value at 0.57 which is higher than the world average, while the values of China and Kyrgyzstan are close to the average. Only Tajikistan, Turkmenistan and Uzbekistan have values far lower than the average which may indicate the inadequate ICT infrastructure to be accessed by people in these countries. Focusing on readiness of people to use ICT tools and services by using the human capital sub-index, all the countries studied have values above the world average (i.e., more than 0.64). This information clearly shows the readiness of people in China and Central Asia to use ICT to share their information or support their collaboration in this digital economy era.

[42] According to EGDI levels, there are totally four levels: very-high, high, middle and Low. More information about EGDI can be found from "United Nations E-Government Survey".

Figure 3-3: EGDI and its Components in China and Central Asia

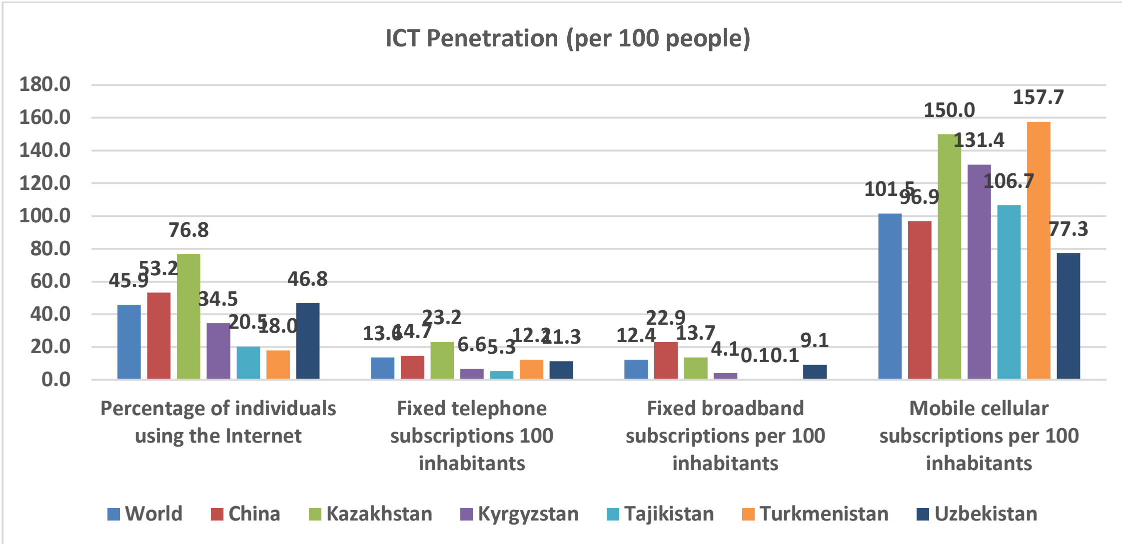


Source: "United Nations E-Government Survey", 2016

3.2.2 ICT Penetration

The number of individuals using the Internet in China and Kazakhstan is over the world average at 50.3 per cent and 72.9 per cent as illustrated in Figure 3-5, while it is nearly the same as the world average in Uzbekistan at 42.8 per cent. However, less than 20 per cent of individuals use the Internet in Kyrgyzstan, Tajikistan and Turkmenistan. According to fixed infrastructure subscriptions (including both fixed telephone and fixed broadband subscriptions), only China and Kazakhstan exhibit a number of fixed telephone networks subscriptions above the world average at 16.5 per cent and 24.7 per cent, respectively. Furthermore, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan have low fixed broadband penetration (less than 3.6 per cent). This fact coincides with the statistic in telecommunications infrastructure sub-index shown in Figure 3-4 which may depict insufficient fixed ICT infrastructure in these countries.

Figure 3-4: ICT Penetration in China and Central Asia



Source: "ITU World Telecommunication/ICT Indicators database", 2017

However, the penetration of mobile cellular telephone subscriptions per 100 inhabitants is quite high in China and Central Asia and especially in Kazakhstan and Turkmenistan with values of over 100, which illustrates that a person may have more than one mobile cellular telephone subscription. The mobile cellular telephone subscriptions of Kyrgyzstan and Tajikistan are equivalent at 98.6, similar to the world average, while China exhibits a value slightly lower than average at 93.2. The lowest value is exhibited by Uzbekistan at 73.3 mobile cellular telephone subscriptions per 100 inhabitants.

Mobile-broadband networks (3G or above) now reach 84 per cent of the global population but only 67 per cent of the rural population.To enhance the quality of using the Internet, Long-Term Evolution (LTE) networks are gaining presence, and 53 per cent of the global population or around 4 billion people subscribe to these LTE networks[43]. In Figure 3-5, the trend of communications on mobile devices (e.g. phones, tablets and so on) rather than fixed devices such as traditional telephones connected to Public Switched Telephone Networks (PSTNs) is illustrated. In addition, according to traffic forecasts by Cisco, mobile data traffic will be two-thirds of total IP traffic by 2020[44].

3.2.3 International Links

The details of international links are listed in Table 3-5. Note that, in this table, baseline information is obtained from a publication entitled "Unleashing the Potential of the Internet in Central Asia, South Asia, the Caucasus and Beyond" which is co-published by ADB, ESCAP

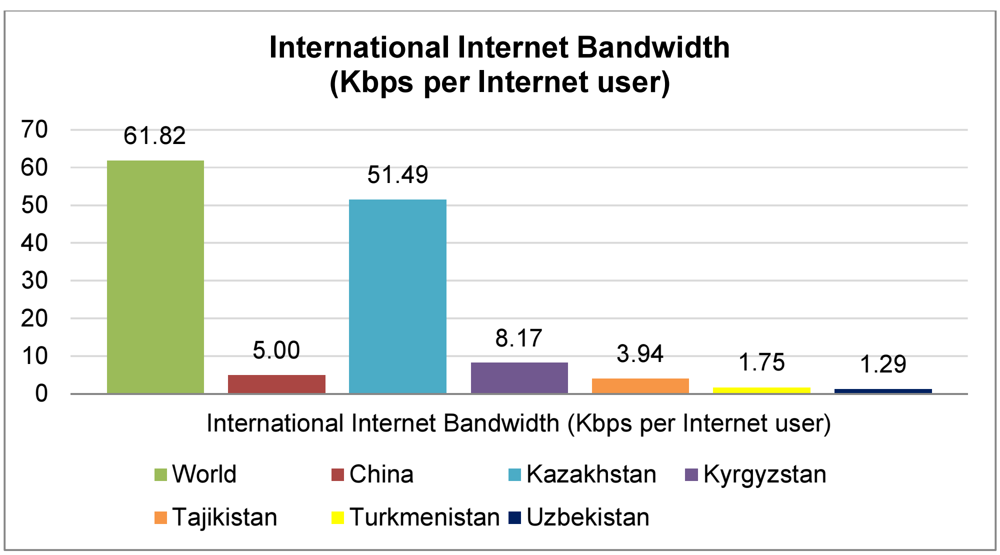
[43] The details about mobile network coverage and technologies can be found from "ICT Facts and Figures 2016" by ITU.
[44] The details of traffic forecast can be found from "Cisco VNI Forecast and Methodology, 2015-2020" by Cisco.

and the ISOC, with more updated information from ESCAP, China Internet Network Information Center (CNNIC) and ITU Interactive Transmission Map is also added.

By focusing on the international bandwidth per capita, it becomes evident that Kazakhstan has the largest bandwidth per capita at 61.67 Kbps, followed by Kyrgyzstan at 5.05 Kbps; whereas bandwidth per capita of China is 3.93 Kbps. Although China has very large international bandwidth, it is ranked third among these countries in terms of bandwidth per capita because of its large population size; while the bandwidth per capita of other countries is usually less than 1 Kbps. In addition, it is important to note that ITU and World Bank also use a different metric to measure international Internet capacity in terms of international Internet bandwidth per Internet user because each country has a different level of Internet penetration. From Figure 3-8 it follows that Kazakhstan is the only country in this region that has international bandwidth per user near the world average at 51.49 Kbps, while other countries are far below the average (1.29 to 8.17 Kbps). Note that information in this figure was obtained in the year 2014 and is expected to have improved by now.

China has six major backbone networks, and the international gateway bandwidth for each network is listed in Table 3-6. Among these networks, China Telecom has the largest international bandwidth of 3,223.63 Gbps, followed by China Unicom and China Mobile with bandwidth of 1,414.87 Gbps and 645.07 Gbps, respectively. Notably, the total international bandwidth of China is 5,392.12 Gbps, which is larger than the total international bandwidth of Central Asia. The country that has the largest international bandwidth in Central Asia is Kazakhstan with 1,082 Gbps, while Turkmenistan has the lowest international bandwidth at 2.4 Gbps.

Figure 3-5: International Internet Bandwidth per Internet User in China and Central Asia



Source: "World Development Indicators: The Information society" by World Bank, 2014 (latest as of 2017).

Table 3-5: International Fiber Routes in China and Central Asia

Economy	International Bandwidth (Gbps)	Landline Routes + Submarine Routes	Number of Main Routes (Landline + Submarine)	International Bandwidth Per capita (Kbps)
China	5,392	Landline – DREAM; Trans Asia-Europe (TAE); Trans-Eurasian Information Super Highway (TASIM); Greater Mekong Subregion (GMS); China-Kazakhstan (2 routes via Alashankou and Khorgos); China-Kazakhstan; China-Tajikistan; China-Kyrgyzstan; China-Mongolia; China-Russia (3 routes via Manzhouli, Heihe and Suifenhe); China-Vietnam; China-Lao PDR; China-Myanmar; China-India. Submarine - EAC-C2C; Trans-Pacific Express (TPE); APCN-2; Asia Pacific Gateway (APG); China-U.S. Cable Network (CHUS); New Cross Pacific (NCP); FLAG Europe-Asia (FEA); SeaMeWe-3; Taiwan Strait Express-1 (TSE-1); Southeast Asia Japan Cable (SJC).	17+10	3.93
Kazakhstan	1,082	DREAM; TAE; TASIM; China-Kazakhstan, Kazakhstan-Kyrgyzstan (2 routes via Merke and Korday); Northern Kazakhstan-Russia; North-western Kazakhstan-Russia; Western Kazakhstan-Russia; Kazakhstan-Turkmenistan; Kazakhstan-Eastern Uzbekistan; Kazakhstan-Western Uzbekistan	12+0	61.67
Kyrgyzstan	30.1	TAE; Kyrgyzstan-Tajikistan; China-Kyrgyzstan; Kazakhstan-Kyrgyzstan (2 routes via Merke and Korday); Kyrgyzstan-Uzbekistan	6+0	5.05
Tajikistan	4.5	Afghanistan-Tajikistan; China-Tajikistan; Kyrgyzstan-Tajikistan; Tajikistan-Uzbekistan	4+0	0.53
Turkmenistan	2.4	TAE; Kazakhstan-Turkmenistan; Afghanistan-Turkmenistan (eastern and western links)	4+0	0.45
Uzbekistan	30.7	TAE; Kazakhstan-Eastern Uzbekistan; Kazakhstan-Western Uzbekistan; Kyrgyzstan-Uzbekistan; Tajikistan-Uzbekistan; Afghanistan-Uzbekistan	6+0	0.98

Source: Information is based on "An In-Depth Study of Broadband Infrastructure in North and Central Asia" by ESCAP, 2014; "Unleashing the Potential of the Internet in Central Asia, South Asia, the Caucasus and Beyond" by ADB, ESCAP and ISOC, 2015; "Updated Analysis of the Broadband Infrastructure in the ESCAP Region (Draft version)" by ESCAP, 2016; "Statistical Report on Internet Development in China" by CNNIC, 2016; "ITU Interactive Transmission Map"; and "TeleGeography Submarine Cables Map".

Table 3-6: International Bandwidth in Backbone Networks in China

Backbone Networks	Nature of Organization	International Gateway Bandwidth (Mbps)
ChinaNet (China Telecom)	Commercial	3 223 629
UniNet (China Unicom)	Commercial	1 414 868
CMNet (China Mobile)	Commercial	645 073
CERNET (China Education and Research Network)	Public Sector (Ministry of Education)	61 440
CSTNet (China Science and Technology Network)	Academy (Chinese Academy of Sciences)	47 104
CIETnet (China International Economy and Trade Network)	Public Sector (Ministry of Foreign Trade and Economic Cooperation)	2
Total		5 392 116

Source: "Building e-Resilience in China: Enhancing the Role of Information and Communications Technology for Disaster Risk Management" by ESCAP, 2016; and "Statistical Report on Internet Development in China" by CNNIC, 2016

China has cross-border fibre-optic cables to 3 adjacent countries in Central Asia which are Kazakhstan, Kyrgyzstan, and Tajikistan. As previously mentioned, China is the only country studied that has submarine cables (i.e., China has six international submarine cable landing stations to interconnect with other countries in Asia, Africa, Australia, Europe and North America). These submarine cable landing stations are illustrated in Table 3-7 and Figure 3-9.

In addition to submarine cables, China and Central Asia can interconnect with each other and link to Europe through three important terrestrial cables which are listed below:

- The Trans Asia-Europe (TAE)[45] - a 27,000km fibre-optic route running from China to Frankfurt in Germany which was originally proposed by China in 1992 and implemented in late 1990s. It traverses 20 countries including Kazakhstan, Kyrgyzstan, Turkmenistan and Uzbekistan in Central Asia. However, the capacity of the TAE is very low.

[45] The details of TAE can be found at http://www.taeint.net.

- The Trans-Eurasian Information Super Highway (TASIM)[46] - a proposed fibre-optic route running from Hong Kong to Frankfurt in Germany, the estimated length of the shortest route connecting Asia to Europe is 11,000km. This route will pass through China, Kazakhstan, Azerbaijan, Georgia, Turkey and Germany, with currently no information regarding a completion date available.
- The Diverse Route for European and Asian Markets (DREAM)[47] - a 8,700km fibre-optic route connecting Frankfurt in Germany to the China-Kazakhstan border, with a capacity typically ranging from 1 to 10 Gbps.

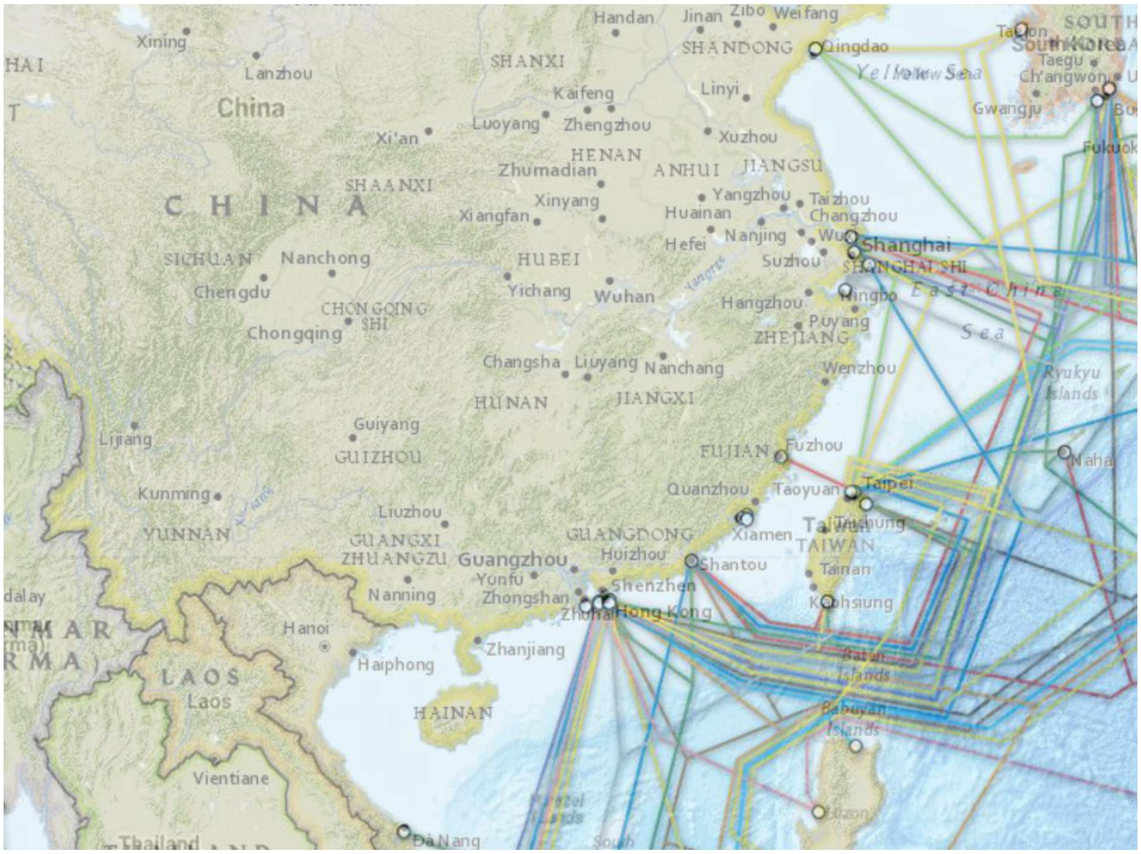
Table 3-7 International Submarine Cable Landing Stations in China

International Submarine Cable Landing Stations	Submarine Cable Routes[48]
Chongming	APCN-2; Asia Pacific Gateway (APG); China-U.S. Cable Network (CHUS); New Cross Pacific (NCP) Cable System; Trans-Pacific Express (TPE) Cable System
Fuzhou	Taiwan Strait Express-1 (TSE)-1
Nanhui	Asia Pacific Gateway (APG); New Cross Pacific (NCP) Cable System
Qingdao	EAC-C2C; Trans-Pacific Express (TPE) Cable System
Shanghai	EAC-C2C; FLAG Europe-Asia (FEA); SeaMeWe-3
Shantou	APCN-2; China-U.S. Cable Network (CHUS), SeaMeWe-3; Southeast Asia Japan Cable (SJC)

Source: "TeleGeography Submarine Cables Map"

[46] The details of TASIM can be found at http://tasim.net.
[47] The details of DREAM can be found at http://carriers.megafon.ru/ip_and_capacity/dream
[48] The details of each submarine route can be found from "TeleGeography Submarine Cables Map" at http://www.submarinecablemap.com.

Figure 3-6: Submarine Cables in China's East Coast



Source: Adapted from "TeleGeography Submarine Cables Map" and "National Geographic Mapmaker Interactive"

In addition, China has 3 international gateways (i.e. Beijing, Shanghai and Guangzhou) which are also the carrier-neutral Internet Exchange Points (IXPs) that link together these six Chinese major backbone networks. In total, there are 6 regional international gateways in Fuzhou, Harbin, Kunming, Nanning, Urumqi, and Xiamen[49] as represented in Figure 3-7. Furthermore, China also implemented multiple small border international gateways in Alashankou, Dongguan, Fuyuan, Shenzhen, and Suifenhe for international services (mainly on voice services) between China and its neighboring countries. It must be noted that only Dongguan and Shenzhen border gateways are able to provide both international voice and data services, while the other gateways can likely provide only international voice services.

The international fibre-optic routes between China and other countries in Central Asia, as well as national fiber routes among multiple cities in China are illustrated in Figures 3-7 and 3-8, respectively. Note that, in Figure 3-7, cross-border fibre-optic routes between China-Kyrgyzstan, Kazakhstan-Kyrgyzstan, Kyrgyzstan-Tajikistan, and Kyrgyzstan-Uzbekistan are

[49] The details of international gateway in China can be found from "Introduction of Chinese Telecommunication: International Interconnection Projects" at https://www.itu.int/net4/wsis/forum/2015/Agenda/Session/192.

not included, as these cross-border fibre-optic routes are not presented in the ITU Interactive Transmission Map.

Figure 3-7: Fibre-optic Routes between China and Central Asia

Source: Adapted from "ITU Interactive Transmission Map" and "National Geographic Mapmaker Interactive"

Figure 3-8: Fibre-optic Routes among Cities in China

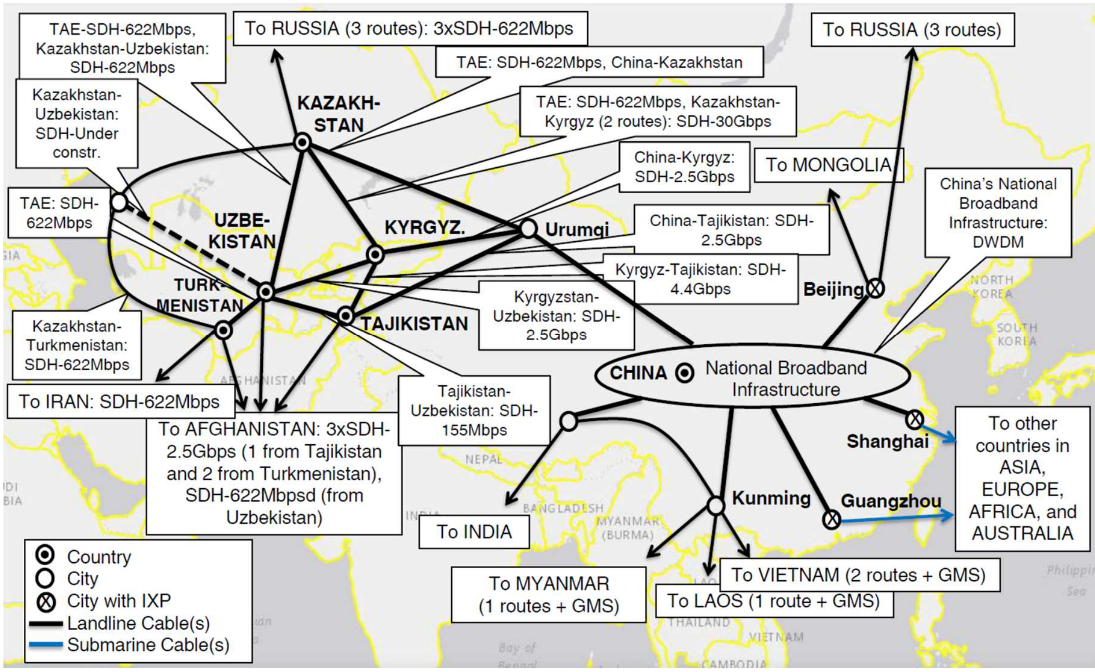
Source: Adapted from "ITU Interactive Transmission Map" and "National Geographic Mapmaker Interactive"

In addition, Central Asia (via China-Kazakhstan, China-Kyrgyzstan and China-Tajikistan routes) can only connect to China via the regional international gateway in Urumqi. Moreover, the Russian Federation (via Harbin gateway) and Mongolia can connect to China via the Beijing international gateway; while China can also connect to Myanmar, Lao PDR, and with shortest route to India via the regional international gateway in Kunming; and Viet Nam via the Nanning gateway. The logical diagram of physical topology of China and Central Asia is also depicted in Figure 3-12.

By concentrating on link capacity between China and Central Asia, China and Kazakhstan are connected using China-Kazakhstan cross-border fibre-optic routes, and with the TAE line with a capacity of 622 Mbps using Synchronous Digital Hierarchy (SDH) technology[50]. Also, there is a China-Kyrgyzstan cross-border link with a capacity of 2.5 Gbps with the same WAN technology. In addition, based on obtained information, WAN technology used to interconnect multiple countries in this region utilizes SDH and the maximum capacity is 30 Gbps (only two international fiber links between Kazakhstan and Kyrgyzstan), while the minimum one is only 155.52 Mbps. Also note that the main WAN technology used in China's national broadband networks is called Dense Wavelength Division Multiplexing (DWDM).

[50] More information about cross-border fiber links between China and Central Asia can be found from "An In-Depth Study of Broadband Infrastructure in North and Central Asia" by ESCAP; and "Unleashing the Potential of the Internet in Central Asia, South Asia, the Caucasus and Beyond" by ADB, ESCAP and ISOC.

Figure 3-9: Logical Diagram of Physical Topology in China and Central Asia



Note: Information is based on "An In-Depth Study of Broadband Infrastructure in North and Central Asia" by ESCAP, 2014; Updated Analysis of the Broadband Infrastructure in the ESCAP Region (Draft version)" by ESCAP, 2016; and "ITU Interactive Transmission Map"

3.2.4 Internet Exchange Points (IXPs)

The ISOC has defined Internet Exchange Points (IXPs or IXs) as "physical locations where different networks connect to exchange Internet traffic via common switching infrastructure." This switching infrastructure typically includes switches, routers, cablings and interfaces. IXPs are usually implemented across various locations in different countries to allow local Internet traffic to be locally exchanged. Then, local traffic between two networks in the same country can be directly exchanged within IXPs without indirectly passing through the international link. This consequently reduces the transit cost over international links. Because network operators' OPEX (in terms of cost associated in traffic exchange) is reduced, Internet access cost for Internet users is also expected to be decreased.

In China, there are three carrier-neutral IXPs (called CHN-IX) in Beijing, Shanghai and Guangzhou[51] as depicted in Figure 3-10. All major six service providers for backbone networks, listed in Table 3-6, also connect to these three locations of CHN-IX. In addition, there are three IXPs in Central Asia: one is located in Tashkent, Uzbekistan which is TAS-IX[52], one is in Almaty, Kazakhstan called KAZ-IX, and another is in Bishkek, Kyrgyzstan

[51] More information about carrier-neutral IXPs in China can be found at http://www.chn-ix.net.
[52] The details about IXP in Uzbekistan can be found at http://tas-ix.uz.

(Kyrgyz-IX)[53]. However, the Network Startup Resource Center (NSRC) reported that KAZ-IX currently has no peering member[54] (not currently functional). In addition, according to a report from the ISOC[53], Kyrgyz-IX currently does not allow international ISPs, content providers, or data-center operators to exchange traffic at the IXP. Note that both KAZ-IX and Kyrgyz-IX are not included in this figure.

Figure 3-10: IXPs in China and Central Asia

Source: Adapted from "TeleGeography Internet Exchange Map"

4. GAP ANALYSIS TOWARDS AN EFFECTIVE ICT CONNECTIVITY

As discussed in Section 1.3, the main approach taken in this study is to perform a comparative analysis (Gap analysis) on ICT connectivity in the China-Central Asia corridor. Gap analysis is an effective analysis tool used to find gaps by comparing between current state (As-Is) and future state (To-Be) of ICT connectivity. In the first stage, the future state is naturally obtained in terms of expectations on ICT connectivity (ICT technical goals), and can be carried out by carefully characterizing the BRI initiative including its vision, goals and objectives as discussed in Section 2. In addition, in the next stage, the current state of ICT connectivity in China and Central Asia is studied as discussed in Section 3. The results of these two states will consequently serve as the inputs for Gap Analysis. The outputs or results of Gap

[53] The details about IXP in Kyrgyzstan can be found from "Kyrgyz Internet Environment Assessment" by ISOC.
[54] More information about IXPs in Asia and the Pacific can also be found at https://nsrc.org/ixp/AsiaPacific.html.

Analysis typically reveal the gaps (i.e. challenges, issues or barriers) which are required to be bridged to meet the future state (here it is to meet and fulfill the ICT technical goals).

4.1 Gap Analysis on ICT Connectivity

"Gaps" in this study, typically refers to the insufficiency or lacking of capacity, process, policy and system in specific ICT areas which consequently cause these areas to work/function improperly or not up to expectations. In this section, gaps are revealed through the implementation of the template provided by United Nations Public Administration Network (UNPAN)[55]. For the sake of consistency, Gap Analysis is summarized and categorized using the same ICT areas as defined Section 2.3. These ICT areas include capability, security, mobile, innovation, and implementation and operation. Tables A4-1 to A4-4 (Annex 4) illustrate the results of Gap Analysis in each ICT area.

4.2 ICT Connectivity Challenges and Issues

In the previous section, the inefficiency and/or missing of systems and processes are represented in terms of gaps. There is a strong relationship between gaps and challenges/issues. Once gaps are identified they can lead to either minor or major problems, with these problems viewed as challenges or issues. In addition, if these challenges/issues are not solved, they can havea negative impact on ICT connectivity. Here, the template for challenge characterization recommended by UNPAN is also adopted to summarize challenges, issues and barriers found via conducting a Gap analysis. Tables A4-5 to A4-8 list all challenges and issues that can impact ICT connectivity in China and Central Asia.

According to the impact used to classify ICT challenges, there are three categories used: high, medium and low. If challenges or issues are not properly corrected and cause serious negative effects, they will be assigned to the high impact category. In addition, if there is no proper solution to them and the problems cause minor impacts (i.e., can still operate with some effects), they will be assigned to the medium impact category. However, if the challenges or issues cause no effect (or possibly small effects) on ICT connectivity when they are not solved, they will be classified as low impact (see Annex 5).

5. RESILIENT NETWORK TOPOLOGY AND IXPS

ICT connectivity is one of the fundamental keys that could be used to drive collaboration and cooperation among countries along the Belt and Road. People and organizations in different countries can digitally exchange or share information across ICT infrastructure (over national backbone networks and international links). In this section, the

[55] The template of Gap analysis and Challenges can be found from "ICT Strategic Planning in Parliaments" by UNPAN.

design of network topology and IXPs in China and Central Asia are discussed. However, to effectively support ICT connectivity in this corridor to other regions such as West Asia and South Asia, ICT connectivity to five more countries is also proposed in this design, which includes Afghanistan, Azerbaijan, The Islamic Republic of Iran (I.R.), Pakistan, and Turkey (hereafter referred to as the ICT connectivity for China-Central Asia). In addition, there are three key drivers that usually affect this design which are BRI Force, Technological Forces and ICT Connectivity Challenges, which are discussed as follows:

- **BRI Force** is naturally reflected by the BRI framework that affects the strategic decision on network architecture and topology. The BRI force refers to the effective connectivity and collaboration between countries along the Belt and Road. In total, there are six economic corridors:(1) New Eurasian Land Bridge; (2) China-Mongolia-Russia Corridor; (3) China-Central Asia-West Asia Corridor; (4) China-Indochina Peninsula Corridor; (5) China-Pakistan Corridor; and (6) Bangladesh-China-India-Myanmar Corridor. As this study is aimed at enhancing collaboration in the China-Central Asia corridor, network topology and IXPs must provide effective connectivity among countries within this corridor (i.e., intra-corridor connectivity among countries within China-Central Asia corridor) and also take into account the connectivity with other corridors stated above (i.e., inter-corridor connectivity with other countries in each economic corridor).
- **Technological Forces** also impact topological design. These forces include removal of communication barriers and growth of applications. From a removal of communication barriers point of view, this network architecture and topology must have no restrictions, be open and facilitate people, organizations and countries to freely access broadband networks. With regard to the growth of the application aspect, people are likely to use their devices (both stationary and mobile devices) to access broadband networks in order to make transactions or collaborate with others using multimedia communications such as IP telephony, video conferencing and so on. Hence, network architecture and topology must be capable to effectively support this multimedia traffic with high speeds and low loss, latency and jitter. This simply means that topology and IXPs must be resilient and do not have bottlenecks (no congestion).
- **ICT Connectivity Challenges** presented in the previous section could also possibly impact connectivity and collaboration among countries along the Belt and Road, especially in the China-Central Asia corridor. However, among them, the main ICT connectivity challenges that affect network topology and IXP design within intra-corridor and among inter-corridor connectivity are redundant route requirement, unscalable network topology, and inadequate carrier-neutral IXPs. Note that the other challenges are also considered because they also have indirect impacts on the design.

Consequently, network architecture or framework to design network topology must take into account these three key drivers. From these drivers, four main approaches must be carefully considered which are collaboration, being borderless, resilience and performance, as illustrated in Figure 5-1. In this figure, network topology and IXPs must provide high performance, be resilient networks and support borderless communications to achieve highest levels of collaboration among countries related to BRI.

Figure 5-1: Topology and IXP Design Approaches

Furthermore, to design topology and IXPs refers to re-creation of a network graph G(*V*,*E*) where *V* is a set of nodes (or vertices) and *E* is a set of link (or edges). Hence, a set of nodes *V* for IXPs (to provide both intra- and inter-corridor connectivity) must be firstly selected. Once they are chosen, the next design activity is to create connections or a set of links *E* among them including topology selection (i.e., how nodes in a set *V* are physically and logically connected). The below section focuses on the proposed topology. Assocaited actions on ICT strategies and other recomendations are listed in the Annex.

5.1 Node Selection for IXPs

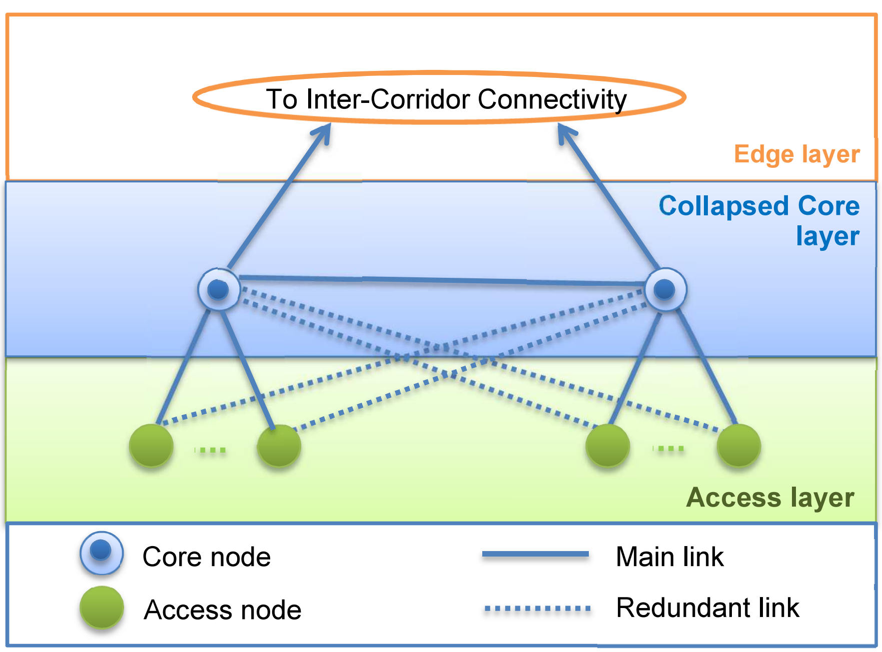
The hierarchical network model is preferred to the flat network model to achieve scalability. In a hierarchical one, there are different layers (or tiers) and each layer typically provides different functions. This model is suitable for medium and large networks. However, a higher number of layers incurs a long routing path and high latency; then, only three layers are typically recommended which are core, distribution or aggregation, and access layers. The core layer provides backbone connections among other nodes, while the distribution layer provides aggregation of access nodes in access layer. In this study, two-tier hierarchical design is recommended in the China-Central Asia corridor (corridor of China-Central Asia and five more countries) to shorten communication distance among nodes and also reduce network cost as depicted in Figure 5-3. This model could also maintain approximately the same benefits of the three-tier hierarchical model. In this two-tier hierarchical model, partial mesh connections with only two direct links in each access node are required to achieve full redundancy. Note that more than two links in each access node can optionally be considered to increase performance and improve resilience (availability), but this naturally results in a higher cost to implement and maintain an increased number of links.

In this two-tier hierarchical model, there are only two layers in the China-Central Asia +5 corridor: a collapsed core layer (combination of core and distribution layers) and an access layer. The core nodes in the collapsed core layer typically provide backbone connection to both intra-corridor (to countries within this corridor) and inter-corridor connectivity (to other countries located in different corridors) via an edge layer. Note that an edge layer is not part of this corridor and typically provides international connectivity to other economic corridors.

To efficiently support BRI to connect China and more than 60 countries along the Belt and Road, utilizing the hierarchical model is strongly recommended, rather than utilizing the flat model. Thus, core nodes must be carefully selected first before the topological design stage. Core nodes are expected to provide connectivity to the access nodes in this China-Central Asia corridor, and also act as the gateway to provide connections to other corridors. Therefore , they should be specifically selected from the nodes located in the China-Central Asia corridor (i.e. China, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan).

To be more precise in the selection of nodes in China, only nodes with international gateway capability are considered due to their ICT connectivity readiness, which include Beijing, Shanghai and Guangzhou. Note that all of them are also the carrier-neutral Internet Exchange Points (IXPs) as explained in Section 3.2.4. Among them, only the Urumqi node is finally taken into account in the core node selection process due to the fact that it is the only node which has a direct connection to Central Asia via Kazakhstan, Kyrgyzstan and Tajikistan; while Beijing and Shanghai are too distant and do not have direct connection to Central Asia.

Figure 5-2: Partial Mesh Connections in Hierarchical Network Model



Furthermore, the criteria used to select the core nodes are geographical location, intra-corridor connectivity and international connectivity as listed in Table 5-1. According to the score of node selection criteria, with a total maximum score of 10 points, it must be noted that there is more weight on geographical location (4 points) due to the fact that core nodes must be easily accessed by other countries in the same and different corridors. Moreover, there is an equal lower weight on intra-corridor connectivity and international connectivity (3 points for each criterion). Note that a criterion with regard to national backbone networks is not taken into account due to the fact that the main responsibility of core nodes is to provide the connections to other country nodes (both core and access nodes).

According to the Geographical Location criterion, there are 4 and 3.5 points for Urumqi and Kazakhstan, respectively. This is because they share a border with other countries outside the China-Central Asia corridor, and they also have the potential to provide direct connections to inter-corridor connectivity (Kazakhstan to New Eurasian Land Bridge corridor via the Russian Federation, and China to other corridors as illustrated in Figure 2-1). However, because Kazakhstan is a landlocked country, it has only 3.5 points. There are 3 points for Tajikistan, Turkmenistan, and Uzbekistan because they do not have direct connection(s) to other countries outside Central Asia (Tajikistan and Uzbekistan to Afghanistan, and Turkmenistan to both the Islamic Republic of Iran and Afghanistan). Also, they are landlocked countries with none sharing a border with other countries beyond the China-Central Asia corridor.Also, based on core node selection critieria, only 2.5 points are given to Kyrgyzstan due to the fact that the country shares land borders with China and its Cnetal Asian nieghbours of Kazakhstan, Usbekistan, and Tajikistan..

Table 5-1: Core Node Selection Criteria

Gateway	Geographical Location (0-4)	Intra-corridor Connectivity (0-3)	International Connectivity (0-3)	Total Score (0-10)
Urumqi, Xinjiang, China	4.0	2.5	3.0	9.5
Kazakhstan	3.5	2.5	3.0	9.0
Kyrgyzstan	2.5	2.5	2.0	7.0
Tajikistan	3.0	2.5	2.5	8.0
Turkmenistan	3.0	2.5	2.5	8.0
Uzbekistan	3.0	2.5	2.5	8.0

All candidates for core node selection as listed in Table 5-1 have the same scores on Intra-corridor Connectivity criterion because of a similar level of connectivity as illustrated in Figure 3-12. Furthermore, in International Connectivity criterion, both Urumqi, Xinjiang, China and Kazakhstan have full scores due to their strong international links and bandwidth (see Table 3-5 for more details about the international link). Even though Tajikistan, Turkmenistan and Uzbekistan have international links to other countries outside Central Asia, they have low international bandwidth compared to Urumqi in China and Kazakhstan, and hence their scores are 2.5; whereas there are only 2 points for Kyrgyzstan as it only has cross-border fibre-optic routes to countries in Central Asia (while the other countries have international links to countries in West Asia, South Asia and so on).

By comparing total scores, only Kazakhstan and Urumqi have scores greater than or equal to 9, thereby clearly illustrating that they have a high potential and are selected to be the core nodes to provide both intra- and inter-corridor connectivity. The others are consequently assigned as access nodes and can connect to other countries in other economic corridors through the core nodes in Kazakhstan and Urumqi, Xinjiang, China.

Also, each country in Central Asia is expected to have their own IXP(s) to keep local traffic within national backbone networks without unnecessarily rerouting traffic via international links. In addition, traffic from each country in this China-Central Asia corridor can be directly exchanged among these IXPs. Moreover, to implement and maintain IXPs (including core and access nodes) in each country, their location is very important. They must be well planned and located in secure and neutral areas that are least exposed to disaster and conflicts. Redundancy in IXPs is also strongly recommended and should be seen as a requirement. Thus, redundant power sources, backbone connections, cabling systems and switching/routing infrastructure are critical to ensure high availability (be able to operate in 24/7 fashion). Moreover, these IXPs must be carrier-neutral IXPs in order to provide equal access for every peer member in order to prevent barriers to specific members.

5.2 Resilient Network Topology

5.2.1 Topology Selection

Once nodes including core and access nodes are chosen, the connections among them are required in order to implement regional or global IXPs (interconnection of IXPs among countries) as an important part of "Information Silk Road" or "Silk Road Information Superhighway". The process of determining how they are logically or physically connected is referred to as topology selection and design, which is described below.

5.2.1 **Table 5-2: Network Topology Selection Criteria**

Topology	Performance (0-2)	Redundancy (0-2)	Scalability (0-2)	Complexity (0-2)	Cost (0-2)	Total Score (0-10)
Star	1.5	0.5	1.5	2.0	1.5	7.0
Ring	1.5	2.0	1.5	1.5	2.0	8.5
Full Mesh	2.0	2.0	1.5	1.0	0.5	7.0
Partial Mesh	2.0	2.0	2.0	1.5	1.5	9.0

Table 5-2 illustrates the comparison among various topologies such as star, ring, full mesh and partial mesh (see Annex 4). There are five criteria in this comparison which are performance, redundancy, scalability, complexity and cost. Each criterion has an equal weight of 2 points. For performance, full mesh and partial mesh have a full score because of direct links among nodes which could also possibly provide short communication paths (with low number of hops) from one node to another. In star topology, congestion can possibly occur at central nodes, while ring naturally represents a longer path (traffic will be serially passed one by one) in large networks. Thus, both of them only have 1.5 points via this criterion.

With regard to redundancy, ring and mesh (both full and partial mesh topologies) are very redundant, resulting in 2 assigned points for each of them. However, as there is a single point of failure at central nodes in star topology, its score is only 0.5. Moreover, partial mesh is very scalable and has full score on the scalability criterion because only two links are required from access nodes to core nodes (via main and diversity links), as illustrated in Figure 5-3. Star and ring topologies are also scalable but there are some negative impacts in large networks, so their score is 1.5; while full mesh is not very scalable in terms of number of links, so its score is also 1.5.

Difficulty or ability to implement and maintain each topology is taken into account in the complexity criterion. In star topology, each node (local IXP) manages its own local traffic; and jointly forms a regional IXP, each local node needs just one connection to a central node. Its complexity is not high and it should therefore be assigned a full score in this criterion. Ring topology has to manage two connections among neighboring nodes, and partial mesh has to maintain the same two connections at each access node, so both of them are equivalent at 1.5 scores. In full mesh, complexity is increased when networks are increased (more connections are required) and thus its score is 1.

With regard to the last criterion which is cost, ring has 2 points because of only two required connections. However, both CAPEX and OPEX are naturally lower among the others. In addition, only two connections are required at each access node in partial mesh topology but core nodes typically require a higher number of connections to provide connectivity to these access nodes, its score is 1.5. In star topology, even though only one connection is required from local nodes to central node, a high CAPEX/OPEX is required at the central node to build/maintain redundant power and transmission systems, thus its score is 1.5. Due to a large number of connections required in full mesh networks which is directly proportional to cost,the mech topgraphy score 0.5.

By comparing all topologies, partial mesh has the highest score, and it is the most appropriate topology to be used to form ahierarchical model in regional (or global) IXPs in China-Central Asia corridor. Furthermore, because of a shorter path in the 2-tier hierarchical network model, traffic delivery is very efficient; while resilience is also achieved because of redundant link(s).Therefore, partial mesh is recommended in this study.

5.2.2 Topology Design

From China's perspective, Central Asia is very important as it is a direct gateway to West Asia and Europe; while most countries in this China-Central Asia corridor are landlocked countries and their international connectivity is dependent on only neighboring countries.ICT connectivity plays an important role to connect countries in this corridor as is an important part of Silk Road Information Superhighway. To successfully implement this information superhighway connecting countries countries along the Belt and Road, Kazakhstan and Urumqi have been selected to be the core nodes for both intra- and inter-corridor connectivity among each economic corridor, while the other nodes are access nodes and can possibly reach other countries (in other regions/corridors) via core nodes.

Moreover, partial mesh topology offers many advantages in terms of performance, redundancy and scalability and it is consequently chosen to connect multiple nodes together to form a regional (or global) IXP in the China-Central Asia corridor. Figure 5-5 shows the logical network topology of ICT infrastructure in this corridor. Note that logical topology normally illustrates how each node logically communicates with the others.

Figure 5-3: Logical Network Topology in China-Central Asia corridor

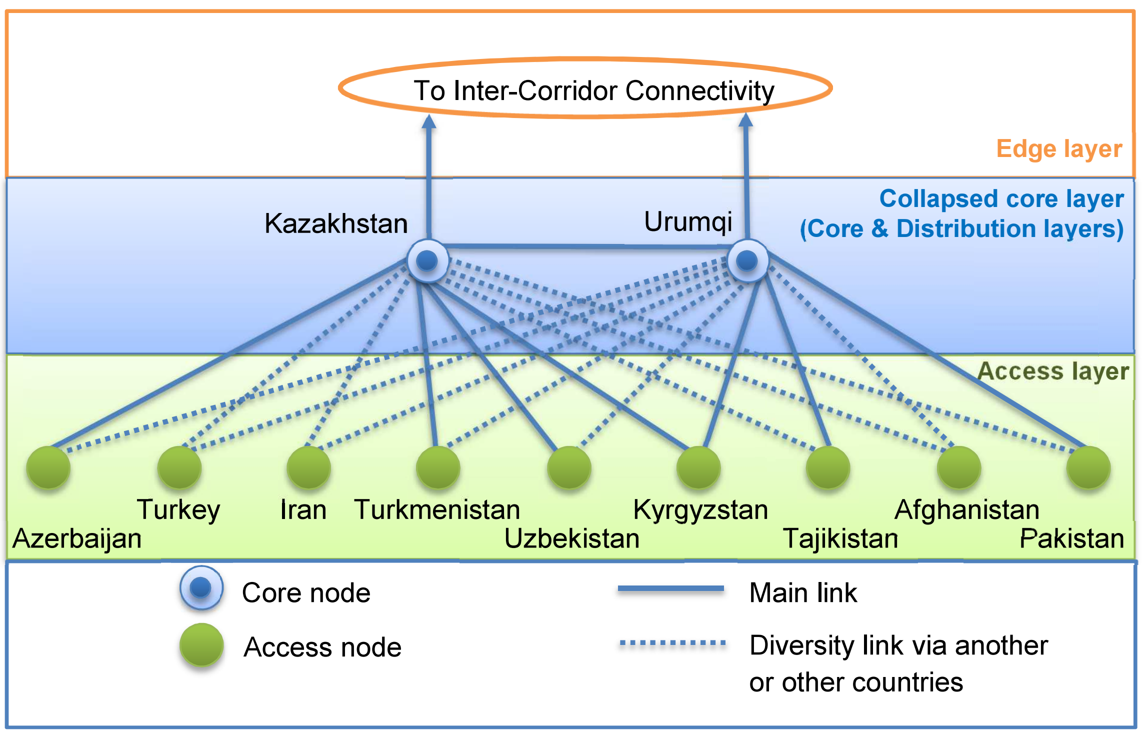
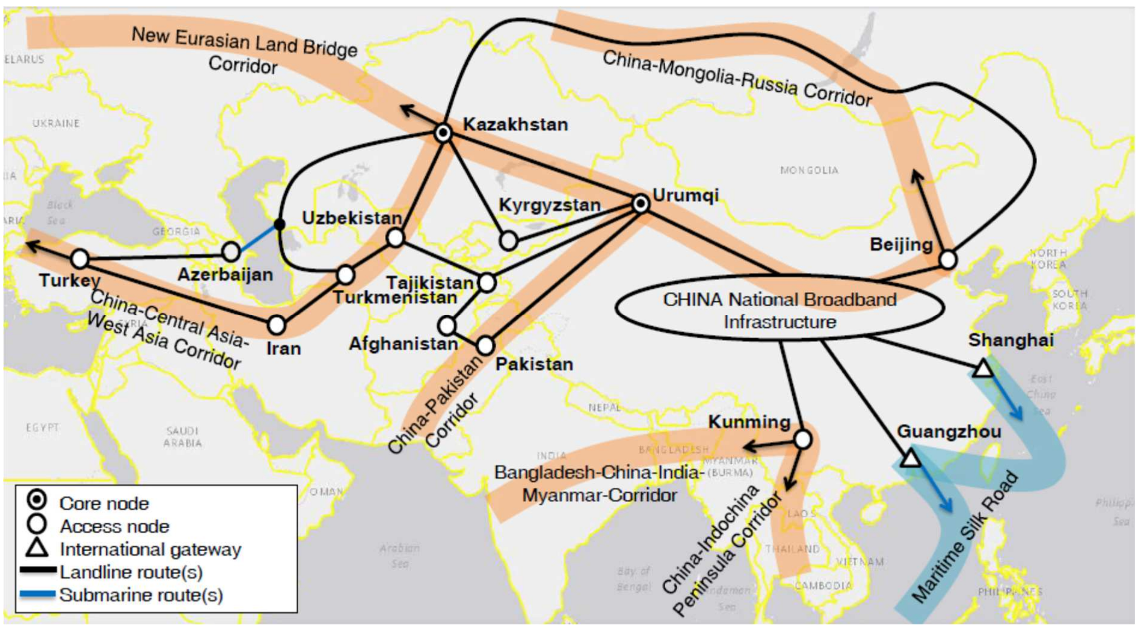


Figure 5-3 illustrates the logical network topology in the China-Central Asia corridor. Note that to effectively support ICT connectivity in this corridor, ICT connectivity to five more countries is also proposed, which are Afghanistan, Azerbaijan, Iran, Pakistan, and Turkey. The hierarchical network model is applied instead of the flat network model in order to achieve scalability. There are two layers/tiers in this topology: collapsed core layer (combination of core and distribution layers) and access layer. Core nodes typically provide backbone connection to both inter-corridor and intra-corridor connectivity. In this proposed topology, Kazakhstan and Urumqi are selected to be the core nodes because of their strong international connectivity, while the others are dynamically classified as the access nodes.

In addition, each access node has at least two fibre-optic routes to two different core nodes using both main route and/or diversity route(s) via other countries (a diversity route is used in case that the access nodes does not share the direct border with core nodes) in order to achieve resilience. Hence, in the case that one node is experiencing outage, this does not affect the others because they can use redundant route(s) to directly access this Silk Road Information Superhighway.

Figure 5-4 below depicts the proposed physical network topology and cross-border fibre-optic routes in the China-Central Asia corridor. Both Kazakhstan and Urumqi nodes in this corridor could effectively provide inter-corridor connectivity to the other five economic corridors: New Eurasia Land Bridge, China-Mongolia-Russia, China-Pakistan, Bangladesh-China-India-Myanmar, and China-Indochina Peninsula corridors.

Figure 5-4: Physical Network Topology of Intra- and Inter-Corridor Connectivity



According to the ITU Transmission Map, two cross-border fibre-optic routes in this topology are not currently present, which is a terrestrial route in Pakistan-Urumqi (there is a fibre-optic route to the Chinese border which is not currently connected to Pakistan) and a submarine route connecting Azerbaijan and Kazakhstan. These two routes are necessary in order to provide the shortest route to core nodes (and other corridors) and also achieve resilience. Thus, Afghanistan and Turkey could have a redundant route to reach core nodes and other countries in different regions. There is an option to connect Azerbaijan to the Islamic Republic of Iran, but if the node in the country is experiencing an outage, and this will consequently cause network isolation (i.e., a broken connection from Turkey & Azerbaijan to the rest in this corridor). It must be noted that there are plans to implement both routes but they are not implemented to date.

In addition, to improve performance and ensure resilience, the route between the Islamic Republic of Iran and Afghanistan can be included in the design, but this results in additional CAPEX and OPEX for implementation and maintenance of this route. Yet, this route could also shorten the communication distance between South Asia and Europe. Currently there exists one cross-border route between Mashhad in the Islamic Republic of Iran and Herat in Afghanistan. In addition, this cross-border route is still not connected with Kabul and other parts of Afghanistan. The fibre-optic route to connect this Mashhad-Herat route and other parts of Afghanistan is currently under construction.

To jointly connect the Silk Road Economic Belt (six economic corridors) and the maritime Silk Road, core nodes must also provide connections to International Gateways (e.g. Shanghai, Guangzhou and others). These connections between the Belt and Road would bring more benefits by connecting countries in each corridor to other countries in different regions via international submarine cables.

Even though there are redundant paths to reach another node, high reliability on each node is still required to prevent network isolation for national backbone networks which are directly connected to this node. Hence, redundant power sources and transmission systems are of great importance. In addition to reliability at each node, performance in terms of capacity of transmission systems to deliver traffic or perform switching/routing must be also taken into account to prevent congestion or bottlenecks, especially at core nodes.

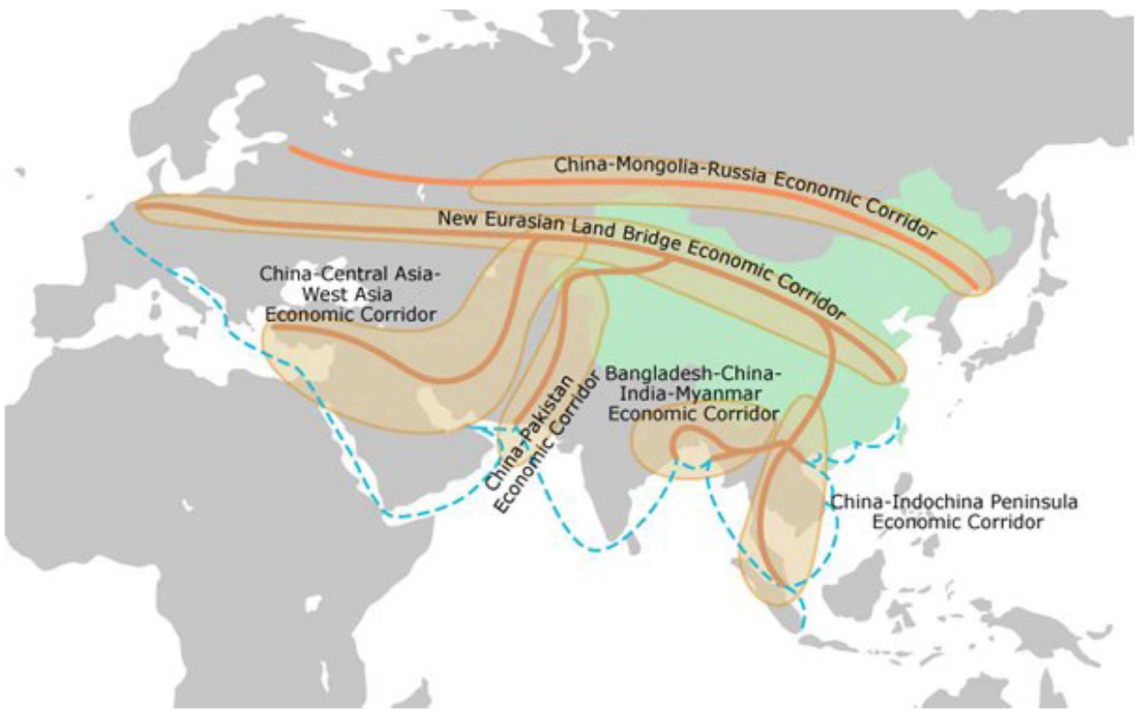
Annex 1:

1.1 BRI Vision and Framework

The Belt and Road Initiative inherently carries the spirit of the ancient Silk Road to connect the continents of Asia, Europe and Africa, which enables "peace and cooperation, openness and inclusiveness, mutual learning and mutual benefit". This Silk Road spirit is very important in the development of countries along the Belt and Road, and essential to fulfilling the BRI vision, which is to realize connectivity and enhance collaboration on policy, infrastructure, trade, financial and people.

According to BRI, there are six economic corridors proposed as the framework to connect more than 60 countries along the Belt and Road which are (1) New Eurasian Land Bridge corridor, (2) China-Mongolia-Russia corridor, (3) China-Central Asia-West Asia corridor, (4) China-Indochina Peninsula corridor, (5) China-Pakistan corridor, and (6) Bangladesh-China-India-Myanmar corridor as clearly illustrated in Figure 2-1.

Figure 2-1: Six BRI Economic Corridors



Source: Hong Kong Trade Development Council (HKTDC), 2015

Moreover, in BRI, the Silk Road Economic Belt is the route that connects China, Mongolia, the Russian Federation and countries in Europe through the New Eurasian Land Bridge and China-Mongolia-Russian Federation corridors; link China to the Mediterranean Sea and Persian Gulf through multiple countries in Central Asia and West Asia along the China-Central Asia-West Asia corridor; bridge China to countries in South Asia and the ASEAN region using the Bangladesh-China-India-Myanmar and China-Indochina Peninsula corridors; and can also possibly provide a shortcut to Africa (via Dubai and Oman) through China-Pakistan corridor. Whereas the 21st-Century Maritime Silk Road naturally refers to the sea routes, focused on marine transportation and communications from China's east coast to other countries in Asia, Africa and Europe across the South China Sea and the Indian Ocean.

1.2 BRI Goals and Objectives

To reinforce connectivity and collaboration on policy, infrastructure, trade, finance, among multiple countries along the Belt and Road, the National Development and Reform Commission (NDRC) of China stated in the official document that the "BRI initiative is aimed at promoting orderly and free flow of economic factors, highly efficient allocation of resources and deep integration of markets; encouraging the countries along the Belt and Road to achieve economic policy coordination and carry out broader and more in-depth regional cooperation at higher standards; and jointly creating an open, inclusive and balanced regional economic cooperation architecture that benefits all." To successfully achieve these basic goals, its objectives have been set up and are listed below:

- **To enhance policy coordination -** This is one of the key objectives required to effectively implement the BRI initiative. Intergovernmental cooperation is required to strengthen mutual political trust. In addition, countries along the Belt and Road should closely coordinate to align their policies and strategies to reach higher levels of practical cooperation and be ready for large-scale international projects.
- **To improve infrastructure connectivity -** Another key objective that must be taken into account when implementing the BRI initiative is infrastructure connectivity. The two most important concerns to successfully link multiple countries along the Belt and Road are (a) national and international connectivity plan to define how facilities or infrastructure are linked/connected, (b) standard systems for seamlessintegration and compatible operations, and (c) ensuring that infrastructure is more resilient to disasters. In addition, the infrastructure discussed here refers to transport infrastructure, energy infrastructure and ICT infrastructure.

With regard to transport infrastructure, there is a focus on the key passageways and junctions, linking unconnected road sections, relieving traffic congestion, and finally improving road safety and traffic management facilities. In addition to a road network connectivity plan, marine transportation such as port infrastructure construction should also be considered to provide smooth land-water transportation channels, and advanced port operation to efficiently enhance marine transportation. This plan is to expedite logistics and transportation processes among countries along the Belt and Road.

With regard to energy infrastructure, there is a focus on securing/enhancing oil and gas pipelines, power grids and power networks that consider co-deployment strateiges with ICT infrastructure. Considering that ICT infrastructure is the key to move forward to develop a global digital economy, there is a focus on strengthening ICT infrastructure connectivity such as national and cross-border fibre-optic cables, submarine fibre-optic cable, and broadband wireless communications. This is to create an "Information Silk Road" to efficiently and effectively provide digital connectivity and communications among countries in Asia, Europe and Africa.

- **To reinforce trade and investment cooperation -** This objective is to provide trade and investment facilities, and also remove barriers among countries along the Belt and Road. For trade facilitation, custom cooperation should be efficiently improved; this includes the concept of the "Single Window" system that allows international traders to complete all necessary processes at one single location/entity. Moreover, new forms of trade and cross-border e-commerce should be developed at a rapid pace. Investment facilitation should also be sped up, as well as eliminating investment barriers in accordance to the principles of openness and mutual benefit.
- **To move forward to financial integration -** This objective can be carried out by strengthening financial regulation cooperation, putting more efforts in developing credit information systems, improving the system of risk and crisis management, and also stabilizing currency systems.
- **To support people-to-people collaboration -** This cooperation typically includes collaboration and information exchange such as cultural and academic exchanges, radio and TV programme co-production, tourism promotion, health technology transfer, skill training and development, science and technology joint lab/center establishment and so on.

Annex 2:

- **Capability**
  - **Highly available ICT infrastructure -** To guarantee that the information exchanged among countries along the Belt and Road will be always available (24x7).
  - **ICT infrastructure expansion -** To fulfill the missing communication links, either wired or wireless, in order to effectively support collaboration among people, organizations and countries.
  - **High speed networks -** To smoothly support cross-border electronic applications (e.g. e-government, e-commerce, e-learning, etc.), high speed communications are required to reduce latency and jitter which directly affect the quality of communications.
  - **Scalable networks** –To support larger networks (higher number of communication nodes) that connect and link more than 60 countries along the Belt and Road, ICT infrastructure must be expandable.
- **Security**
  - **Trusted and secured ICT infrastructure -** Trust is the fundamental principle that allows people, organizations and countries to utilize ICT infrastructure to support their collaboration. Hence, to build confidence of people, organizations and countries to share potentially sensitive information and/or perform their electronic transactions, ICT infrastructure must be secure.
- **Innovation**
  - **New innovation on ICT solutions -** Innovation or new forms of ICT solutions are important to support trade cooperation or financial integration such as cross-border e-commerce, custom clearance, financial technology (FinTech) and so on.
- **Mobile**
  - **Mobility solutions -** To facilitate collaboration among countries and relationship among people, the tools used for information sharing/exchanging must be agile and flexibly designed to fully support mobile devices (e.g., smart phones, tablets).
  - **Flexible networks -** ICT infrastructure must be flexible and can support various types/forms of ICT applications/services and end-devices including mobile devices.
  - **Borderless communications -** ICT infrastructure is also expected to be accessed anytime from anywhere along the Belt and Road to reach a high level of connectivity and collaboration.
- **Implementation and Operation**
  - **Open and standard based technologies and systems -** To simplify operation and ensure compatibility of ICT connectivity among countries, =ICT platforms are to be characterized by openness and standardization.

- **Seamless integration and connectivity -** There are various ICT technologies utilized by countries along Belt and Road, but ICT connectivity must be seamless integrated for effective synergy/collaboration. This also includes the seamless integration of ICT infrastructure such as connection between land- and sea-based fibre-optic cables.
- **Simple ICT operation and management** – Because an information route may pass through multiple countries, ICT infrastructure must be easy to manage. In addition, to improve cross-border cooperation, ICT operation must be efficient and effective. The example of this cooperation is the previously discussed Single Window system.
- **Synergy on ICT policies -** ICT policy coordination is critical to facilitate information exchange among countries along the Belt and Road, and also to remove communication barriers.
- **Cost reduction** – To allow more people to have the opportunity to access networks to increase people-to-people relationships and also reduce digital divides of countries along the Belt and Road. Internet and broadband prices should be affordable. By reducing both CAPEX and OPEX on ICT connectivity, Internet access prices offered by service providers/operators may be directly affected.

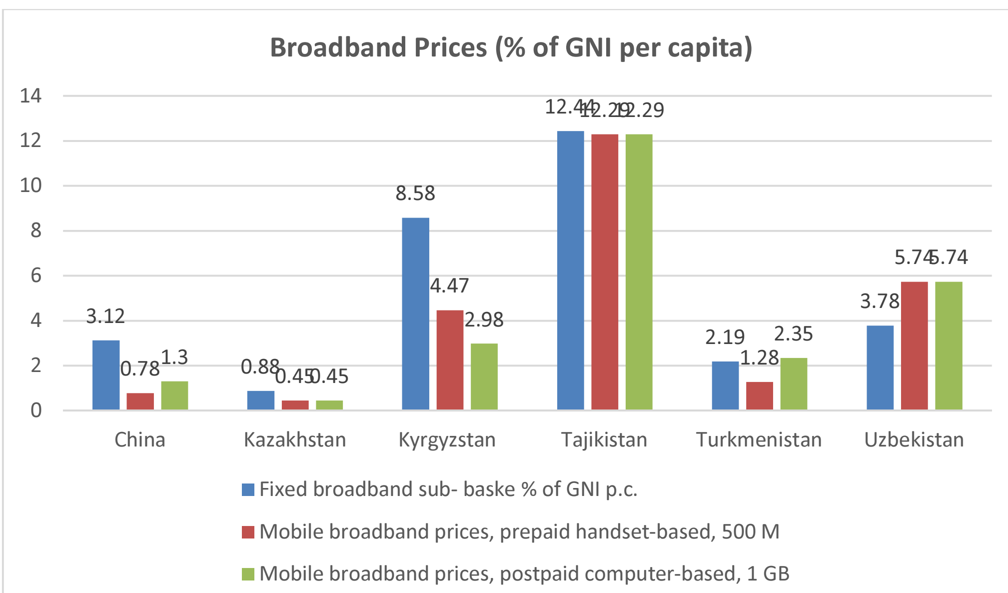
Annex 3:

3.1 Broadband Internet Pricing

In terms of Internet pricing, there are typically two major models of comparison: one model compares prices with currency and another with percentage of GNI per capita. As the purpose of this study of broadband pricing is to analyze whether local people in each country can afford broadband access or not, it is more reasonable to compare prices in terms of percentage of GNI per capita: this seems to be a more appropriate metric and a fair comparison relevant to this study. Figure A3-1 exhibits fixed and mobile broadband prices in terms of percentage of GNI per capita. Note that information for GNI per capita of each country is also presented in Table 3-2.

For fixed broadband prices, it is stated by the Broadband Commission for Sustainable Development that fixed broadband is considered affordable when the price is lower than 5 per cent of GNI per capita[56]. However, to be more precise in affordability of broadband pricing, this study utilizes the same evaluation criteria as utilized in a report co-published by ADB, ESCAP and ISOC which defines four levels of affordability: unaffordable (>25 per cent), expensive (5-25 per cent), moderate (2-5 per cent) and affordable (<2 per cent) compared to GNI per capita[57].

Figure A3-1: Fixed and Mobile Broadband sub-basket in per cent of GNI per capita



Source: "Measuring the Information Society Report 2016" by ITU

[56] The details of affordability criteria on fixed broadband services can be found from "The State of Broadband: Broadband catalyzing sustainable development" by Broadband Commission for Sustainable Development.
[57] The details of more precise affordability criteria can be found from "Unleashing the Potential of the Internet in Central Asia, South Asia, the Caucasus and Beyond" by ADB, ESCAP and ISOC.

By using this evaluation criterion, it is clear that fixed broadband in Kazakhstan is affordable, at only 1.12 per cent of GNI per capita, while prices in China, Turkmenistan and Uzbekistan are moderate, at 3.58 per cent, 4.3 per cent and 4.73 per cent, respectively. However, fixed broadband in Kyrgyzstan is expensive at 10.66 per cent of GNI per capita. This is another factor of lower fixed broadband penetration in Central Asia, in addition to inadequate fixed ICT infrastructure.

However, if the same criterion is used on mobile broadband, China, Kazakhstan and Turkmenistan (for postpaid with 500MB) have affordable mobile broadband (lower than 2 per cent of GNI per capita). Mobile broadband is priced moderate in Turkmenistan (prepaid with 500MB) and Uzbekistan (for prepaid with 500MB), and expensive in Tajikistan, Kyrgyzstan, Turkmenistan (for both postpaid and prepaid with 1GB). Moreover, in Uzbekistan, mobile broadband is considered unaffordable at 28.75 per cent of GNI per capita.

3.1.2 Internet Addresses

Table A3-1 depicts the comparison of IPv4 and IPv6 addresses in China and Central Asia. Note that IP is the abbreviation for Internet Protocol which is the routed protocol used to carry information in the Internet. IP addresses are necessarily required to identify both source and destination(s) of communications over the Internet. By looking at the global average of IPv4 addresses per capita, a person should have at least one IPv4 address, and this does not seem to be adequate nowadays, because one single person can possibly own more than one device (e.g. smart phones, tablets). The number of IPv4 per capita is considered low in China and Central Asia, as it is shown that one single IPv4 address must be shared by many people.

Table A3-1: IPv4 vs IPv6 Addresses in China and Central Asia

Economy	IPv4 Addresses (/32s) Per capita[58]	IPv6 Addresses (/64s) Per capita[59]	IPv4 Deployment (per cent of use)	IPv6 Deployment (per cent of use)
World	1.091	125 262	77.10	11.99
China	0.468	65 966	88.08	0.30
Kazakhstan	0.293	32 097	97.24	0.01
Kyrgyzstan	0.131	33 658	95.56	0.03
Tajikistan	0.043	19 879	92.81	0.00

[58] In IPv4, a single "/32" address is usually assigned to each end user.
[59] In IPv6, a single "/64" address refers to the average block assigned to a single site.

Turkmenistan	0.022	6 244	97.14	0.01
Uzbekistan	0.015	7 836	90.80	0.01

Source: "IP Resource per Country Distribution Report" by APNIC, 2015 - 2017

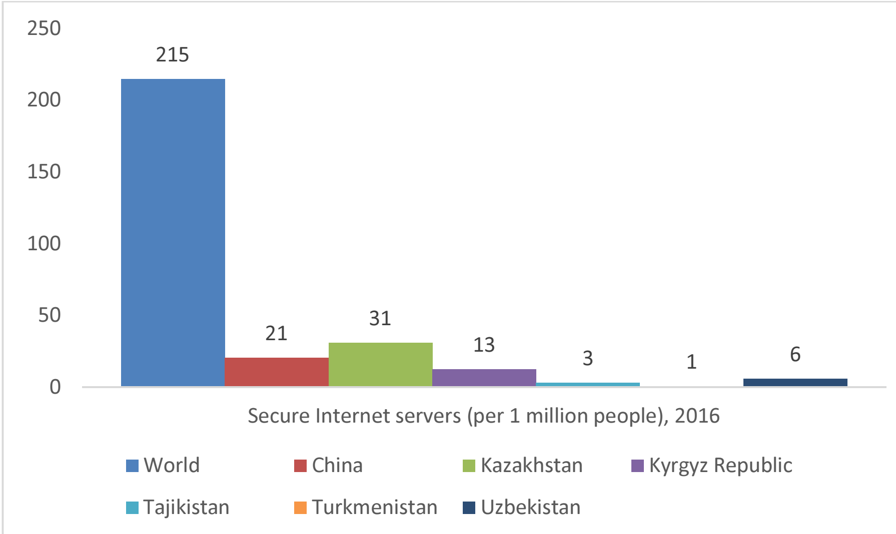
The solution to the insufficient IPv4 addresses is to use some technical solutions such as Network Address Translation (NAT) and private IP addresses defined in RFC 1918 (Address Allocation for Private Internets) proposed by the Internet Engineering Task Force (IETF). However, these techniques are not very efficient because it usually has some processing delays to translate from private IP address and public IP address before data packets are routed over the Internet and vice versa.

In addition, with the Internet of Things (IoT) and Internet of Everything (IoE), devices, people, processes and data are effectively connected together over Internet. Eachrequires an IP address to identify itself, and there are not enough IPv4 addresses, Thus, migration to IPv6 is a sustainable option (Table 3-4), as there are more than sufficient IPv6 addresses due to its size at 128 bits, that corresponds to 2^{128} addresses compared to only 32-bit IPv4 addresses. per centper cent

3.1.3 Internet Security

Cyber or Internet security ensures confidentiality (i.e., data is transmitted to only intended recipients), integrity (i.e., data is arrived at recipient(s) without changing/modifying), authentication (the sender is the true senders, not imposter) and authorization (i.e., right to access ICT resources). One key indicator used by the World Bank to characterize Internet security is "secure Internet servers" which indicates how many servers utilize encryption technology to secure Internet transactions. The world average of secure servers are 209 servers per one million people as shown in Figure A3-2. However, the highest number of secure servers in the compared countries is equal to 18 servers, exhibited by Kazakhstan. China and Kyrgyzstan have approximately the same at 10 and 11 secure servers, respectively, while less than 3 secure servers per one million people are available in Tajikistan, Turkmenistan and Uzbekistan.

Figure A3-2: Secure Internet Servers in China and Central Asia



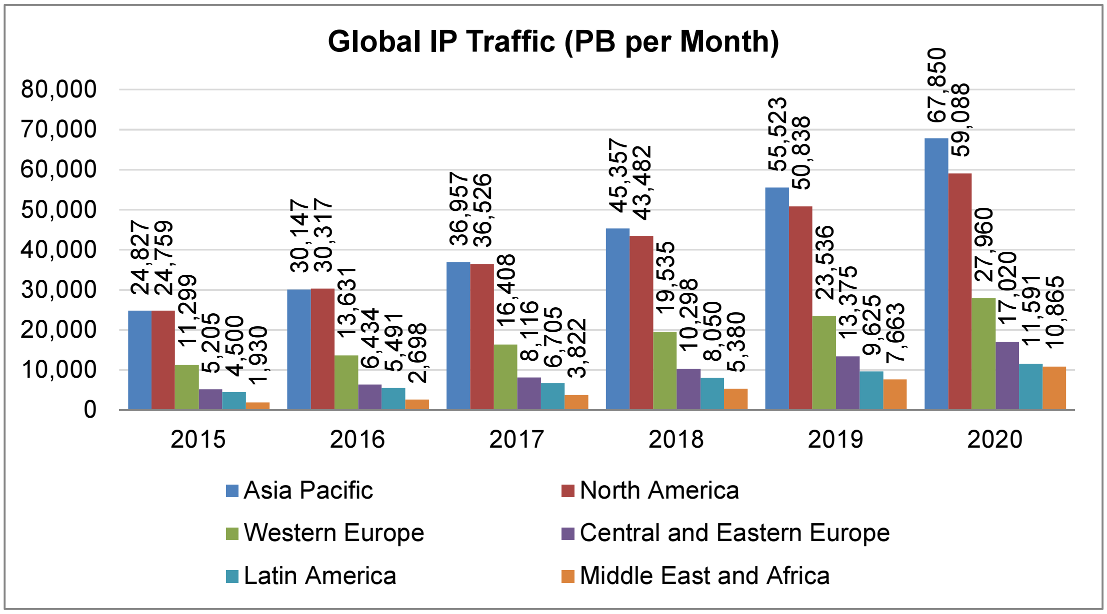
Source: "World Development Indicators" by World Bank, 2016

3.1.4 Global IP Traffic and Service Forecast

Figure A3-3 depicts the current and estimated global IP Traffic (total IP traffic generated to IP networks) in different regions including Asia and Pacific. In 2015, IP traffic generated in Asia and the Pacific is around 34 per cent of the world's total traffic. Moreover, in 2015, the total IP traffic in the Asia-Pacific region is about 24,827 PB generated to IP networks per month (1 PB = 1,000 TB or 10^{15} Bytes) and will reach 67,850 PB by 2020. It appears that annual global IP traffic growth in Asia and the Pacific is around 22 per cent.

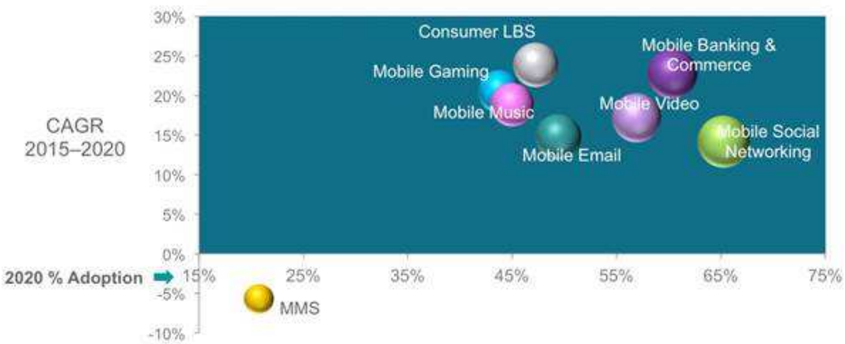
According to consumer mobile services as shown in Figure A3-4(a), the two most widely used services in 2020 will be "Mobile Banking and Commerce", and "Mobile Social Networking"; and the two services exhibiting the highest growth are "Consumer Location Based Services (LBS)" and "Mobile Banking and Commerce" at growth rates of more than 20 per cent. Hence, this clearly illustrates that people are increasingly likely to use mobile banking and commerce to make financial transactions. The one with the highest growth in business service is "Desktop Video Conferencing" as illustrated in Figure A3-4(b), signaling a clear trend that business users typically use desktop video conferencing for their communications and business collaborations.

Figure A3-3: Global IP Traffic

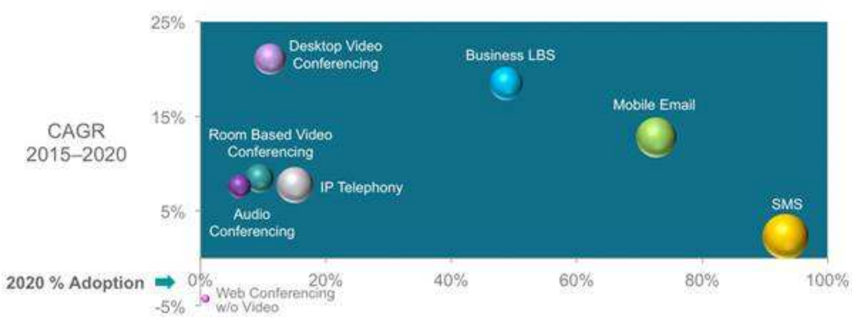


Source: Cisco VNI Forecast and Methodology, 2015-2020

Figure A3-4: Global Services Adoption and Growth for (a) Consumer Mobile Services, and (b) Business Services



(a)



(b)

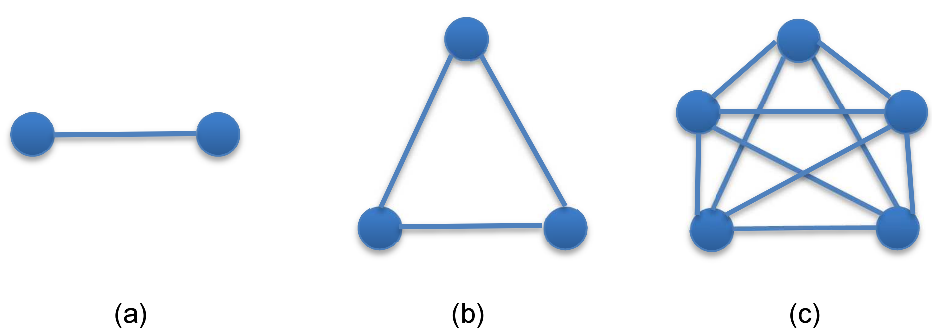
Source: Cisco VNI Forecast and Methodology, 2015-2020

Annex 4:

4.1 Node Selection for IXPs

To provide the connectivity among countries within the China-Central Asia corridor (intra-corridor connectivity) and with other corridors (inter-corridor connectivity), flat network model where all nodes act as the same peers and have the same responsibilities is not scalable, because the number of connections or members in a set E will be exponentially increased when there are more nodes in a set V. For full-mesh connections (each node has direct linkages to every other nodes), the number of connections can be computed using $n(n-1)/2$, where n is a number of nodes in a set V. For example, one connection is required in 2 nodes, 3 connections in 3 nodes, and 10 connections in 5 nodes as shown in Figure A4-1. This flat model with full mesh connections is required to guarantee full redundancy, and it is adequate for small networks. However, when networks become larger, they usually require a very number of connections (e.g. 45 connections in 10 nodes, 190 connections in 20 nodes and so on). Then, this is not a cost-effective solution. Note that to reduce cost in terms of both OPEX and CAPEX, partial mesh connections where each node has connections to a group of nodes can be considered. However, complexity still exists in terms of operation and maintenance because more connections among nodes refer to more cooperation among various countries (in case that a node represents a country node).

Figure A4-1: Full Mesh Connections in Flat Network Model of (a) 2 Nodes, (b) 3 Nodes and (c) 5 Nodes

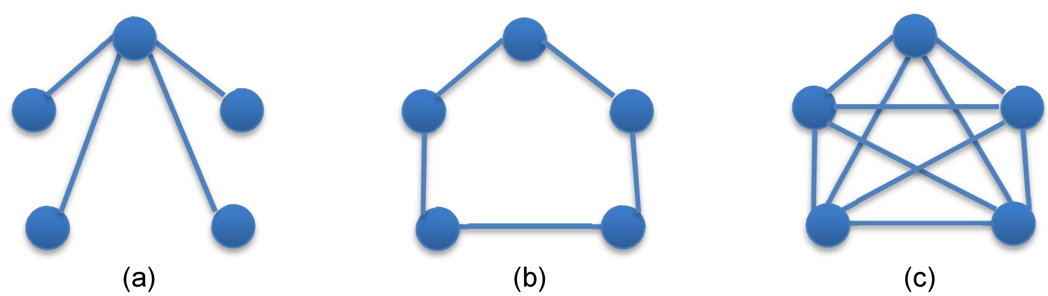


Annex 5:

Network topology type and their Pros and Cons

According to network topology, the most widely used topologies are star, ring and mesh topologies as illustrated in Figure A5-1. In star topology, sometimes called a hub and spoke topology, there is one main hub or central node which is responsible for all connections as shown in Figure A5-1(a), while the others require only one single connection to this central node. When all nodes are serially connected in a closed loop manner, this is called ring topology, and each node requires only two connections to its adjacent nodes as shown in Figure A5-1(b). In addition, Figure A5-1(c) depicts the mesh topology; each node has either all connections to every other nodes in a network (full mesh) or some connections to a group of nodes in a network (partial mesh). In full mesh, number of connections is $n(n-1)/2$, where n is number of nodes in a network; while number of connections in partial mesh is varied and depended on connections to a group of nodes in a network. Note that apart from these topologies, there is another called bus topology where nodes are serially connected in the same way as ring, but not in a closed loop; hence if there is one broken connection or link, this will consequently cause network isolation. In addition, it also presents very long latency to deliver traffic between a node from one end of connection to another and vice versa, then bus topology is not taken into account in this work.

Figure A5-1: Network Topologies of (a) Star, (b) Ring and (c) Mesh



In addition, there is no perfect solution or best topology which is suitable for every scenarios. To select topology to be effectively applied to connect all nodes (local IXPs) in order to form regional IXP, all of them have both pros and cons as listed in Table A5-1. Thus, topology selection is an important stage in the design of network topology and IXPs, and the most suitable topology in this China-Central Asia corridor must be carefully chosen.

Table A5-1 depicts the network topology selection criteria for star, ring and mesh topologies. To be more précised in topology selection to be used to efficiently and effectively connect countries in China-Central Asia corridor and support BRI, mesh topology is divided into full mesh and partial mesh topologies because of their different characteristics.

Table A5-1: Pros and Cons of Network Topologies

Topology	Pros	Cons
Star	- The regional IXP typically requires less number of connections to connect all nodes to a central node. - The administrative tasks are reduced in each node or local IXP (not a central node) because they have to be mainly responsible for only its local traffic.	- There is single point of failure at a central node. Redundancy is limited because regional IXP is relied on only a single central node. - Very high capacity is required at central node because of both local and regional traffic responsibilities (High CAPEX at central node) - More cross-border connections are required at a country where central node locates to support all connections. - There is limitation in a location of central node of regional IXP which must be located in a center of all connections to reduce CAPEX.
Ring	- There are both lower CAPEX and OPEX because each local IXP manages only two connections to neighboring nodes. - Redundancy is inherently obtained because if there is a link break, traffic can be rerouted in a reverse direction.	- High redundancy is required in every nodes (local IXPs) to prevent broken connection. Outage at one local IXP, possibly affects quality of service (longer latency). - Policy coordination is strongly required for consistency in forwarding traffic and uniform quality of service because traffic must passes many country nodes before arriving at destination(s).
Mesh	- Regional IXP has high efficiency in terms of data delivery due to direct connections among nodes in full mesh networks. - Regional IXP has very high redundancy. Outage at one local IXP does not impact the others.	- In large networks, regional IXP requires a huge number of connections in full mesh networks (very high CAPEX and OPEX). - When a direct link from one node to another is broken, this may affect quality of service at this node due to traffic rerouting. - If networks become larger, complexity will be increased in terms of traffic delivery from source to destination (switching/routing). It is not scalable for full mesh networks in large networks.

Table A5-2: Gap Analysis in ICT Area of Capability

ICT Area: Capability		
No.	**Current State (As-Is)**	**Gap**
1	China and Central Asia can connect together via three cross-border fiber routes by using China-Kazakhstan, China-Kyrgyzstan, and China-Tajikistan fiber routes.	Redundant fiber route(s) is required - All three fibre-optic routes provide connections from Central Asia to China (and vice versa) via Urumqi regional international gateway only. According to BRI, Central Asia is also the gateway to South Asia, West Asia and Europe. Then, Urumqi international gateway is very important, because all three connections rely on this Urumqi gateway, redundant route(s) to connect together China and Central Asia are strongly required to guarantee uninterrupted communications.
2	China and all countries in Central Asia can access Internet and internationally connect to other countries with different levels of international bandwidth ranged from 2.4 Gbps in Turkmenistan to 5.39 Tbps in China. However, by focusing on Internet speed per user, the country which has the maximum of international Internet bandwidth per Internet user is Kazakhstan at 51.49 Kbps and the minimum one is only 1.29 Kbps in Uzbekistan; while the world average is at 61.82 Kbps.	Inadequate international bandwidth - By focusing on international Internet bandwidth per Internet user, every country in this region has speed far below the world average except Kazakhstan which has speed per Internet user slightly below the world average at 51.49 Kbps. Especially in Tajikistan, Turkmenistan and Uzbekistan which have average international bandwidth per user lower than 4 Kbps. This bandwidth typically causes negative impacts on multimedia communications (such as digital voice services with G.729 standard requires 8 Kbps) which may consequently interrupt collaboration among people and organizations in different countries along the Belt and Road.
3	Figure 3-10 illustrates national fiber cable connections within China and countries in Central Asia. Every country in this region has different levels of national fiber backbone networks (more information can be found from ITU Interactive Transmission map) to provide connections among cities in each country. Apart from infrastructure, both Internet penetration and fixed broadband penetration in Kyrgyzstan, Tajikistan and Turkmenistan are	Inadequate national ICT Infrastructure including domestic backbone networks, and low ICT penetration - China has high fiber connection density in the eastern part of the country (where main cities are located), but has low fiber connection density in central and western parts (including Urumqi which is the gateway to Central Asia). Low fiber connection density can also be found in other countries in Central Asia, and this

	below the global average (less than 20 per cent in Internet penetration and less than 3.6 in fixed broadband penetration).	illustrates their lack of fiber route redundancy in these parts of China and Central Asia. Lack of fiber connections, is main factor which consequently causes low Internet penetration in Central Asia, especially in Kyrgyzstan, Tajikistan and Turkmenistan; in every 100 people, only less than 20 people has an opportunity to access valuable information available in the Internet. Fixed broadband penetration in these countries is also low (only 0.1 per cent in Kyrgyzstan, Tajikistan and Turkmenistan, and 3.6 per cent in Uzbekistan). This low ICT penetration consequently affects people connectivity and collaboration.

Table A5-3: Gap Analysis in ICT Area of Security

ICT Area: Security		
No.	**Current State (As-Is)**	**Gap**
1	Encryption techniques is adoption rates are low among servers in China and countries in Central Asia. One indicator used to measure Internet security is the number of secure server per a million people which illustrates number of servers utilizing encryption techniques to secure their transactions. The world average is 209 servers. However, a number of secure servers in each country in this region is less than 18 servers.	Less security in ICT infrastructure - In China and central Asia, the number of secure servers in each country is less than 18 servers which explicitly indicate that most of servers in this region are not utilizing encryption techniques to protect information in their communication channels.

Table A5-4: Gap Analysis in ICT Area of Innovation and Mobile

ICT Area: Innovation and Mobile		
No.	**Current State (As-Is)**	**Gap**
1	There is high penetration in mobile communications. The global penetration in mobile subscriptions is 98.6 per cent; while Kazakhstan and Turkmenistan have very high mobile penetration at 187.2 and 145.9 per cent, respectively. Kyrgyzstan and Tajikistan are tie with the global average. China is slightly lower at	Borderless communications is essential and ICT connectivity must support mobility - The statistic about ICT penetration clearly illustrates the communication trend where data and voice communications continuously shift towards mobile devices. Based on traffic forecast by Cisco, mobile data traffic will be two-thirds of total IP traffic[44].

	93.2 per cent, while mobile penetration in Uzbekistan is at 73.3 per cent.	Hence, ICT connectivity must be borderless and support mobility by allowing people to use any devices (mobile phones, tablets and wearables) to access networks anywhere at anytime.
2	According to global IP traffic reported by Cisco[44], in Asia Pacific, consumers generate IP traffic at 19,869 PB (1 PB = 1000 TB or 10^{15} Bytes) out of the total of 58,539 PB in 2015 and will grow 23 per cent by 2020; while there are 4,958 PB out of 13,982 PB generated by business users in this region and will reach 11,356 PB by 2020 (18 per cent growth). In addition, mobile services will be widely used by 2020.	Innovation and new forms of ICT connectivity are required to support trade cooperation and financial integration - The two most widely used services for consumer mobile services by 2020 will be Mobile Social Networking and Mobile Banking & Commerce, while Mobile Banking & Commerce is also the mobile service that ranked second in year over year growth (37 per cent). To facilitate trade cooperation or financial integration in the future, new form of ICT connectivity and innovation will play an important role to successfully drive trade cooperation and financial integration among countries along the Belt and Road especially between China and Central Asia.

Table A5-5: Gap Analysis in ICT Area of Implementation and Operation

ICT Area: Implementation and Operation		
No.	**Current State (As-Is)**	**Gap**
1	The network topology for the fiber connections and nodes among China and countries in Central Asia is flat topology which is typically adequate for small networks (a few number of nodes and connections). This topology is naturally easy for design and implementation as long as the networks are still very small.	Network topology is not scalable - The flat topology is suitable for small number of nodes and links (or connections). There is no hierarchy or layer among them, all nodes have the same duty, and more number of direct links among them is strongly required to increase redundancy. However, is very complex when networks (in terms of fiber nodes and links) become larger. In addition, networks in Central Asia must be scalable to support network growth, because in China's perspective, Central Asia is also the gateway to South Asia, West Asia and Europe.
2	Since the world IPv6 launch began on 6 June 2012, many countries are aware of migrating from IPv4 to IPv6. However, the world average in IPv6 adoption is only 6.73 per cent; while there	Low IPv6 adoption – IPv4 address is not enough for people due to its limitation in its size (32-bit address). According to Asia Pacific Network Information Centre (APNIC) and Réseaux IP Européens Network Coordination Centre (RIPE

	is less than one per cent of IPv6 adoption in China and Central Asia.	NCC) which directly manages IP addresses in Central Asia, they exhaust their own managed IPv4 addresses in April 2011 and September 2012, respectively. Even though many technologies can be used to preserve IPv4 address i.e. NAT and private IP addresses, these techniques incur some processing delay for IP address translation. According to a Cisco report[60], it estimates that IPv6 capable devices (including both stationary and mobile devices) will globally growth at 27 per cent from about 4 billion in 2015 to 13 billion by 2020. However, IPv6 adoption percentage in China and each country in Central Asia are currently less than one per cent.
3	According to fixed broadband pricing in terms of percentage of GNI per capita, prices in China, Turkmenistan and Uzbekistan are moderate at 3.58, 4.3 and 4.73 per cent, respectively; and prices in Kyrgyzstan are expensive at 10.66 per cent. Mobile broadband prices are moderate in Turkmenistan (prepaid with 500MB) and Uzbekistan (for prepaid with 500MB) at 3.06 and 3.83 per cent, respectively; and they are expensive in Tajikistan, Kyrgyzstan, Turkmenistan (for both postpaid and prepaid with 1GB) at 9.8-16.44 per cent. Moreover, prices are at about 28.75 per cent of GNI per capita which are unaffordable in Uzbekistan.	High broadband pricing - Broadband pricing is another factor that directly affects ICT penetration. If they are too expensive or unaffordable, people cannot afford to access broadband networks affecting collaboration among them. According to fixed broadband pricing, it is moderate in China, Turkmenistan and Uzbekistan, and expensive in Kyrgyzstan; while for mobile broadband pricing, it is expensive in Tajikistan, Kyrgyzstan, Turkmenistan (for both postpaid and prepaid with 1GB). Moreover, mobile broadband pricing are unaffordable in Uzbekistan.

4	China has three carrier-neutral IXPs (CHN-IX) in Beijing, Shanghai and Guangzhou, where all six major Chinese backbone networks are connected. In Central Asia, there are three more additional IXPs, one IXP is in Uzbekistan (TAS-IX), and others are in Kazakhstan (KAS-IX) and Kyrgyzstan (Kyrgyz-IX). However, there is a	Not enough carrier-neutral IXPs - There is no IXP in some countries in Central Asia i.e. Tajikistan and Turkmenistan. There is one in Kazakhstan but currently it has no peering member, and IXP in Kyrgyzstan currently does not allow international ISPs, content providers, or data-center operators to exchange traffic at IXP itself.

[60] More information about IPv6 adoption can be found from “The Zettabyte Era—Trends and Analysis” by Cisco.

	report from NSRC, University of Oregon which states that KAS-IX has currently no peering member[54].	Local traffic among national backbone networks operated by different service providers cannot be efficiently exchanged unless there exist the bilateral peering (or multilateral peering) among them. In this case, traffic must be routed back and forth to another national network across international link which consequently results in inefficient and ineffective operations in terms of higher transit cost and latency.
5	From the Broadband Commission for Sustainable Development's report, there are national broadband policies/plans in China, Kazakhstan and Kyrgyzstan[61]. In China, there is Telecom Industry Development Plan 2011-2015 and EU-China Joint White Paper on The Internet of Things, Broadband China strategy, Internet Plus Action Plan, and etc.; in Kazakhstan, there is a plan about ICT Development; and there exist the digital terrestrial broadcasting service and the digital plan in Kyrgyzstan.	There are no national broadband policy/strategy in some countries in Central Asia, and ICT policy coordination among countries is also needed – There is no concrete ICT policy in Tajikistan, Turkmenistan and Uzbekistan. Hence, the goals for ICT development among stakeholders are not clearly defined as well as the low level of coordination in ICT-related activities among relevant stakeholders. In order to successfully implement an effective "Information Silk Road" among countries along the Belt and Road, ICT policy coordination among relevant countries is strongly required for efficient and effective implementation and operation.

[61] More details about national broadband policy in each country can be found from "The State of Broadband: Broadband catalyzing sustainable development" by Broadband Commission for Sustainable Development.

6	The main fiber routes such as Trans Asia-Europe (TAE) and cross-border fiber routes are typically managed by different national service providers. For example, the TAE route in Central Asia , is operated and managed by Kazakhtelecom, Kyrgyztelecom and Turkmentelecom.	Building QoS between endpoints comes with high transit costs. Because fiber routes are operated differently by multiple operators for Operations, Administration and Maintenance - OAM). Also it is challenging tobuild-in uniform quality of services between endpoints to guarantee traffic delivery which additionally incurs high transit costs. Moreover, ICT infrastructure including backbone networks must be open to simplify seamless integration for effective synergy and collaboration.
7	The main fiber route that links together China and countries in Central Asia is TAE. The technology used in this route as well as cross-border routes among them is Synchronous Digital Hierarchy (SDH)[50].	Outdated WAN transport technology and High OPEX - SDH is the main transport technology used in TAE and cross-border fiber routes. This pure SDH technology is said to be reliable. However, it is a legacy technology and initially designed to support voice services. In addition, it is very complex, and also incurs higher OPEX compared to other technologies such as Optical Transport Network (OTN), Dense Wavelength Division Multiplexing (DWDM), and Multiprotocol Label Switching - Transport Profile (MPLS-TP).
8	Digital transformation is one of the important keys to support digital communications and collaboration among countries along the Belt and Road. It also accelerates the inter-linkages, interdependencies, and synergies across all types of infrastructure (i.e. energy, ICT and transport infrastructure). However, most infrastructure projects have yet to embrace co-deployment strategies to reduce costs.	Often infrastructure projects are undertaken without thought into whether co-deployment with other sectoral infrastructure is feaseable. Infrastrcture can typically be implemented along energy and/or transport infrastructure (e.g. gas pipelines, roads and rails). Moreover, with cross-sectoral synergies, new international digital routes could be efficiently developed at a fast pace with lower additional investment cost.

Table A5-6: Challenges and Issues in ICT Area of Capability

ICT Area: Capability		
No.	**Challenge and Issue**	**Impact**
1	Redundant fiber route(s) is required. For example, in connections between China and Central Asia, redundant route to another China regional international gateway (apart from Urumqi node) is recommended to guarantee high availability connections among China and other countries along the Belt and Road including Central Asia, South Asia, West Asia and Europe.	High
2	More international bandwidth is required and the increasing in speed per Internet user must be taken into account to support new forms/applications of people and country connectivity and collaborations (e.g. e-government, e-commerce, e-training, e-health and so on). Some of these ICT forms are multimedia applications, and Quality of Service (QoS) in terms of bandwidth, latency, jitter and packet loss are very important because they directly affect or possibly interrupt communications and collaboration.	High
3	National ICT Infrastructure including domestic backbone networks is required to increase capacity and service coverage and bridge the digital divide in China and Central Asia.	High

Table A5-7: Challenges and Issues in ICT Area of Security

ICT Area: Security		
No.	**Challenge and Issue**	**Impact**
1	Security in ICT infrastructure is required to be improved to guarantee secured connections and operations, and also facilitate people and organizations to share their sensitive information and/or make secure transactions.	High

Table A5-8: Challenges and Issues in ICT Area of Innovation and Mobile

ICT Area: Innovation and Mobile		
No.	**Challenge and Issue**	**Impact**
1	Borderless communications are required to allow people to use any devices (smart phones, tablets and wearables) to connect and access ICT infrastructure from anywhere at anytime.	Medium
2	Innovation or new forms of ICT solutions are required to support trade cooperation or financial integration with countries along the Belt and Road such as cross-border e-commerce, custom clearance, single window system, financial technology (FinTech) and so on.	Medium

Table A5-9: Challenges and Issues in ICT Area of Implementation and Operation

ICT Area: Implementation and Operation		
No.	**Challenge and Issue**	**Impact**
1	Network topology is not scalable, new network topology redesign (in terms of arrangement of nodes and their connections) is required to build hierarchical network topology to support network scalability.	Medium
2	IPv6 adoption should be increased to support huge number of mobile devices as well as electronic devices in IoT/IoE.	Low
3	Broadband pricing must be reduced to be affordable by people in Central Asia. This reduction in prices can consequently improve digital inclusion.	High
4	A number of carrier-neutral IXPs are required to be implemented in Central Asia to prevent unnecessary local traffic transited across international links. Operator OPEX will be reduced and Internet access cost is expected to be decreased with improvement in quality of service in terms of response time.	Medium
5	National ICT policy/plan/strategy is required to define the concrete directions of ICT development in each country in Central Asia.	Medium
6	International cooperation or policy coordination among countries along the Belt and Road especially in China and Central Asia is required for effective implementation and operation of information Silk Road. This is also required to build uniform quality of services between endpoints to guarantee traffic delivery among people, organizations and countries. In addition, this cooperation could possibly lead to lower transit cost among multiple service providers.	High
7	More cost-efficient and effective WAN transport technologies (OTN, DWDM or etc.) must be taken into account for international fiber routes to directly improve Operation, Administration and Maintenance (OAM) to reduce OPEX. This new technology migration also directly improves capacity of international routes.	High
8	ICT Infrastructure must be open and standardized to simplify seamless network integration	Medium
9	Cross-sectoral infrastructure synergies are required to accelerate and support connectivity among countries along the Belt and Road.	Medium

Annex 6:

Imprementation under the framework of the BRI

ICT strategies are essential for sustainable development in each country, they typically provide the concrete framework for ICT implementation in order to close all the gaps (in this work, gaps also refer to challenges and issues which are found by using Gap analysis as described in Section 4). Here, the effective ICT strategies and their actions (or activities under each strategy) provide a framework to successfully enhance connectivity and collaboration among countries along the Belt and Road. The details of ICT strategies and their recommended actions are described in the following.

6.1 ICT Vision

Before describing strategies for ICT connectivity to drive BRI initiative, the ICT vision should be clearly defined in order to picture how ICT connectivity could be used to effectively support BRI within the framework of AP-IS. Moreover, this ICT vision could lead to an achievement of BRI objectives which are to reinforce collaboration in policy, infrastructure, trade and investment, financial, and people. The vision for ICT connectivity to effectively support BRI is illustrated below:

"*Using ICT and Silk Road Information Superhighway as a CORE to Enhance Collaboration and Develop Digital Economy among Countries along the Belt and Road.*"

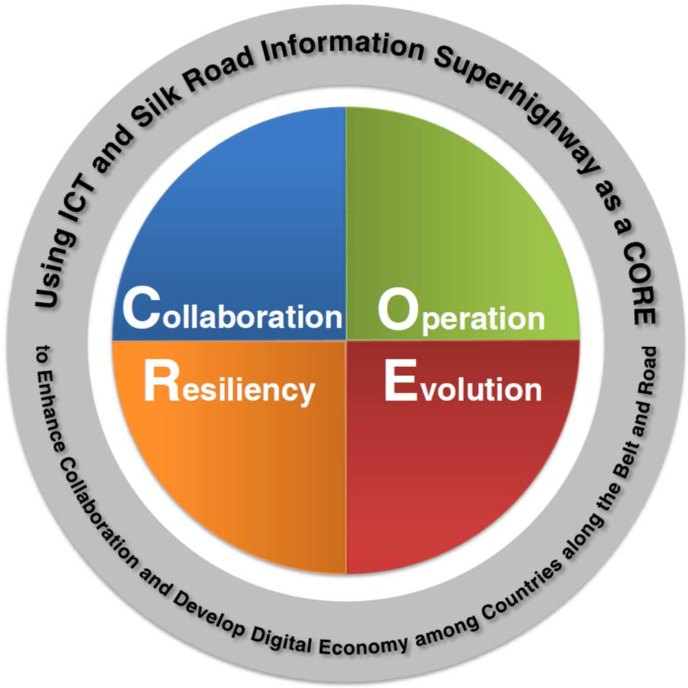
The main purpose of this work is to enhance ICT connectivity for BRI and support the implementation of the AP-IS Master Plan. One key component used to accomplish this task is to build the Silk Road Information Superhighway (SR-IS) which refers to the digital communication channel to provide efficient and effective communications and collaboration among more than 60 countries along the Belt and Road. This information superhighway could be effectively used as the fundamental ICT infrastructure to allow people, organizations and countries to share/exchange t information or make transactions using cross-border electronic applications (such as e-government, e-commerce, e-health, e-learning and so on), as envisioned in the AP-IS Master Plan.

This ICT connectivity and Silk Road Information Superhighway could also lead to the transformation from traditional economy to digital economy in each country associated with the BRI by providing the high level of ICT capabilities and readiness to support various digital technologies. Furthermore, the digital economy could naturally improve innovation, increase competitiveness and have beneficial impacts in many sectors such as technology, energy, transportation, healthcare, financial, education, manufacturing and so on. Apart from these benefits, digital economy can potentially reduce inequality and bridge the digital divide by allowing more people to be able to access digital networks in terms of broadband networks and Internet (increase ICT penetration). Hence, these collaboration enhancements and digital economy development directly facilitate sustainable development in each country associated with the Belt and Road.

Recognizing ICT connectivity deficits in the Asia Pacific region, ESCAP commenced the AP-IS initiative which aims to increase the availability and affordability of broadband Internet by strengthening the underlying Internet infrastructure through promotion of terrestrial and submarine fibre-optic connectivity. The recently endorsed AP-IS Master Plan identified Central Asia as the one of the sub-regions with the most missing links and outlines the principles, deliverables, timeline and financing mechanisms to connect the missing links and narrow the digital divide. As both BRI and AP-IS aim to enhance regional integration through improved infrastructural development and connectivity, there are great opportunities for complementarity between the AP-IS initiative and the Belt and Road initiative for enhanced synergies. The AP-IS initiative can provides a regional platform that brings together several stakeholders including ESCAP member governments, donors and financiers, research and academic institutions, regional and sub-regional organisations, telecom operators, and private sector companies, to carry out initiatives in support of the Belt and Road initiative, in particular for the Information Silk Road.

To effectively support this vision on ICT connectivity and also resolve all gaps found via conducting Gap analysis (the comparative analysis between future state and current state), four strategic principles on ICT connectivity called CORE principles are carefully proposed which consist of (1) Collaboration, (2) Operation, (3) Resiliency, and (4) Evolution as shown in Figure A6-1.

Figure A6-1: ICT Vision and Strategic Principles for BRI



6.2 ICT Strategic Principle 1 - Collaboration

There are 60 countries and beyond in Asia, Africa and Europe that are associated with the BRI initiative, they typically have their own economic systems, policies and regulations, ICT technologies and standardizations, and etc. Hence, this ICT strategic principle focuses on using ICT connectivity and policy to strengthen diversity and also enhance collaboration among them. Three key strategies (C1 to C3) and their actions that are recommended to be carried out are discussed as follows.

6.2.1 C1 - Silk Road Information Superhighway (SR-IS) Implementation

Objectives:

- To implement Silk Road Information Superhighway as the core ICT infrastructure to enhance connectivity and collaboration among countries along the Belt and Road.
- To allow countries, especially landlocked countries, to equally have direct digital communication channels to interconnect with the other.

Recommended Actions:

- The Silk Road Information Superhighway (SR-IS) should be firstly promoted to all countries along the Belt and Road in order to clearly demonstrate its importance and benefits.

- The working group on SR-IS should be established which typically consists of representatives from each country, provider, operator and international organization e.g. ESCAP, ITU, ADB, World Bank and so on to achieve high levels of inter-governmental collaboration towards SR-IS implementation. Note that to facilitate SR-IS implementation, it can be effectively carried out under the framework of AP-IS initiative which aims to increase the availability and affordability of broadband Internet across Asia and the Pacific.
- The operation model of SR-IS should be established to facilitate the formation of trans-border fiber networks and enhance the quality and efficiency of transition. In addition, this model could support the more efficient use of fiber networks resources, and also promote global and regional connectivity among countries along the Belt and Road.
- Detailed analysis on ICT connectivity, ICT policies/plans and other ICT dimensions should be carefully conducted to understand challenges, issues and barriers to implement SR-IS.
- A master plan for the SR-IS should be developed to study and analyze ICT infrastructure including IXPs, land-based and sea-based fiber routes in different regions along the Belt and Road. This master plan must also include ICT architecture design solutions for the SR-IS. In addition, a clear direction and action plan towards SR-IS implementation must be stated.
- A feasibility study on SR-IS for inter-corridor connectivity should be conducted to assess the possibility and readiness of SR-IS implementation.
- The SR-IS funding platform should be carefully explored and formulated to be ready and feasible for SR-IS implementation.

Priority: High

6.2.2 C2 - ICT Strategy and Policy Cooperation towards ICT Integration

Objectives:

- To reinforce international ICT policy coordination among countries along the Belt and Road.
- To develop national ICT policies or roadmap to clearly state the ICT direction of each relevant stakeholder in order to comply with international ICT policies and also support inter-governmental coordination.

Recommended Actions:

- Close coordination among countries is strongly required to establish international ICT policies/plans to support the SR-IS and integration on ICT connectivity. In addition, all ICT policy and regulation barriers should also be effectively resolved.
- High level meetings, symposium or conferences among relevant stakeholders who are representatives from each country, service provider,

telecommunications operator and international organization (e.g. ESCAP, ITU and so on) should be regularly organized on at least an annual basis for international ICT policy coordination.

- Countries along the Belt and Road should regularly develop their own national ICT policies/plans/strategies to support technological change and comply with international ICT policy coordination.

Priority: Medium

6.2.3 C3 - Cross-sectoral Infrastructure Synergies to accelerate connectivity

Objectives:

- To promote cross-sectoral infrastructure synergies among countries along the Belt and Road.
- To accelerate and support connectivity among people, organizations, and countries.
- To develop infrastructure including energy, ICT and transport infrastructure at a faster pace with lower CAPEX.
- To increase opportunities to implement ICT infrastructure together with energy and transport infrastructure in the distant and isolated areas. Recommended Actions:
    - Close coordination among countries is strongly required to form cross-sectoral infrastructure synergies across energy, ICT and transport infrastructure.
    - High level meetings, symposium or conferences among relevant stakeholders who are relevant to energy, ICT and transportation fields should be regularly organized for cross-sectoral infrastructure synergies.
    - Countries should promote cross-sectoral infrastructure synergies and also encourage investors to simultaneously deploy ICT infrastructure along fundamental infrastructure in order to reduce investment cost and increase opportunity for digital inclusion especially in landlocked communities.
    - Dry ports along the roads and rails especially in landlocked countries should be converged with ICT infrastructure. Such a convergence can typically increase operational capacity, modernize trade and investment processes, and increase competitiveness. In addition, there is an option to implement Internet Exchange Points alongside the dry ports.

Priority: Medium

6.3 ICT Strategic Principle 2 - Operation

This principle can be potentially used to bridge all gaps which are related to ICT Operations, Administration and Maintenance (OAM). This OAM is essential to effectively maintain ICT connectivity among countries along the Belt and Road, and it could lead to more efficient and effective operations regarding ICT connectivity. There are totally three major ICT strategies (O1 to O3) introduced in this principle that are stated as follows.

6.3.1 O1 - ICT Infrastructure Strengthening and Enhancement

Objectives:

- To improve international bandwidth which consequently leads to higher international bandwidth per Internet user.
- To smoothly support multimedia traffic (e.g. IP telephony, video conferencing and etc.) in order to enhance collaboration among people and organizations, and be ready for new forms of cross-border electronic applications (e-commerce, e-government, e-learning and etc.).
- To reduce operating expense or OPEX to maintain ICT infrastructure.
- To be ready to support mobility and new ICT/energy technologies such as IoT/IoE, smart grid and so on.

Recommended Actions:

- Migration to more efficient and effective technologies
    - WAN technology used in TAE and international (cross-border) fiber routes which falls under SDH is not an effective solution. In addition, the current bandwidth in most of these routes is low and not enough to simultaneously support new cross-border ICT applications. Hence, migration to new WAN technologies is strongly recommended. At present, the recommended WAN technology is DWDM which typically provides very high bandwidth over fibre-optic by using Wavelength Division Multiplexing (WDM) technique to achieve higher bandwidth capacity. In addition, it is also a cost-effective solution that can be used to reduce OPEX compared to SDH which is more complex and was intentionally designed to support voice, not IP data.
    - The working group on technology migration should be established consisting of representatives from each country, service provider, operator and international organization e.g. ESCAP, ITU, ADB World Bank and so on. The main responsibilities of this working group include studying underlying technologies, managing technologies, securing all issues associated with new design and technologies, and exploring and formulating funding support for technology migration.
    - Detailed study and technical analysis should be conducted to obtain the technical requirements, current status of ICT infrastructure, traffic characteristics among various countries (e.g. speed, load, loss and congestion, routing path and etc.) and issues/barriers for new technology migration.
    - A technology migration plan should be developed to clearly state the time frame and actions to provide smooth migration from legacy WAN technology to new technologies and design.
- IPv6 deployment

- Research and study on IPv6 readiness in the industry should be conducted and published to raise awareness for IPv6 deployment.
- There should be knowledge transfer of IPv6 to industry to support human development and to be ready for IPv6 transition.
- Government in each country should also develop roadmaps to enable or deploy IPv6 in network infrastructure (dual-stack migration strategy is recommended to maintain ability to support both IPv4 and IPv6 for smooth migration processes).
- National ICT policies or plans for IPv6 readiness should be developed to support and facilitate all organizations including public sectors, private companies and state-owned enterprises to move forward to IPv6 transition.

Priority: High (for migration to more efficient and effective technologies), and Low (for IPv6 deployment)

6.3.2 O2 - Network Infrastructure Expansion and Pricing Reduction towards Bridging the Digital Divide

Objectives:

- To expand national ICT infrastructure, especially in low fiber density areas and rural areas, to allow more people to be able to access Internet and broadband networks.
- To make Internet and broadband access prices affordable (typically lower than 5 per cent of GNI per capita).
- To reduce transit cost which directly affects broadband Internet access price.
- To reduce digital divide by increasing opportunity and removing barriers for people to access Internet and broadband networks.

Recommended Actions:

- Government or policymaker in each country should make Internet and broadband markets more open and encourage new players (service providers and operators) to invest in the market by giving initial funds or allowing new providers/operators to lease government ICT infrastructure in order to reduce their CAPEX and implement their own ICT infrastructure.
- Because spectrums or frequencies are naturally limited resources and are not enough to support a wide variety of wireless communications (e.g. TV and radio networks, cellular networks, satellite communications, and etc.), spectrum management in each country is mandatory. However, national spectrum agencies in each country should allow unlicensed use of white space (TV and radio frequencies that are not currently in use) to be utilized by wireless networks (e.g. WhiteFi or Super Wi-Fi networks). Thus, government or providers/operators could have more spectrums to be utilized to provide Internet and broadband access services. Note that it could be better if government can

implement these wireless networks in public areas as a pilot project to allow people to use them for free in order to promote and facilitate the use of the Internet.

- Government in each country should support and encourage operators to share access to ICT facilities and resources to reduce their CAPEX and OPEX to increase the potential development of broadband networks, especially in remote and rural areas.
- ICT policies and regulations are updated to aim at increased affordability at consumer level.
- Government in each country should support and encourage the current and/or new service providers to implement broadband access networks as a pilot project in rural areas. In addition, mobile broadband networks are recommended to coincide with the trend on mobile communications .
- When building new transport (roads and rails) or energy infrastructure (oil and gas pipelines), especially in low fiber density areas, government or relevant stakeholders in each country should have a plan to implement ICT infrastructure (i.e. laying fiber conduit) along these infrastructure to allow providers/operators to simply implement their new fiber routes. This also reduces providers' CAPEX which directly affects Internet and broadband access prices.
- ICT policies to support carrier-neutral IXPs and bilateral peering to prevent unnecessary Internet transit cost should be developed (this is also an important part of SR-IS implementation). Note that these IXPs must provide equal access and traffic exchange among various relevant stakeholders.

Priority: High

Priority: Medium

6.4 ICT Strategic Principle 3 - Resiliency

Resilience is essential in ICT connectivity because it guarantees that ICT services will be always available in 24x7 manner. ICT connectivity must be able to provide services at an acceptable level when there is outage/failure on fiber nodes or links. In addition, it must be able to quickly recover ater a disaster strikes.. Two ICT strategies (R1 and R2) are carefully proposed in order to obtain resilience in ICT connectivity.

6.4.1 R1 - Resilience-Aware Networks for ICT Operational Continuity

Objectives:

- To have resilience-aware networks to serve as the fundamental ICT infrastructure to support communications and collaboration among people, organizations and countries. In addition, it must be able to operate with acceptable performance when there is a link broken or outage in an IXP or gateway.

- ICT infrastructure is always available to provide uninterrupted services (24x7) for users in terms of both consumers and business users to use various cross-border electronic applications (e-commerce, e-health, e-learning and so on) to support their connectivity.

Recommended Actions:

- ICT infrastructure, in terms of fiber nodes and links, among countries along the Belt and Road should be redesigned to support resilience as illustrated in Section 5. In addition, redundant fiber routes and diversity routes via other countries should be taken into consideration to prevent single point of failure and bottleneck.
- There should be close cooperation among countries associated with redundant and diversity routes to discuss and take actions on implementation of these routes.
- Feasibility study and detailed design on redundant and diversity routes should be conducted to carefully study and analyze the potential to successfully implement these routes.
- In each fiber node/center and IXP along the fiber routes that are used to connect together multiple countries along the Belt and Road, redundancy and backup systems should also be taken into account. These systems typically include both electrical (multiple active power and cooling systems, UPS, generators, and so on) and telecommunications systems (redundant cabling systems, and multiple active switching/routing infrastructure).

Priority: High

6.4.2 R2 - ICT Security Reinforcement for Trusted and Secured Collaboration

Objectives:

- To secure ICT connectivity to ensure confidentiality, integrity, authentication and authorization.
- To prevent failure in ICT infrastructure caused by cyber-attacks such as DoS (Denial of Service), Distributed Denial of Service (DDoS) and so on.
- To protect sensitive information exchanges during communications and collaboration among people, organizations, and countries.
- To build people's trust to exchange their sensitive information and make electronic transactions.

Recommended Actions:

- A national security agency or Computer Emergency Response Team (CERT) should be formed to be responsible for all security issues, coordinating all matters regarding security concerns within countries and also cooperating with other stakeholders to provide a common platform for ICT security.

- Each country should have national ICT security policies or roadmaps to address all related security issues to raise awareness and provide recommendations to secure ICT connectivity and communications.
- Government in each country should support and encourage organizations to develop their own security policies to proactively protect their information and network infrastructure.
- Research and Development (R&D) should be conducted to produce effective security solutions that meet ICT security challenges.
- Each country should encourage both public and private sectors to implement their ICT infrastructure to be complied with security standards and best practices (e.g. ISO 27001 and etc.)
- There should be a main communication channel for all matters related to ICT security and knowledge transfer of cyber security to people and industry to increase their ICT security skills and awareness.
- Each country should coordinate with others to discuss and support security implementation on ICT connectivity used to provide communications and collaboration among them in order to achieve regional or global ICT security.

Priority: High

6.5 ICT Strategic Principle 4 - Evolution

The last strategic principle proposed in this study is Evolution which can be used to drive innovation on ICT connectivity to mainly facilitate collaboration on trade and finance. Moreover, borderless communications among people, organizations and countries are also taken into account in this strategic principle to effectively support connectivity and collaboration. There are two strategies (E1 and E2) in this principle as described below.

6.5.1 E1 - Innovation on ICT Connectivity towards Digital Economy

Objectives:

- To use innovation to support new forms of digital communications and collaboration among people, organizations and countries along the Belt and Road.
- To have various cross-border electronic applications to mainly support trade cooperation, financial integration and collaboration.
- To use ICT connectivity to move forward in the digital economy era.

Recommended Actions:

- Government in each country should encourage and support Research and Development (R&D) programmes related to innovation especially in terms of electronic or mobile applications to be used to support collavoration on trade and finance.. This R&D should also address all aspects of using innovation to support digital economy development.

- Government in each country should support and facilitate the outputs of R&D by putting them into commercial products and services to be used for both national and international (cross-border) collaboration.
- Each country should establish a Center of Excellence (CoE) to provide a R&D roadmap to use innovation to mainly support ICT connectivity and collaboration on trade and finance among countries.
- Countries should coordinate with the others to implement a Single Window System to facilitate international (cross-border) trade.
- Countries should support new forms of cross-border electronic applications (such as e-commerce, e-government, e-health, e-learning, e-training and so on) to be used among various countries along the Belt and Road. Note that this application must also support mobile devices (mobility).
- Countries should encourage the utilization of Financial Technology (FinTech) for financial integration and to support digital economy development.

Priority: Medium

6.5.2 E2 - Borderless Communications to Enhance Connectivity

Objectives:

- To allow people to use any devices (smartphones, tablets, wearables and etc.) to access ICT infrastructure anywhere at anytime.
- To have mobile applications to be mainly used for trade cooperation, financial integration and collaboration.

Recommended Actions:

- Countries should encourage organizations to develop mobile applications (mobile commerce, mobile payment and so on) to support mobile users and allow them to use their mobile devices to share & access information, and make their transactions. This will greatly improve connectivity and collaboration among people, organizations and countries.
- Cloud Computing should be utilized to allow people to easily and effectively access or share information among the others.
- Government in each country should encourage each organization to flexibly support a mobile workforce environment to allow people to move across areas of work. Note that a secure mobile workforce should be also taken into consideration.
- To support mobility across countries, close coordination among them is strongly required to enable ICT infrastructure to utilize mobile technologies to effectively support mobility.

Priority: Medium