Bangladesh Broadband Connectivity Report

Executive summary

A new wave of technological revolution is sweeping across the world, transforming modern life from the digital world into the intelligent world and leading to worldwide industrial advancement and economic restructuring. Being one of the most critical communication infrastructures, broadband connectivity directly influences the pace of a country's digital revolution. Bangladesh is now moving towards a wider and deeper smart vision and has proposed the construction of a high-quality and affordable broadband network covering the entire country.

Based on the existing national broadband policies, international standards, ecosystems, business scenarios for broadband development, and actual national conditions of Bangladesh, this report, led by Bangladesh Telecommunication Regulatory Commission (BTRC) and assisted by China Academy Information and Communications Technology (CAICT), conducts a comprehensive study on the development of broadband connectivity in Bangladesh. This report aims to provide important insights for the construction of broadband connectivity in Bangladesh over the next 5 to 10 years, which can be a reference for different stakeholders.

This report discusses the development trajectory of Bangladesh’s broadband network development path into two parts:

Part I, titled “Mobile Broadband” focuses on Bangladesh 5G network construction strategy along with development plans for 5G applications and digitization of various industries. It comprises of five chapters.

Chapter 1 introduces the characteristics of 5G technology and its crucial relationship with digitization. It explains how 5G deeply influences the global digital transformation process and its value to the development of the digital economy.

Chapter 2 presents the global trends of 5G development from five aspects: policy, spectrum, standards, networks, and applications. This includes the global 5G spectrum usage status, 3GPP international and regional standards, 5G policies in major countries, 5G network construction,

and the development of 5G applications worldwide, including To Consumer (ToC), To Home (ToH), and To Business (ToB).

Chapter 3 systematically analyzes the current level of development of Bangladesh's mobile broadband service. It provides insights of Bangladesh's mobile spectrum licenses and 4G network construction suggestions. Assessing the commercial development experience and strategic development plans for 5G in Asia-Pacific, particularly in China, it proposes an evolution path for network advancement. This includes recommendations for new spectrum planning, network construction models, network deployment models and network application models.

Chapter 4 analyzes the level and potential of Bangladesh's 5G application development from three aspects: ToC, ToH, and ToB. Based on Bangladesh's industrial characteristics and development trends, it proposes a development path for 5G applications in Bangladesh and suggests exploring industrial digitization in smart cities, fully-connected factories, smart agriculture and digital healthcare.

Chapter 5 summarizes Bangladesh's mobile network development plan in different time domains. It proposes short-term, mid-term, and long-term development goals for Bangladesh's mobile broadband service and provides specific suggestions for the development of mobile broadband business in terms of policy, networks, and applications.

Part II, titled “Fixed Broadband” mainly analyzes the development status and experience of optical fiber broadband network in the world and China. It comprises of four chapters and gives the development plan and provides recommendations for the advancement of fiber broadband network in Bangladesh.

Chapter 6 analyzes the current development trend of global broadband network from the perspective of fixed broadband policies, broadband network development and broadband applications in various countries.

Chapter 7 draws upon China's experience in broadband network development and introduces a detailed overview of China's policy tools for broadband development, including the National Broadband Strategy, the Broadband Universal Service Program, and the policies for fiber network infrastructure promotion.

Chapter 8 analyzes the current situation and challenges of broadband network in Bangladesh and proposes the evolution path with a technical roadmap for the development of Bangladesh's fiber broadband network.

Chapter 9 summarizes the development plan of Bangladesh's fiber broadband network, puts forward the development goals of Bangladesh's fiber broadband network in the short, medium and long term. It also puts forward some policy suggestions for accelerating the construction of optical fiber broadband network.

In conclusion, this document intends to provide a comprehensive analysis and strategic recommendations to guide the continued development and optimization of Bangladesh's broadband network infrastructure, ensuring its alignment with global standards and future technological advancements.

Part I Mobile Network

1.5G Introduction

1.1 Mobile Technology Evolution

Since the 1980s, a new generation of revolutionary mobile communications technologies has emerged every decade, promoting innovation in information and communications technologies, industries, and applications, and injecting a steady stream of powerful impetus into global economic and social development. Up to now, mobile communication technology has experienced five eras from 1G to 5G: from 1G to 2G, mobile communication technology has completed the transformation from analog to digital, and on the basis of voice services, the mobile communication technology has expanded to support low-speed data services. From 2G to 3G, the data transmission capability is significantly improved. The peak rate can reach 2 Mbps to dozens of Mbps. Mobile multimedia services such as video phones are supported. The transmission capability of 4G is an order of magnitude higher than that of 3G, with a peak rate of 100 Mbps to 1 Gbit/s. Compared with 4G technologies, 5G uses a brand-new network architecture to provide peak bandwidth of more than 10 Gbit/s, millisecond-level latency, and ultra-high-density connections. 5G expands from the traditional mobile Internet to the Internet of Everything (IoE) field and deeply integrates with cloud computing, big data, and artificial intelligence technologies. Build the key foundation and driving force for digital transformation in all walks of life.

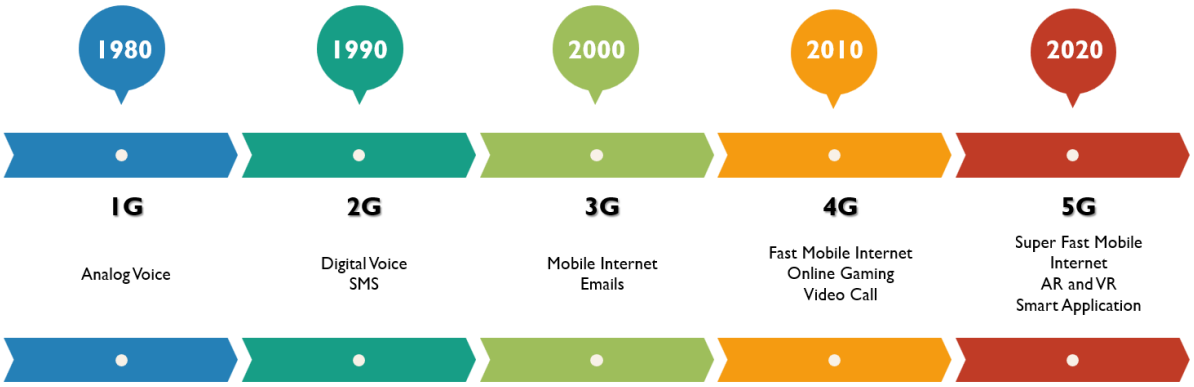


Figure 1 Mobile Technology Evolution

1.2 5G Technique Features

The International Telecommunication Union (ITU) defines three 5G scenarios, as shown in Figure 2.

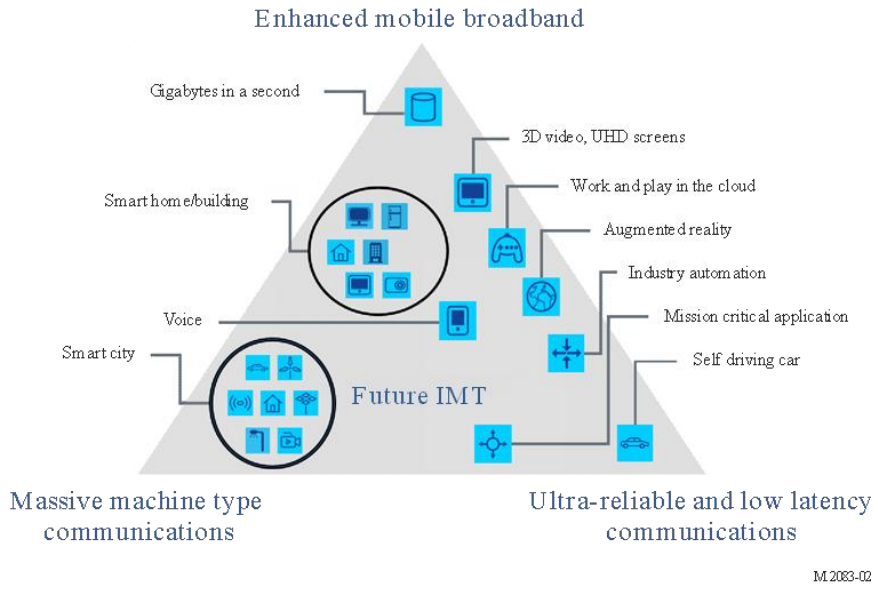


Figure 2 3 major application scenarios of 5G and their extended scenarios

- Enhanced Mobile Broadband (eMBB) focuses on services that require ultra-high bandwidth, such as high-definition video (4K/8K), virtual reality (VR), and augmented reality (AR), to meet the needs of users for digital life.
- Massive Machine Type Communications (mMTC) focuses on scenarios that require high-density connections, such as intelligent transportation, smart grid, smart manufacturing (Industry 4.0), and smart logistics, to meet the needs of users in the digital society.
- Ultra-Reliable Low Latency Communications (URLLC) focuses on latency-sensitive services such as autonomous/assisted driving, Internet of Vehicles (IoV) and remote control to meet the needs of users in the digital industry.

With the extension of 5G application scenarios to deeper and deeper fields, 5G mobile communications technologies add four key capability indicators: user experience rate, connection density, traffic density, and energy efficiency in addition to traditional indicators such as peak rate, mobility, latency, and spectral efficiency. Specifically, 5G users can

experience a rate of 100 Mbps to 1 Gbit/s, supporting ultimate service experience such as mobile virtual reality. The connection density can reach 1 million per square kilometer, effectively supporting the access of massive IoT devices. The traffic density can reach 10 Mbps per square meter, supporting a 1000-fold growth of mobile service traffic in the future. The transmission latency can reach milliseconds, meeting the strict requirements of Internet of Vehicles and industrial control.

1.3 5G Digitalization

5G has promoted the full release of the next-generation information technology innovation vitality, enabled digital transformation and upgraded of industries, and promoted high-end, intelligent, and green economic and social development. According to the statistics[1] of China Academy of Information and Communications Technology (CAICT), by 2030, the direct contribution of 5G to total output, economic added value, and employment opportunities will reach 6.3 trillion yuan, 2.9 trillion yuan, and 8 million jobs, respectively. Indirect contributions to total output, economic added value and employment opportunities reached 10.6 trillion yuan, 3.6 trillion yuan and 11.5 million jobs respectively.

First, 5G continues to drive the booming digital economy. 5G promotes the continuous growth of enterprise information service services and continuously improves user experience, drives the rapid development of video and live broadcast services, and promotes the continuous growth of monthly mobile Internet access traffic. According to mobile data traffic outlook[2] from Ericsson, since 2019 5G commercialization, global mobile data traffic has increased from 33.4EB per month to 129.8EB per month by 2023, which result a 388% growth rate. 5G contributes more than 30% growth to global data traffic increase and will become a most important power of driving global data traffic growth.

[1] CAICT, White Paper on the Economic and Social Impact of 5G
http://www.caict.ac.cn/kxyj/qwfb/bps/201804/t20180426_158438.htm

[2] https://www.ericsson.com/en/reports-and-papers/mobility-report/dataforecasts/mobile-traffic-forecast

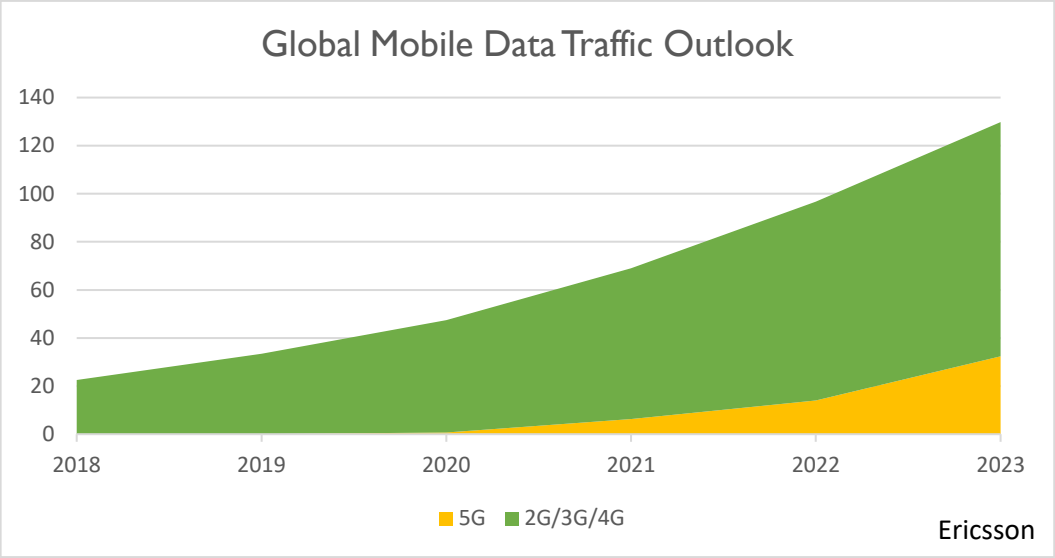


Figure 3 Global Mobile Data Traffic Outlook

Second, 5G technology accelerates the innovation and development of digital technologies. In terms of core technologies, 5G technologies drive the iterative development of communications-related industries. According to Canalys data[3], global smartphone shipments reach 1.14 billion units by 2023 and the demand for smartphones will drive the iteration of the smartphone chip manufacturing process from 8 nanometers to 3 nanometers. In terms of industrial technologies, 5G is deeply integrated with the industry, incubating many industrial platforms and streamlining industrial technology processes.

Third, to meet different service requirements in 5G scenarios, To Consumer (ToC) continuously evolves in three application types: **traditional service upgrade applications, new interactive applications and XR-based immersive applications** and expands many new applications in fields such as work, study, life and entertainment.

Forth, 5G promote vertical industry digitalization process. The in-depth integration of 5G industrial applications with cultural tourism, healthcare, and energy industries has incubated many 5G ToB (enterprise-oriented) applications, including 5G+cultural tourism, 5G+healthcare, 5G+mine, and 5G+port. It has effectively promoted the development of industrial economy.

[3] Canalys estimates (sell-in), Smartphone Analysis, January 2024

2.Global 5G Development Trends

2.1 Policy

Major countries and regions around the world have identified the digital economy as a strategic development area and 5G technology as a priority development focus. At the national strategic level, these countries have set 5G industry development goals and introduced corresponding industry support strategy portfolios.

The Chinese government attaches great importance to the construction and application development of 5G networks. The national government, local governments, and all ministries are deeply involved in the research and promotion of policy documents, and use various policy means to jointly promote the in-depth development of networks and applications. **National-level policies lead the macro tendency**. On 2020 May Government work report indicate "*strengthen the development of new infrastructure*" and "*expand 5G applications*". On 2020 March, Chinese government also state "*Accelerate the development of 5G networks, data centers and other new infrastructure*". **Ministerial policies design specific strategy and planning**. The National Energy Administration released *5G Application Implementation Plan in Energy Industry*. Ministry of Industry and Information Technology, National Health Commission jointly release *Notice on Organizing the Application of 5G+ Medical and Health Pilot Projects*. **Local government-level policies build customized planning and promotion.** According to statistics of CAICT, by the end of August 2023, all provinces and municipalities had issued 980 5G support policy documents, including 163 provincial-level documents, 455 municipal-level documents, and 362 county-level documents.

The Korean government has developed a continuous and systematic strategic plan for the development of 5G applications at the top level. Korean designed a top-down system to generally guide the 5G national development by set up the 5G Working Committee, the 5G Strategy Committee, and the 5G Policy Committee, and formed an industrial alliance. In terms

of promotion, the Korean government has continuously and systematically promoted the implementation of 5G application development through the formulation of strategic plans.

The United States focuses on the country's advantages in 5G technology and has introduced top-level policies to strengthen 5G infrastructure construction at the national level. The U.S. will make strategic plans for comprehensively promoting 5G network construction from spectrum planning, infrastructure policy, and modernizing outdated regulations to strengthen the U.S. advantages in the field of 5G technologies[4]. In the past two years, the US government has frequently released spectrum planning policies to promote 5G innovation by releasing more spectrum resources. In January 2023, the White House in US released the National Spectrum Strategy, announcing the release of a total of 2,786 MHz of wireless spectrum.

Europe has released a series of policies to promote 5G industry applications in a sequential manner and has built a clear path for 5G and vertical industry integration applications. The European Commission officially released the 5G action plan (5G for Europe: An Action Plan[5]), which includes releasing a specific test plan in March 2017 and starting tests and developing a complete 5G deployment roadmap by the end of the year. Initial commercial tests would be started in 2018. At the beginning of 2021, the European Commission released the Digital Decade plan, which takes 5G as the core pillar and vigorously promotes 5G network coverage. The goal is to achieve 100% urban coverage by 2025 and 100% densely populated area coverage by 2030.

2.2 Spectrum

5G spectrum bands have been allocated to more than 100 countries/regions around the world, and mid-band 5G networks have been deployed in most countries/regions including TDD 3.5GHz and 2.6GHz. Low-frequency networks are used to extend coverage, and high-frequency networks are used to cover hotspots and improve capacity.

[4] The FCC's 5G FAST Plan https://docs.fcc.gov/public/attachments/doc-354326a1.pdf

[5] 5G Action plan | Shaping Europe's digital future https://digital-strategy.ec.europa.eu/en/library/europes-5g-action-plan

Many countries allocate spectrums through spectrum auctions. The US auctions multiple frequency bands, such as 2.6 GHz, 3.5 GHz, and 28 GHz, to operators for 5G commercial deployment. Brazil auctioned the 20-year extension of the national 3.5 GHz spectrum to three mobile operators with Claro, Vivo, and TIM. Most European countries, such as United Kingdom, Italy, Germany, and Spain, have used 700 MHz low band, 3.5 GHz mid band, and 26 GHz high band for 5G commercial deployment through spectrum auctions. In addition, the 4G+5G DSS technology is used to enhance the utilization of legacy MBB frequency bands such as 2.1GHz. In Asia, South Korea auctioned the 300 MHz of 3.5 GHz spectrum to three operators including SKT, KT, and LGU+. Vietnam auctioned 15 years of the national 3.5GHz and 2.6GHz to Viettel, VNPT and Mobifone. Both South Korea and Vietnam are planning to assign 700MHz low band in 2025. India also auctioned all 5G bands including 700 MHz, 3.5 GHz and 26 GHz to four operators for 5G national wide rollout.

Some countries use the beauty contest model for 5G spectrum allocation. Mobile network operators (MNOs) submit business cases to regulators, who evaluate operators' plans and commitments and select the most appropriate candidates for spectrum allocation. In Singapore, the 200 MHz bandwidth from 3.45 GHz to 3.65 GHz is allocated to the two operators by the Beauty Contest.

China strengthens 5G spectrum management by directly assigning spectrum licenses. China has authorized a total of 792 MHz of low and mid frequency bands for 5G network construction, ensuring 5G capabilities and coverage requirements. In 2017, the Ministry of Industry and Information Technology (MIIT) released the 5G Frequency Band Planning, becoming the first country in the world to release the 5G frequency allocation solution for low and mid bands. In June 2019, the MIIT officially issued 5G commercial licenses to four mobile operators. In December 2020, the MIIT officially issued 5G frequency license including 3.5GHz, 2.6GHz,4.9GHz and 700MHz to four mobile operators. And since 2022 China allows some of 2G/3G/4G frequency resources to be refarmed for 5G technologies including 850/900/2100MHz. In 2024, China stars to commercial launch of 5G-Advanced (5G-A) with multi Carrier Aggregation to achieve 5Gbps to 10Gbps user download speed.

The global mass markets are driving 5G ecosystem to be maturing. Based on Global mobile Supply Association (GSA) statics, there are 2,995 devices support 5G till September 2024. The 3.5GHz, 2.6GHz, 2.1GHz and 700MHz are most 5G devices supported bands. While the mmWave high bands are yet to be matured with limited devices supported.

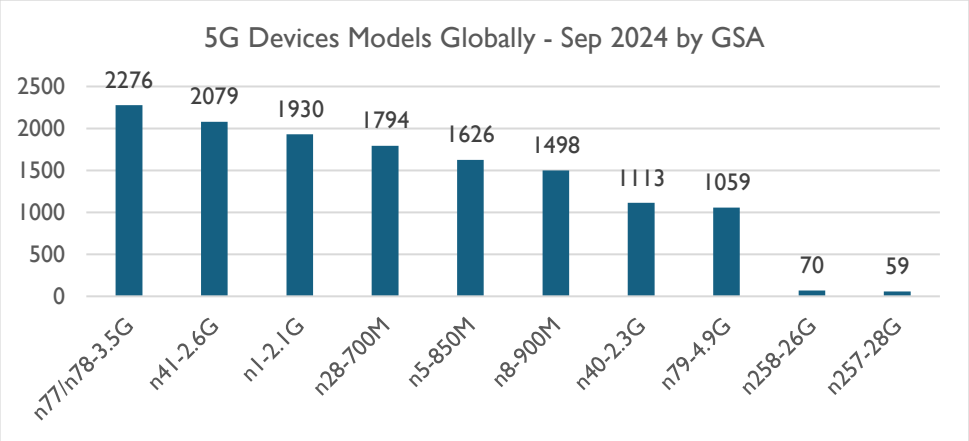


Figure 4 Global 5G devices quantity with support bands

2.3 Standard

The Third Generation Partnership Project (3GPP) continues to promote the development of 5G international standards as planned. According to the version management standards, 3GPP releases a new version every 15 to 18 months to continuously optimize the performance of existing standard technologies and introduce new technologies to new services and scenarios.

In June 2018, 3GPP released Release 15, the first 5G independent networking standard, which focuses on enhanced mobile broadband services. The network transmission rate is improved. It is mainly used for high-bandwidth services such as ultra-HD video and AR/VR.

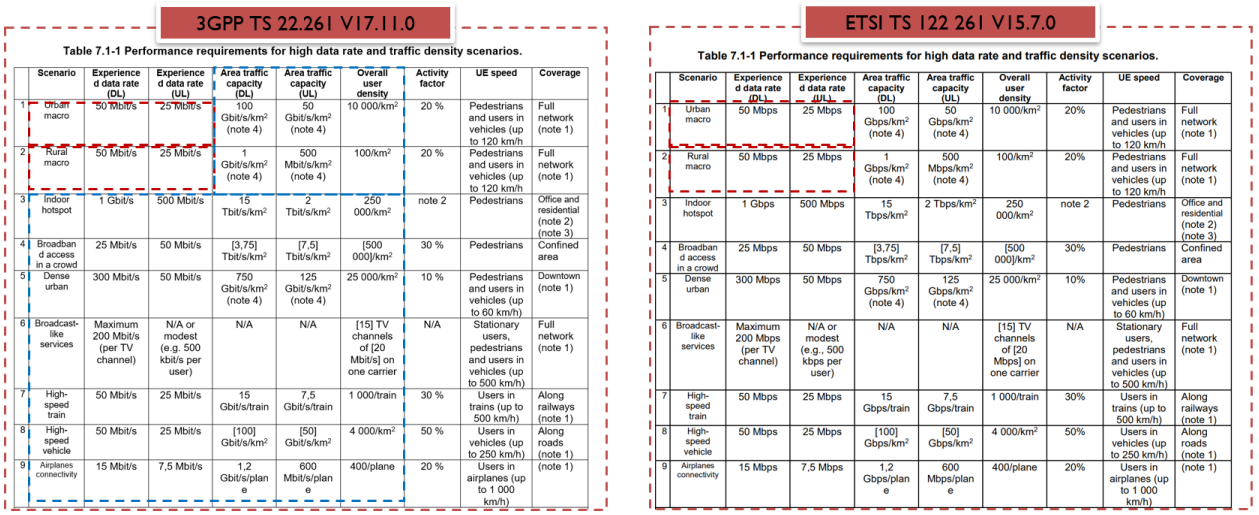
In June 2020, 3GPP released the R16 standard version, which focuses on low-latency and high-reliability services and supports applications such as 5G Internet of Vehicles (IoV) and industrial Internet.

In June 2022, 3GPP R17 will complete the formulation, focusing on implementing differentiated IoT applications and medium- and high-speed connections. R17 supports richer intermediate frequency and high frequency spectrum resources, deeper and wider network

coverage through technologies such as coverage enhancement and non-terrestrial communication, and multiple-input multiple-output (MIMO) capabilities on more frequency bands, such as frequency division duplex (FDD) and low-frequency. In addition, R17 provides a wide range of service support capabilities, such as low-power medium- and high-speed Internet of Things (IoT), submeter-level positioning, and enhanced wireless slicing.

In April 2021, 3GPP decided to officially start the formulation of 5G evolution standards 5G-Advanced (5G-A) from R18 to R20, focusing on eMBB network enhancement, MIMO enhancement, XR-Pro, and multi-frequency convergence. R18 further improves ontology networking capabilities, systematically expands support for XR immersive multimedia communication, and explores the application of AI in 5G networks to deepen integrated air-ground communication. 3GPP R18 has been frozen in June 2024.

Currently, the international 5G eMBB service requirements are mainly in compliance with the 3GPP TS 22.261 5G Service requirements for the 5G system. Other organizations, such as ETSI, also comply with the same standard. In the standard, enhanced mobile broadband (eMBB) capabilities are designed to meet a new set of KPIs. These involve high data rates, high user density, high user mobility, highly variable data rates, deployment, and coverage. High data rates are driven by data that is increasingly used for services such as streaming media, interactive services, and IoT. These services impose stringent requirements on the data rate experienced by the user and the associated requirements for the latency to meet the service requirements. In addition, the expansion of coverage in densely populated areas (such as sports fields, urban areas and transport hubs) has become a necessity for urban vehicle pedestrians and users. The new KPIs for traffic and connection density can transmit both large amounts of data traffic per area (traffic density) and data for large numbers of connections (e.g., UE density or connection density). As shown in Figure 5, 3GPP specifications and ETSI specifications for the downlink rate, uplink rate, and user density in nine application scenarios. Urban macro and rural macro scenarios are concerned. In both scenarios, the downlink rate is 50 Mbps and the uplink rate is 25 Mbps. In addition, 3GPP and ETSI also specify indoor hotspots, high-density areas, broadcast services, high-speed trains, high-speed vehicles, and aviation connections.



3GPP TS 22.261 V17.11.0

Table 7.1-1 Performance requirements for high data rate and traffic density scenarios.

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density	Activity factor	UE speed	Coverage
1	Urban macro	50 Mbit/s	25 Mbit/s	100 Gbit/s/km² (note 4)	50 Gbit/s/km² (note 4)	10 000/km²	20 %	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
2	Rural macro	50 Mbit/s	25 Mbit/s	1 Gbit/s/km² (note 4)	500 Mbit/s/km² (note 4)	100/km²	20 %	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
3	Indoor hotspot	1 Gbit/s	500 Mbit/s	15 Tbit/s/km²	2 Tbit/s/km²	250 000/km²	note 2	Pedestrians	Office and residential (note 2) (note 3)
4	Broadband access in a crowd	25 Mbit/s	50 Mbit/s	[3,75] Tbit/s/km²	[7,5] Tbit/s/km²	[500 000]/km²	30 %	Pedestrians	Confined area
5	Dense urban	300 Mbit/s	50 Mbit/s	750 Gbit/s/km² (note 4)	125 Gbit/s/km² (note 4)	25 000/km²	10 %	Pedestrians and users in vehicles (up to 60 km/h)	Downtown (note 1)
6	Broadcast-like services	Maximum 200 Mbit/s (per TV channel)	N/A or modest (e.g. 500 kbit/s per user)	N/A	N/A	[15] TV channels of [20 Mbit/s] on one carrier	N/A	Stationary users, pedestrians and users in vehicles (up to 500 km/h)	Full network (note 1)
7	High-speed train	50 Mbit/s	25 Mbit/s	15 Gbit/s/train	7,5 Gbit/s/train	1 000/train	30 %	Users in trains (up to 500 km/h)	Along railways (note 1)
8	High-speed vehicle	50 Mbit/s	25 Mbit/s	[100] Gbit/s/km²	[50] Gbit/s/km²	4 000/km²	50 %	Users in vehicles (up to 250 km/h)	Along roads (note 1)
9	Airplanes connectivity	15 Mbit/s	7,5 Mbit/s	1,2 Gbit/s/plane	600 Mbit/s/plane	400/plane	20 %	Users in airplanes (up to 1 000 km/h)	(note 1)

ETSI TS 122 261 V15.7.0

Table 7.1-1 Performance requirements for high data rate and traffic density scenarios.

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density	Activity factor	UE speed	Coverage
1	Urban macro	50 Mbps	25 Mbps	100 Gbps/km² (note 4)	50 Gbps/km² (note 4)	10 000/km²	20%	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
2	Rural macro	50 Mbps	25 Mbps	1 Gbps/km² (note 4)	500 Mbps/km² (note 4)	100/km²	20%	Pedestrians and users in vehicles (up to 120 km/h	Full network (note 1)
3	Indoor hotspot	1 Gbps	500 Mbps	15 Tbps/km²	2 Tbps/km²	250 000/km²	note 2	Pedestrians	Office and residential (note 2) (note 3)
4	Broadband access in a crowd	25 Mbps	50 Mbps	[3,75] Tbps/km²	[7,5] Tbps/km²	[500 000]/km²	30%	Pedestrians	Confined area
5	Dense urban	300 Mbps	50 Mbps	750 Gbps/km² (note 4)	125 Gbps/km² (note 4)	25 000/km²	10%	Pedestrians and users in vehicles (up to 60 km/h)	Downtown (note 1)
6	Broadcast-like services	Maximum 200 Mbps (per TV channel)	N/A or modest (e.g., 500 kbps per user)	N/A	N/A	[15] TV channels of [20 Mbps] on one carrier	N/A	Stationary users, pedestrians and users in vehicles (up to 500 km/h)	Full network (note 1)
7	High-speed train	50 Mbps	25 Mbps	15 Gbps/train	7,5 Gbps/train	1 000/train	30%	Users in trains (up to 500 km/h)	Along railways (note 1)
8	High-speed vehicle	50 Mbps	25 Mbps	[100] Gbps/km²	[50] Gbps/km²	4 000/km²	50%	Users in vehicles (up to 250 km/h)	Along roads (note 1)
9	Airplanes connectivity	15 Mbps	7,5 Mbps	1,2 Gbps/plane	600 Mbps/plane	400/plane	20%	Users in airplanes (up to 1 000 km/h)	(note 1)

Figure 5 5G 3GPP and ETSI Performance requirements

In China, under 3GPP standard and national ministries guideline, some local governments have their own 5G network service performance indicators to guide operators in building high quality 5G networks. In the 14th Five-Year Plan for Information and Communications Industry, the Ministry of Industry and Information Technology (MIIT) of China proposes to give priority to outdoor 5G network coverage in key areas such as central urban areas, industrial parks, ports, transportation hubs, institutions of higher learning, and hot spots. Provides a high-quality network with a downlink rate of 100 Mbps and an uplink rate of 5 Mbps for common users. Build a 5G network quality monitoring and analysis platform, carry out quality of service evaluation, and promote continuous performance optimization. At the local government level, take the Shanghai 5G Mobile Communication Base Station Layout Planning Guidelines as an example. The guidelines specify that 5G public service requirements are divided into four levels, as shown in Table 1[6]. Among them, the business district, financial and trade district, commercial street, new city of each district, and the city's main transportation hubs, tourist attractions and other high-density areas are defined Level A. Other areas of Level B areas in the main urban area, as well as user-intensive areas such as central towns, core towns, cultural and creative stadiums, educational sites and large residential communities outside the main urban area. Level

[6] Shanghai 5G Mobile Communication Base Station Layout Planning Guidelines https://app.sheitc.sh.gov.cn/zxgh/687322.htm

C areas are general towns, villages, agriculture and forestry outside urban areas, and non-dense areas such as high-speed railways and expressways. Level D area refers to areas except areas A, B, and C.

Table 1 Shanghai 5G Public Service Requirement

Level / Indicator	A	B	C	D
Coverage	⩾ 98%	⩾ 97%	⩾ 95%	⩾ 95%
Uplink Rate (Mbps)	⩾ 60	⩾ 60	⩾ 30	⩾ 5
Downlink Rate (Mbps)	⩾ 500	⩾ 300	⩾ 100	⩾ 50
Note 1: 5G Network Coverage means proportion of geographic area which 5G network signal RSRP⩾-105dBm to whole geographic area; Note 2: Downlink rate and Uplink rate means terminal user 5G service experience in 5G coverage area.				

In 5G scenarios other than public services, local governments and related industry associations have also released a variety of 5G industry network service performance indicators. Also in the Guidelines for Layout Planning of 5G Mobile Communication Base Stations in Shanghai mentioned above, the application characteristic indicators in the fields of smart manufacturing, smart transportation, smart medical treatment, smart hub, and smart agriculture are specified. This includes network bandwidth requirements, latency, connection density, upstream rate, and downstream rate. As shown in Table 2, the uplink and downlink rates of industrial networks are significantly different from those of public networks, which are 2 to 10 times lower than those of public networks. However, the uplink and downlink rates of industrial networks have more requirements on network latency and connection density. In terms of industry associations, all 5G service performance indicators for the manufacturing industry can be summarized based on various manufacturing communications standards listed by the China Communications Standards Association, as shown in Table 3. It can be seen that for 5G application scenarios that may be involved in the manufacturing industry, such as collaborative design, device remote control, and machine vision quality inspection, the China Communications Standards Association has clearly defined the data rate, latency, and reliability, and finally built a manufacturing 5G production index system.

Table 2 Shanghai 5G Innovation Application Scenario

Indicator \ Application	Smart Manufacture	Smart Transport	Smart Medic	Smart Hub	Smart Agriculture
Network Bandwidth	Medium	Mid-High	High	Medium	Medium
Latency	Medium	High	High	Mid-High	Medium
Connect Density	High	Medium	Medium	Mid-High	Medium
Downlink Rate (Mbps)	≥ 10	≥ 20	≥ 50	≥ 20	≥ 12
Uplink Rate (Mbps)	≥ 2	≥ 5	≥ 5	≥ 2	≥ 2

Table 3 Comprehensive 5G Service Performance Indicator for Manufacturing Industry

Typical Scenarios		Technology Analysis		
		Data rate	delay	Reliability
Collaborative R&D Design		U-10Mbps(1080p) D-10Mbps(1080p)	≤100ms	99.9%
Remote Equipment Control		U-10Mbps(4K,one channel) D-10Mbps（one channel）	≤10ms	99.99%
Equipment Cooperative Operation		≥100Mbps	≤10ms	99.999%
Machine Vision Quality Inspection		U-80M(8K)	<10ms	99.99%
Factory Intelligent Logistics		U-50Mbps	≤20ms	99.99%
Unmanned patrol inspection	UAV intelligent inspection	U-80M/D<600k	<10ms	99.99%
	Robot patrol inspection	U-80M(8K)	10-100ms	99.99%
Flexible Manufacturing		Determined by service	≤1ms	99.9999%
Field Auxiliary Assembly		U>5M	≤100ms	99.99%
UHD) Video Monitoring		U-80M(8K)	<30ms	99.9%

2.4 Networks

Global 5G networks are still developing rapidly. In terms of network coverage, for example, according to GSMA data[7] by March 2024, the global 5G network had covered 44.8% of the population, an increase of 9.5 percentage points year-on-year as shown in Figure 6. After five years of construction, the population coverage of 5G networks has exceeded 50% in 69 countries/regions, accounting for 61% of the global 5G network deployment countries/regions. The 5G network coverage is mainly in Europe, America, Asia, and Oceania. 35 countries/regions have a population coverage rate of over 90%. The US (98%) as well as major

[7] https://data.gsmaintelligence.com/data

European countries like Spain (97%) and Germany (96%) have used low-band and dynamic spectrum sharing technologies to rapidly expand 5G network coverage. In other countries/regions, the coverage rate is high due to factors such as the government and operators' efforts to promote the coverage rate or the population density such as Thailand (95%), Philippines (90%).

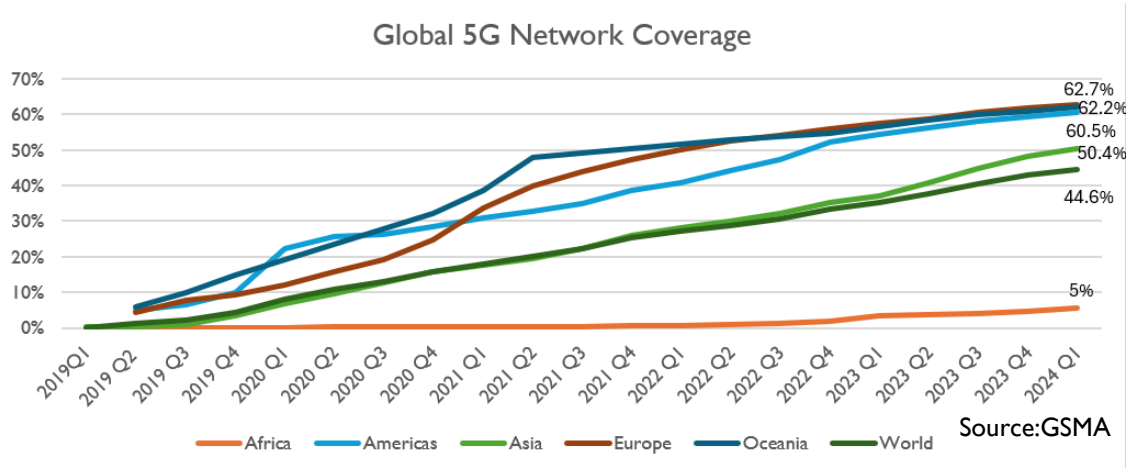


Figure 6 Global Network Coverage

2.5 Applications

2.5.1 5G ToC Application

Years after 5G commercialization, most ToC applications are still mainly upgraded applications based on traditional videos, such as 4K/8K HD videos. New interactive applications (e.g. 5G Calling and 5G Mobile AR) and 5G-based XR immersive applications (Meta). As shown in Figure 7, according to the 5G plan data collected by Omdia from 207 operators in 75 countries and regions, 78 operators provide 5G content and application combination services.

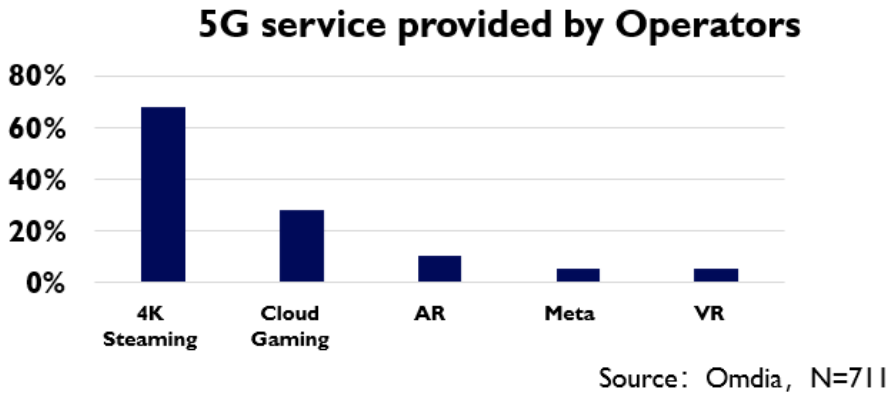


Figure 7 5G Service Provided by Operators

2.5.2 5G ToH Application

5G ToH applications refer to 5G To Home applications. Currently, most applications are fixed wireless access (FWA). FWA combines fixed-line and wireless communication technologies to provide "last mile" broadband services in a more flexible form.

FWA has been widely used worldwide. FWA is already in operation in most countries. According to the GSA data[8], as in Figure 8, 554 operators in 187 countries or regions have declared that they provide FWA services and 477 operators in more than 175 countries or regions have implemented FWA services. In terms of the number of FWA users, according to Ericsson data, the number of FWA connections worldwide has reached 132 million by November 2023 and will increase by 225% from 2024 to 2028. From 132 million in 2023 to 298 million in 2028. The number of 5G FWA connections has increased rapidly, from 4.26 million in 2020 to 35.26 million in 2022, an increase of 827%. It is expected that the number will reach 23622 million in 2028, accounting for 78.7% of all FWA connections. In the Middle East, the number of 5G FWA home broadband users has exceeded three million by 2023, increasing the ARPU by 30% to 80% compared with 4G FWA. In Western Europe, 5G FWA has been extended to multiple scenarios, such as SME and RV. As 5G is deployed in more

[8] GSA: Fixed Wireless Access Nov 2023

countries on a large scale, it also has more room for development in homes, enterprises, and IoT.

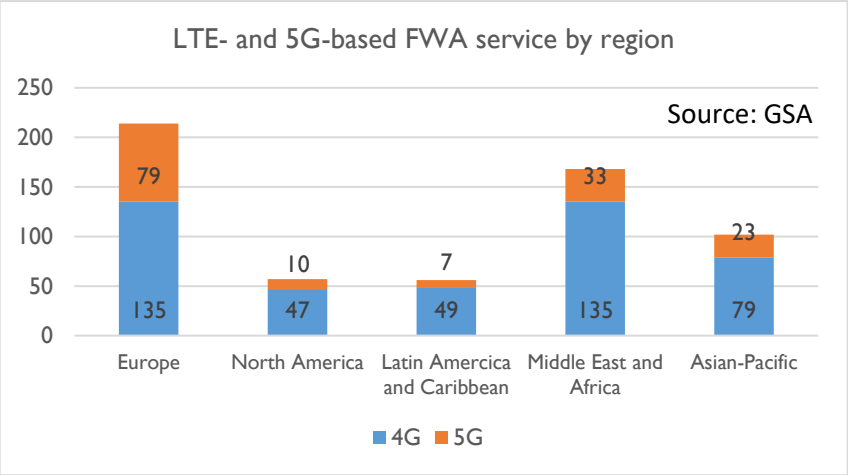


Figure 8 Count of identified LTE- and 5G-based FWA services, by region (excludes soft launches)

2.5.3 5G ToB Application

5G ToB applications are still in the early stage, mainly in manufacturing industries, education, cultural tourism, sports, public safety, health and other fields. According to GSA data, as in Figure 9, by the end of 2023, at least 1384 institutions/organizations in 77 countries had deployed or were deploying LTE or 5G-based networks, reaching 643. Considering the application coverage and scenario deployment, 5G industrial applications are still in the early stage. The manufacturing industry is the most active vertical application industry, involving more than ten manufacturing subdivision industries and the industry with the most extensive automotive applications.

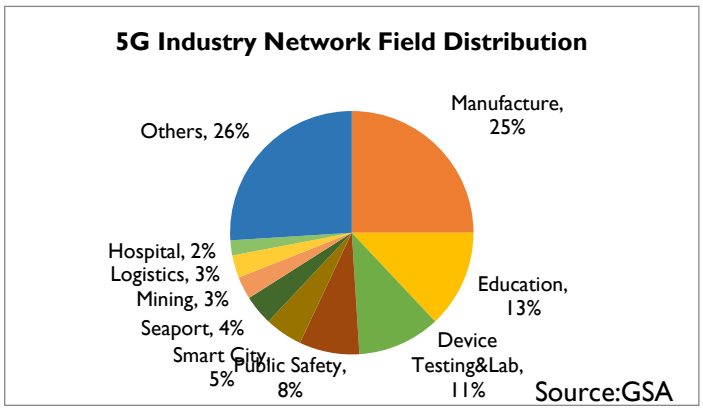


Figure 9 5G Industry Network Field Distribution

3.Bangladesh Network Evolution Path

Based on the current mobile network status in Bangladesh, service requirements, network security, and economic costs, this chapter provides 5G network promotion methods, including 5G spectrum and bandwidth, 5G base station deployment architecture, 5G network construction, and 5G service performance.

3.1 Bangladesh Spectrum Planning

3.1.1 5G Spectrum Analysis in Bangladesh

Spectrum is the core resource that supports 5G networks. 5G spectrum refers to a radio frequency band resource for 5G communication, and covers a wide frequency range, including a low frequency band, an intermediate frequency band, and a high frequency band. Different frequency bands have different characteristics and application scenarios, which directly affect the performance and transmission rate of 5G networks. The large bandwidth and wide coverage feature of 5G networks are officially built on 5G spectrum resources. Therefore, it is necessary to integrate and allocate 5G spectrum resources preferentially during 5G network planning.

According to 3GPP TS 38.104, the 5G NR spectrum is divided into two frequency bands: FR1 and FR2. FR1 refers to the sub-6 GHz frequency band, which corresponds to the frequency range from 450 MHz to 6000 MHz. Currently, most 5G scenarios are in the FR1 frequency band. FR2 refers to the mmWave band, corresponding to the frequency range from 24250 MHz to 52600 MHz. Compared to FR2 band, FR1 band have multiple advantages in performance, cost and industry chain. **In performance,** FR1 can provide uplink and downlink rates of 1 Gbit/s while FR2 can provide a maximum uplink and downlink rate of 20 Gbit/s, which both meet the requirements of citizen scenarios. However, the ultra-high frequency of the FR2 frequency band brings a millimeter-level radio wavelength, resulting in poor penetration capability and small coverage area. **In Cost**, The FR1 frequency band has good coverage capabilities of low and mid frequencies band. Therefore, fewer 5G base stations can be used to cover a wider geographical area during 5G network construction, reducing the cost of the FR1

network. In the FR2 frequency band, a higher carrier frequency causes a more severe attenuation of signal transmission power with a transmission distance, resulting a coverage area of an FR2 base station decreases significantly. In addition, a millimeter-wave antenna is more costly to manufacture and consumes more power. **In Industry,** the FR1 frequency is widely used around the world, particularly golden mid bands 3.5/2.6/2.3GHz, including China, the European Union, the United States, and ASEAN countries in their 5G network construction. Related networks, base stations, and terminals are mature, and the upstream and downstream of the industry chain are stable. The FR2 frequency is only commercialized in a few countries, such as the United States and Japan, and is a supplement to the FR1 frequency. The FR2 related industries are still in the initial stage of development.

According to Bangladesh current spectrum state, there are several spectrum bands are currently available or potential available for 5G networks.

1. 3500 MHz

The 3500 MHz frequency band has sufficient idle spectrum resources in Bangladesh. Except 30MHz bandwidth for police service network, there are more than 460MHz bandwidth available currently from 3340-3800MHz.

3500 MHz spectrum is always the first choice for 5G network construction in various countries. As shown in Table 4, most countries use 3500 MHz for 5G network construction. China Mobile network operators China Unicom and China Telecom use the 5G TDD solution on 3.5 GHz. Southeast Asian countries such as the Philippines, Singapore, Viet Nam and Laos also use 3.5GHz as their first 5G network deployment spectrum.

Table 4 First frequency of 5G network construction in each country

Country	Operator	Licensed/Deployed Date	Frequency	Bandwidth	Country	Operator	Licensed/Deployed Date	Frequency	Bandwidth
Australia	Optus	July-2019	3.5GHz	60MHz	Philippine	DITO	Mar-2021	3.5GHz	140MHz
	Telstra	May-2019	3.5GHz	60-80MHz		Global Telecom	Jun-2019	3.5GHz	60MHz
Brazil	Claro	Jul-2022	3.5GHz	100MHz		Smart	Jul-202	3.5GHz	60MHz
	Tim	Jul l-2022	3.5GHz	100MHz		STC	Jun-2019	3.5GHz	100MHz

	Vivo	Jul l-2022	3.5GHz	100MHz	**Saudi Arabia**	Zain	Jul-2019	3.5GHz	100MHz
China	China Mobile	6-Jun -2019	2.6GHz	160MHz	**Singapore**	M1	Jul-2020	3.5GHz	100MHz
	China Telecom	6-Jun -2019	3.5GHz	100MHz		Singtel	Aug-2021	3.5GHz	100MHz
	China Unicom	6-Jun -2019	3.5GHz	100MHz	**Spain**	Orange	Sep-2020	3.5GHz	60MHz
Finland	DNA	Jan-2020	3.5GHz	130MHz		Vodafone	Jun-2019	3.5GHz	90MHz
	Elisa	Jun-2019	3.5GHz	130MHz	**UAE**	du	May-2019	3.5GHz	100MHz
	Telia	Oct-2019	3.5GHz	130MHz		Etisalat	May-2020	3.5GHz	100MHz
France	Orange	Oc-2020t	3.5GHz	90MHz	**Korean**	LG U+	Dec-2018	3.5GHz	100MHz
	SFR	Nov-2020	3.5GHz	80MHz		KT	Dec-2018	3.5GHz	100MHz
German	Telekom	Sep-2019	3.6GHz	90MHz		SK Telecom	Dec-2018	3.5GHz	100MHz
	Vodafone	Jul-2019	3.6GHz	90MHz	**USA**	ATT	2019	3.6GHz	100MHz
India	Airtel	Oct-2022	3.3GHz	100MHz		Sprint	2019	2.5GHz	100MHz
	Jio	Oct-2022	3.3GHz	100-130MHz		T-Mobile	Jul-2020	2.5GHz	100MHz
Japan	KDDI	Mar-202	3.6GHz	200MHz		Version	2019	3.7 GHz	100 MHz
	NTT DOCOMO	Mar-202	3.5 GHz	100 MHz	**Vietnam**	Viettel	Mar-2024	2.6GHz	100MHz
	Softbank	Mar-2020	3.9 GHz	100 MHz		VNPT	Mar-2024	3.7 GHz	100 MHz
	Rakuten	Mar-2020	3.9 GHz	100 MHz		Mobifone	July-2024	3.7 GHz	100 MHz

The ITU also recommends 3.5 GHz. In the Digital Infrastructure Policy and Regulation in the Asia-Pacific Region September 2019, ITU clearly stated that 3.5 GHz band is an ideal frequency band for 5G as it is able to provide both capacity (the amount of data traffic it can support) and coverage (the distance the radio signals travel). High-speed enhanced mobile broadband services need to be capable of delivering peak download speeds of at least 20 Gbps, a reliable 100 Mbps user experience data rate in urban areas, and 4ms latency.

The 3.5 GHz industry chain is mature. Take terminals as an example. Currently, there are 1573 types of terminals that support mid-frequency (1.6 GHz-7.12 GHz), among which 95.8% or 1507 types of the terminals support n77/n78 bands. A large number of terminal types reflect the rich industry ecosystem of the 3.5 GHz frequency band.

2. Sub 1GHz

Sub 1GHz is what called golden frequency band of 5G. Sub-1 GHz frequency band (generally include 700MHz, 850MHz, 900MHz band) has excellent radio transmission performance, wide coverage, and good penetration. With 700MHz as an example, the 700 MHz transmission distance is 3.7 times that of the 2600 MHz transmission distance under the same transmit power. Several countries have allocated 700 MHz spectrum resources to mobile network operators (MNOs). Vodafone provides 700 MHz wide coverage services for 5G customers. China Mobile cooperates with China Broadcast Network (CBN) to jointly develop 700 MHz spectrum resources. Thailand, the Philippines, Malaysia, India, Brunei and Laos have deployed 700 MHz spectrum. In addition, 700 MHz spectrum resources are widely used in 5G virtual private networks, such as smart ports, smart mining, and smart agriculture. In some scenarios, 700 MHz base stations can cover 96 km.

Bangladesh's 700MHz spectrum resources are currently available for 4G and 5G network. Considering 850MHz and 900MHz interference field tests under POC in urban and rural areas and with limited bandwidth, suggest assigning full 45MHz of 700MHz band B28/N28 to MNOs to further develop wider 4G+5G network service, especially for rural areas and provide 5G MBB / FWA /NB-IoT services to villagers.

3. LTE Band (2.1GHz and 2.6GHz)

2600 MHz is another excellent fifth-generation mid-band frequency. In September 2019, ITU's Asia-Pacific Digital Infrastructure Policy and Regulation recommended that the 2.6 GHz frequency band (especially TDD band 41 (2496 MHz to 2690 MHz)) is another excellent choice for Asia-Pacific countries that want to deploy 5G as early and efficiently. Compared with the 3.5 GHz band, the 2600 MHz band has better radio propagation characteristics. The broadcast capability of the 2600 MHz band is 4 dB to 6 dB higher than that of the 3.5 GHz band. During 5G network construction, many operators share 4G sites and towers. In Bangladesh, both Grameenphone and Robi have 80MHz large block for 4G LTE in 2600MHz, and ready for 5G dual usage at one network. Balance 30MHz out of total 190MHz bandwidth is reserving for government service.

The coverage of 2.1 GHz is better than that of 2.6 GHz. In addition, MNOs have deployed large-scale 3G/4G networks on this frequency band, reducing 5G network deployment costs by using existing 3G/4G sites. However, many operators (including Banglalink, Grameenphone, Teletalk and Robi) are using the 2.1 GHz spectrum in a centralized manner, and the electromagnetic environment is complex. Moreover, as the main frequency band of 3G/4G, re-cultivation of 2.1 GHz will share most of the network load to other frequency bands, which will greatly affect 3G/4G services. However, Considering MNOs are gradually shutting down the 3G network and calculating that these spectrum resources will be allocated to the 5G network. Therefore, the long-term time of shutdown of the 3G network can be used to explore the specific 2.1 GHz allocation mode, providing sufficient time for evaluation and detection.

4. High Frequency Band (4.9GHz and 6GHz)

4.9 GHz is an experimental band for 5G networks, which has a very clean spectrum environment and can provide ultra-high-speed mobile network services. 4.9 GHz has been used in some scenarios. For example, China Mobile uses its 4800 MHz to 4900 MHz for 100 MHz bandwidth to provide 5G virtual private network services and enable coverage at specific hotspot for customers. Currently, only China and Japan have a small number of deployments, and the frequency bands need to be developed for a long time.

Similar to the 4.9 GHz frequency band, the 6 GHz frequency band also has abundant spectrum resources and can provide up to 10Gbps-level high-speed network services, meeting the requirements of ITU IMT-2020. At the ITU WRC-23 meeting held in Dubai in December 2023, a new resolution (Res.220) was decided: Region 1 (Europe, Africa, Russian Federation and Arab States regions) identified the entire 6425–7125 MHz frequency band for IMT. In Region 3 (Asia Pacific), the 7025–7125 MHz frequency band is identified for IMT. In addition, some countries in Region 3 identified the 6425–7025 MHz frequency band for IMT by adding footnote in WRC-23 and other countries can also add the footnote during WRC-27. Meanwhile, some operators like Germany Vodafone, Finland Telia, UAE Etisalat and Malaysia Maxis have finished field trial test 5G services on the 6 GHz band, supporting by industrial ecosystem

partners including Huawei, Ericsson, Nokia and Mediatek. In the future, 6 GHz band will play an important role in the development of 5G networks technology and applications evolution towards 5G-Advanced and beyond. BTRC is planning to assign 6GHz with 6425-7125MHz for 5G evolution and beyond before 2035.

3.1.2 5G Spectrum Allocation Suggestion in Bangladesh

According to current Bangladesh spectrum allocation and spectrum characteristics, a spectrum allocation timeline given in Figure 10.

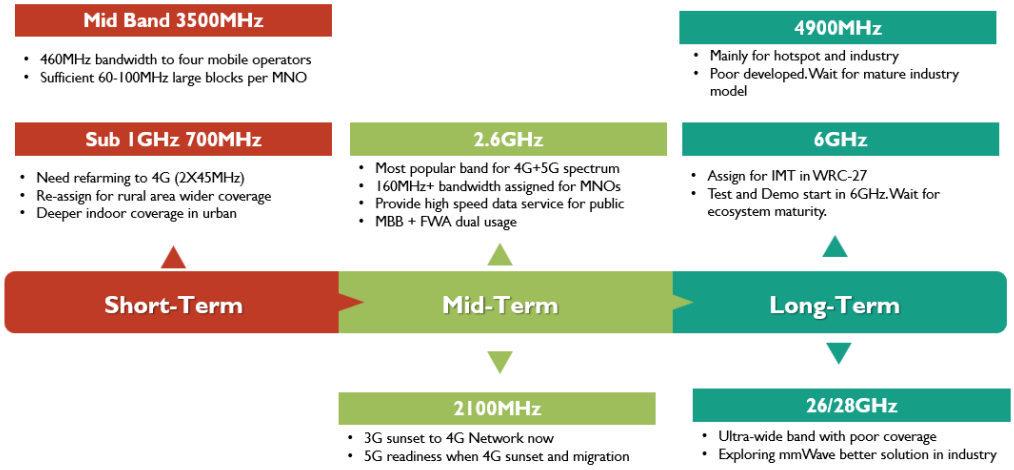


Figure 10 Bangladesh 5G Network Spectrum Path

1. 3.5GHz and 700MHz in Short-term (1-2 year)

3500MHz is the first frequency band recommended for 5G network spectrum allocation as a result of balancing performance, cost and industry.

3340	3400	3500	3600	3700
60MHz	100MHz	100MHz	100MHz	100MHz

Figure 11 3.5GHz allocation planning in Bangladesh

Shown in Figure 11, a total of 460MHz bandwidths is provided from 3300MHz to 3700MHz. The bandwidths are 60MHz for 3340MHz-3400MHz, 100MHz for 3400MHz-3500MHz, 100MHz for 3500MHz-3600MHz, and 100MHz for 3600MHz-3700MHz. It is suggested to allocate these bands to the four largest operators in Bangladesh which are Grameenphone,

Banglalink, Robi and Teletalk with one MNO obtains 60MHz and other three obtain 100MHz each. 100MHz from 3700MHz to 3800MHz temporarily serves as the guard band to separate the 3.5GHz frequency band from the other frequency band after 3800MHz are separated to prevent mutual interference between the two frequency bands.

700MHz spectrum is also recommended for short-term allocation planning. N28 band has double 45MHz FDD band from 703MHz-748MHz to 758MHz-803MHz. 700MHz is perfect band to MNOs for further developing wide 5G network service, especially for rural areas and providing 5G service to villagers. Thus, assigning 10MHz to 20MHz for both downlink and uplink to 3 or 4 MNOs in Bangladesh could largely promote 4G network construction in short time and 5G wider deployment ready.

2. 2100MHz and 2600MHz in Mid-term (2-4 years)

Both 2100MHz and 2600MHz are now using for 3G/4G networks in Bangladesh. 2600MHz (from 2500MHz to 2700MHz in frequency) is now used for LTE. Grameenphone and Robi both have 80MHz for LTE TDD. Grameenphone got 60MHz bandwidth from 2550MHz to 2610MHz and Robi got 60MHz bandwidth from 2610MHz to 2670MHz in 2022. It is suggested to re-allocate 20MHz to two MNOs each to form a continuously large block 80MHz bandwidth 4G/5G network after BTRC assigned each of 20MHz additional bandwidth to Grameenphone and Robi in August 2024. 2600MHz is also a suitable spectrum to provide FWA service for its larger coverage and better penetration performance. This 20MHz bandwidth also needs collaboration between MNOs and government regulatory agencies.

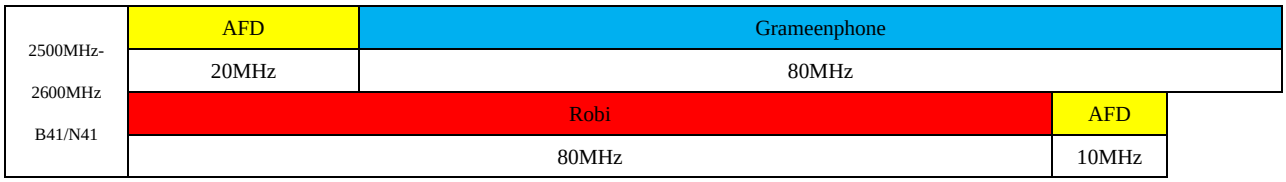


Figure 12 2.6GHz Spectrum Allocation Suggestion

For FDD 2100MHz band 1, Banglalink, Grameenphone, Robi and Teletalk all have paired 10MHz to 20MHz bandwidth for 3G/4G FDD. With quite complex spectrum allocation status and electromagnetic environment, it will be difficult to re-farm this spectrum to 4G and 5G

network. And re-farming will also move current network workload to other and cause huge impact to 3G/4G service. But with 3G network gradually shutting down globally, it can be forecasted that 2100MHz spectrum will migrate to 4G network. This migration requests several years evaluation and testing, therefore starting re-farming work after 5G developed several years is a reasonable choice.

2100MHz	Banglalink	Grameenphone	Robi	Teletalk
B1/N1	15MHz	20MHz	15MHz	10MHz

Figure 13 Current 2.1GHz Spectrum Status in Bangladesh

3. Middle band, 4.9GHz, 6GHz and mmWave in long-term (5+ year)

Middle band in spectrum mentioned here mainly refers to 1.4GHz. The middle band 1.4GHz with 1427-1518MHz for SDL (Supplementary Downlink) assignment can be a candidate spectrum for downlink throughput. Considering 4.9GHz and 6GHz are now both available in Bangladesh. 4.9GHz generally use for hotspot and industry scenario but only limited developed so far which only some countries use it in hotspot compensation and specific scenario like manufacturing, harbor etc. Considering current Bangladesh still in 4G network and need time to develop 5G, 4.9GHz is still long time to consider in 5G network construction. 6GHz is another undeveloped spectrum in 5G network. At ITU WRC23 meeting, a new resolution on 6GHz in area3(Asia Pacific Zone) was made. The entire 7025–7125 MHz frequency band is used for IMT. In addition, some countries in area 3 use the 6425–7025 MHz frequency band for IMT and Bangladesh is excluded. 6GHz will be a hot spectrum in coming several years to provide ultra-high-speed wireless network service, so it is suggested that Bangladesh keep catching up 6GHz industry trends and prepare 6GHz service deployment in long term.

The millimeter wave (26/28 GHz) band is a new frequency band supported by 5G technologies. Compared with the frequency band below 6 GHz, the millimeter wave (mmWave) band has unique advantages such as large bandwidth and low air interface delay. The theoretical downlink rate of the millimeter wave (mmWave) band can reach a maximum of 20 Gbit/s. Due to challenge transmission characteristics of the millimeter wave frequency band, even if the transmission gain is enhanced by using a large-scale antenna array and beamforming technology,

the coverage of the millimeter wave frequency band is still far from that of the FR1 frequency band. In the case of NLOS of dense urban, the coverage of the millimeter wave frequency band is only 100 meters. Therefore, millimeter wave is not a practical choice in the early stages of 5G network deployment for continuous coverage, but in the industry, the application of millimeter wave antennas continues to be developed.

3.2 Bangladesh Network Construction and Development Evolution Path

3.2.1 5G Network Analysis in Bangladesh

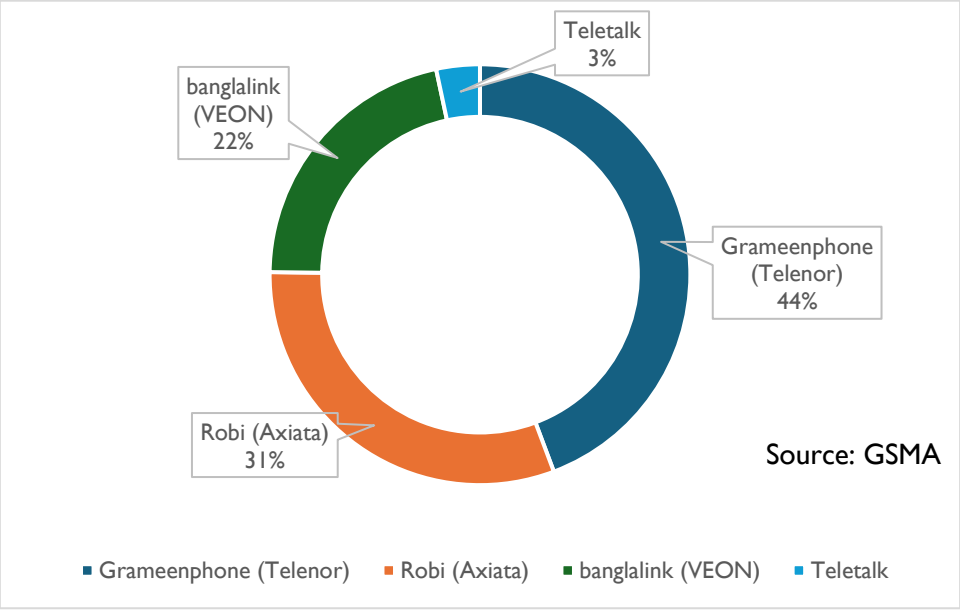


Figure 14 User Proportion of Bangladesh Mobile Operators

Bangladesh has several Mobile Network Operators (MNOs) including Grameenphone, Robi, Banglalink, Teletalk. Grameenphone is joint company established by Norway Telenor and Grameen and is the largest mobile operator in Bangladesh with market share of approximately 44%. Grameenphone provides various mobile communications services such as mobile phone communications, fixed-line phone communications, and internet access services, as well as other value-added services such as bill payments, credit card payments, and mobile bank. Robi is the second largest mobile operator in Bangladesh with market share of 31%, which is invested by Malaysia Axiata Group. Banglalink is the third largest mobile operator with market share of

22%, which is invested by Dutch Veon Group. Teletalk the Bangladesh state-owned mobile operator.

Driven by government-lead national digitalization process, Bangladesh mobile network is rapidly developing. According to BTRC data[9], Bangladesh has 192.43 million mobile users, with a mobile user penetration rate equivalent to 110.98% of the total population. In terms of infrastructure construction, Bangladesh has deployed 4G networks and is conducting 5G network trials. Bangladesh's operators Grameenphone, Robi, and Teletalk have obtained the Unified License for Cellular Mobile Services Operators (including 5G) issued by the Bangladesh Telecommunication Regulatory Commission (BTRC) and completed the auction of 5G spectrum at 2.6GHz & 2.3GHz for mobile networks in the 2022 Q1, making Bangladesh the second country in South Asia to successfully auction 5G spectrum after Maldives.

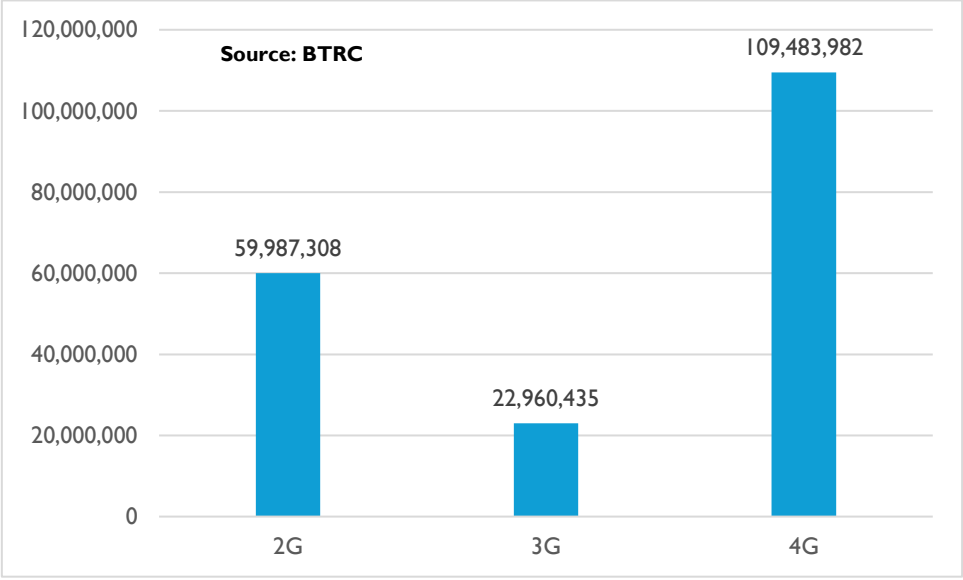


Figure 15 Mobile Connections in Bangladesh

However, the development of Bangladesh's mobile network still faces some challenges. Firstly, current mobile network systems and technologies need to be upgraded. Reference data from Figure 16, around 34.34% of mobile connections in Bangladesh still rely on 2G networks, which only support voice calls and text messaging services. This proportion is the highest

[9] BTRC: SAPIX-WSRTT-INP-26_BTRC__Enhancing_digital_transformation__Perspective_Bangladesh_30Sep2024

among South Asian countries while 2G user penetration rate in India is 8.38%, in Bhutan it is 8.02% and is within 30% in other countries. In addition, due to the large population and the fact that most people live below the poverty line, part of residents cannot afford telecommunications equipment like smartphone. Secondly, smartphones terminal low penetration rate limit the growth of data traffic in Bangladesh. Driven by BTRC mobile network promotion work, Bangladesh median country speed significantly increased 33% in past 1 year[10], but 58.9% smartphone penetration rate[11] make around 100 million mobile network users still experienced 2G/3G network instead of 4G high speed network service, which giant data traffic potential market undeveloped.

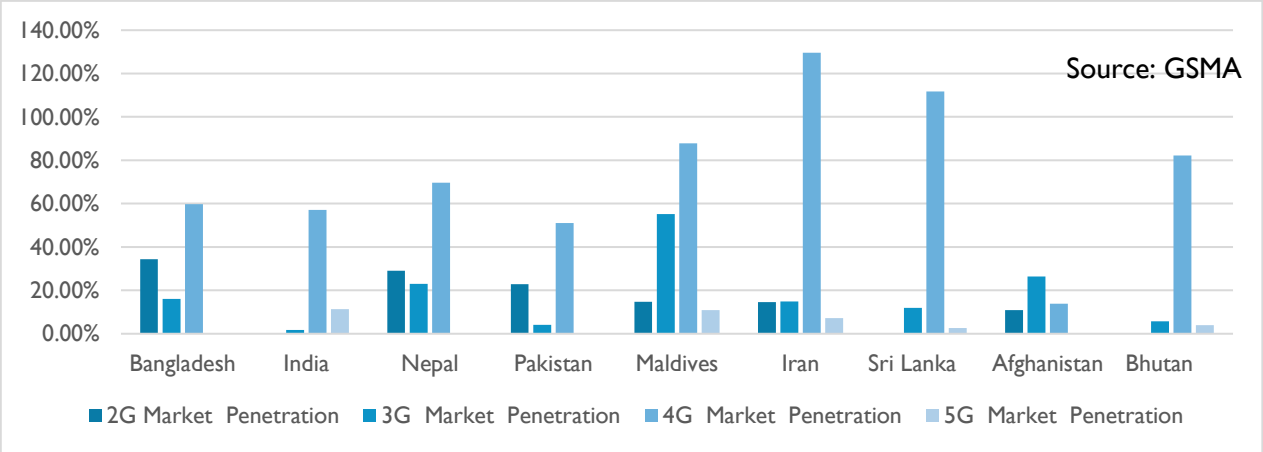


Figure 16 Mobile Service Penetration Rate in South Asia

3.2.2 5G Network Construction Promotion Suggestion

3.2.2.1. 5G Policy

In 2008, the government of Bangladesh recognized the significant social and economic benefits from the application of information technology. Thus, it is recommended that the Bangladesh government further develop a national strategic plan for the integration of 5G applications, continue to enhance network capabilities, and provide policy guidance and support for 5G network construction from the top level.

[10] Speedtest https://www.speedtest.net/global-index/bangladesh#market-analysis

[11] GSMA database https://data.gsmaintelligence.com/data

First, establish indicators for advancing 5G network construction and clarify key tasks and goals. Key indicators could include broadband access to villages, homes, schools, hospitals, and smart cities, as well as population coverage of 4G/5G networks.

For instance, by 2025, population coverage of 4G and 5G could target 65%, broadband accessibility in villages could reach 25%, household broadband penetration rate could aim for 60%, broadband user penetration rate might reach 60%, and smart terminal penetration rate could be set at 75%, encouraging the adoption of emerging telecommunications technologies such as 5G. By 2027, the population coverage of 4G and 5G could increase to 85%, and by 2030, it could reach 100%.

It is recommended that BTRC further define 4G/5G network development indicators at the national level, such as the 4G/5G user penetration rate, 4G/5G village accessibility rate, and the number of base stations per thousand people for 5G. This would help enhance the scale and quality of Bangladesh's 5G network development. Specific indicators can be referred to Table 5。

Table 5 Bangladesh 4G/5G Network Construction Indicators

		2025	2027	2030
Mobile broadband access (% population coverage)	4G	65%	85%	100%
	5G	10%	20%	50%
Smart device penetration	4G	75%	85%	100%
	5G	10%	25%	50%
User Penetration Rate	4G	70%	80%	100%
	5G	5%	10%	30%
Broadband to Village Accessibility Rate	4G	25%	60%	100%
	5G	10%	25%	50%
5G BTS Number per 1K people		0.3	0.6	1

Second, it is recommended that local governments issue local policies for 5G network construction planning according to local demands. Under the guidance of top-level policies, it is recommended that the local governments of Bangladesh issue local policies to promote 5G applications in combination considering local conditions and characteristics, clarify local 5G network construction indicators and specific construction measures and support policies,

including promoting the sharing of social public resources and the pre-deployment of optical fibers, etc. For example, in public area such as transportation hubs, hospitals, schools, exhibition centers, large sports gym, as pushing opening up shared public resources like streetlights, traffic signal poles, and video surveillance poles for the construction of 5G network base stations.

Third, it is recommended that the government increase policy and financial support for state-owned telecom operators in Bangladesh. In various ways such as tax exemptions, cash rewards, and national special support, support state-owned operator Teletalk in carrying out 5G network construction and supporting Teletalk in building 5G industry virtual private networks with core network local deployment for government affairs, power, and other application scenarios to ensure data security.

3.2.2.2. 5G Public Network Construction

In network construction, it is recommended that Bangladesh follow the principle of urban area to rural area with step by step and stage by stage to promote 5G network construction and deployment. Suggest priority deployment key areas in major cities, such as transportation hubs, large stadiums, scenic spots and other high-traffic scenario, to carry out 5G network coverage. Gradually push 5G networks to village and rural areas. The target number of base stations is related to business needs and return on investment. Refer to China's "14th Five-Year Plan for the Development of the Information and Communications Industry", China's 5G has been commercially available since June 2019, reaching 0.5 5G BTS per 1K people by the end of 2020, achieving coverage in major cities and key counties and cities national-wide. It is planned to reach 2.6 5G BTS per 1K people by the end of 2025, achieving full coverage in cities and townships, basic coverage in villages, and deep coverage in key scenarios. The “5G Application Sailing Action Plan” further indicates China's 5G network construction from 2021 to 2023, with a plan to reach 1.8 5G BTS per 1K people by the end of 2023. According to statistics from the Ministry of Industry and Information Technology, by the end of 2023, China's

total number of 5G BTS has reached 3.377 million, with 2.4 5G BTS per 1K people, covering all city districts and villages.

According to China's progress and experience in deploying 5G base stations, in national 5G network construction, it is recommended that Bangladesh first launch 5G network construction in key areas of major cities and key counties and cities, achieving 0.3 5G BTS per 1K people. Then gradually achieve 5G network coverage in all cities and major counties, achieving 0.6 5G BTS per 1K people; Finally, achieve full coverage in all urban and rural areas, as well as deep coverage in key areas, achieving 1 5G BTS per 1K people. In 5G network city construction, referring to the path of 5G network construction in China's two major cities of Shenzhen and Qingdao (see Table 6), both cities started their 5G network construction from covering hot spots, then completed continuous urban coverage and village coverage, while also conducting deep coverage in key areas. It is recommended that Bangladesh first achieve 5G coverage in key application areas such transportation hubs, hospitals, schools, enterprises, and shopping malls in major cities, achieving 1 5G BTS per 1K people. Then gradually achieve continuous urban 5G coverage, achieving 1.5 5G BTS per 1K people. Finally, achieve full coverage in urban and suburban areas and deep coverage in key areas, achieving 2 5G BTS per 1K people.

Table 6 5G Network BTS Number and Coverage of some major cities in China

5G Coverage in Shenzhen City				
Year	BTS Number	BTS Per 1K	Coverage	Comments
2019	15000	0.8	5G Full coverage in key area	Support MNO deploy 5G scale network construction in Key district and transportation hub like airport, HST station
2020	45000	2.5	5G Full coverage	Support MNOs develop 5G network in industry campus, residential area and transportation area
2021	51000	2.8	Spot Replenishment	Promote 5G deep coverage in key area including transportation hub, industry campus, shopping mall, hospital, school, museum etc
2022	65000	3.6		
2023	75000	4.2		

5G Coverage in Qingdao City			
Year	BTS	BTS Per 1K	Coverage
2020	15000	1.4	5G continuously coverage in key area. Build 1700 BTS around hospital, school, research institution, enterprises.
2021	20000	1.8	
2022	30000	2.8	5G full coverage in key cities and towns
2023	37000	3.5	Deepen 5G coverage, village accessibility reach 90%

In BTS construction mode, it is recommended to adopt "Macro-Micro" approach to address 5G network coverage and capacity expansion. In 5G era, due to the higher frequency,

shorter wavelength, and weaker diffraction capability of 5G, the radiation attenuation increases when encountering obstacles, resulting in a smaller signal coverage area for each 5G macro base station. On the other hand, approximately 80% of 5G services are conducted indoors, especially in key scenario such as transportation hubs, buildings, schools, and hospitals, which have higher requirements for network experience, such as ultra-high traffic, ultra-high connection density, and wide coverage which lead to issues such as insufficient capacity and coverage. Therefore, it is necessary to plan the number of 5G macro BTS, micro BTS, and indoor distribution systems according to the business demands of different regions to meet the requirements for both the breadth of signal coverage and hot zone. Refer to China as an example, local governments have issued various policy documents and action plans to promote deep coverage of 5G networks. The Shenzhen Government issued the " Measures on Taking the Lead in Achieving Full Coverage of 5G Infrastructure and Promoting High-Quality Development of the 5G Industry in Shenzhen", and by July 2020, Shenzhen had built 45,000 5G BTS (including 27,685 macro BTS, 2,603 micro BTS, and 14,712 indoor distribution systems), fully promoting the construction of 5G infrastructure.

In BTS co-construction and sharing, it is recommended to promote passive infrastructure co-construction and sharing. According to Bangladesh guidelines for telecommunication infrastructure[12], Operators shall share its owned passive infrastructure with other operators and entities authorized by the Commission. Moreover, Mobile network operators (MNO) shall share their own passive infrastructure with other telecommunication operators through towerco operators upon receiving the request on non-discriminatory basis. Many countries around the world have actively explored the co-construction and sharing of network infrastructure. In India, in addition to sharing towers, it has also announced that MNOs are allowed to share passive infrastructure such as server room, power supply cables. Under the guidance of the Ministry of Industry and Information Technology and the State-owned Assets Supervision and

[12] BTRC: guidelines for telecommunication infrastructure
https://btrc.portal.gov.bd/sites/default/files/files/btrc.portal.gov.bd/notices/fe00f873_0245_4a35_8dca_ef27f6f7d889/2024-05-23-07-10-ecb835b2002db5db6dc432917a023443.pdf

Administration Commission of the State Council, China has established China Tower to achieve co-construction and sharing of base station supporting facilities, including physical site, server rooms, and other facilities, thereby reducing the number of site and solving the problem of repeated construction of supporting facilities. China Tower has signed cooperation agreements with various MNOs to plan the overall layout of base station supporting facilities such as towers and server rooms, as well as indoor distribution systems in key scenario. By the end of June 2024, the average number of tenants at operator towers operated by China Tower reached 1.71, which strengthened the planning and coordination of network facility construction demands, making network construction more orderly and efficient. It is recommended that Bangladesh continue to adopt current flexible approach to tower and fiber-optic sharing construction by allowing MNOs to share base station supporting passive infrastructure through leasing, thereby reducing the cost of repeated base station construction and promoting the large-scale construction of 5G base stations.

With support of government policy, it can be predicted that MBB service of Bangladesh will step into sustainable development stages. MNOs obtain data traffic flow increase and ToC service income by evolving from 4G to 5G network. Based on ITU Global Connectivity Report 2022[13], the affordability target aims to reduce the price of entry-level mobile broadband services in developing countries to less than 2 per cent of monthly GNI (Gross National Income) per capita by 2025. In 2023 Bangladesh MBB affordability index is 0.64% considering average ARPU[14] with $1.5 and GNI per capita is $2860 by World Bank static[15]. According to ITU global traffic forecast model[16] and current Bangladesh 7GB DoU, the DoU of Bangladesh will reach 20GB in 2027 and 50GB in 2030. So with 5G development, it is forecast the MBB affordability index is still <1% till 2030, which is lower than ITU target <2%.

[13] ITU Global Connectivity Report 2022 itu.int/dms_pub/itu-d/opb/ind/d-ind-global.01-2022-pdf-e.pdf

[14] Grameenphone 2023 Annual Report https://www.grameenphone.com/about/investor-relations

[15] World Bank GNI per capita 2023 data https://genderdata.worldbank.org/en/indicator/ny-gnp-pcap-cd

[16] ITU IMT traffic estimates for the years 2020 to 2030

Table 7 MBB service forecast in Bangladesh

MBB service forecast	Year 2023	Year 2027	Year 2030
DOU (GB / month)	7GB	20GB	50GB
Download Average Speed (Mbps, by Speedtest)	23.8Mbps	40Mbps	80Mbps
ARPU ($ per month)	1.5	1.9	2.5
Revenue per GB ($/GB)	0.21	0.09	0.05

3.2.2.3. 5G Industry Network Construction

As industry digitalization revolution spread worldwide, various industries including manufacturing, transportation, energy, medic, media, finance are exploring digital transformation path, seeking breakthroughs in data collection, data transmission, and data application etc. On the one hand, vertical industry enterprises have raised higher requirements for network functions, performance, and stability when using 5G technology. Wireless communication network has to adapt to business and management demands, such as network deployment architecture and network performance requirements. On the other hand, in terms of industry 5G network construction and operation, industry enterprises expect to have a controllable network and smooth integration between operation and maintenance mode of 5G network and their existing network/business manage system, reducing their own network and operational costs while obtaining to operate the 5G network. In industry-oriented 5G network architectures, there are mainly two types: 5G industry virtual private networks and 5G dual-domain private networks. It is recommended that Bangladesh, in response to the requirements of vertical industries, deploy 5G industry virtual private networks and 5G dual-domain private networks on demand in key scenario using technologies such as 5G network slicing and dual-domain private networks to meet the demands of vertical industry customers.

1. 5G industry virtual private network

5G industry virtual private network refers to a high-quality dedicated network provided by MNOs' 5G public network that meets the requirements of business and security from industry customers. It is a core network that provides differentiated and partially self-operated network services to industry clients.

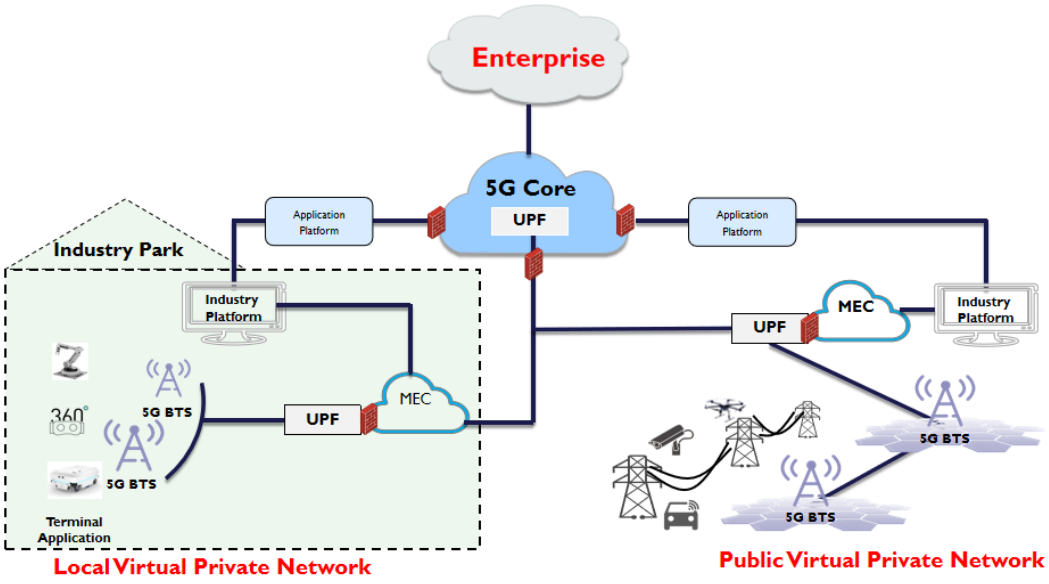


Figure 17 5G Industry Virtual Private Network Architecture

From the perspectives of application scenarios, geographical location, and service scope, 5G industry virtual private networks (5G IVPNs) can be categorized into two main types: wide-area IVPNs and local area IVPNs. Local area IVPNs are typically suitable for businesses that are confined to a specific geographical region, where a closed-loop process can be realized based on the 5G network in that specific area, ensuring that the industry's core business remains within the park. The main application scenarios for local area IVPNs include manufacturing, steel, petrochemical, harbor, education, healthcare, and other enterprise parks/factories. Meanwhile, wide-area IVPNs do not have geographical restrictions and can typically utilize the end-to-end public network resources of MNOs to securely carry different businesses across different industries through network virtualization or physical slicing. The main application scenarios for wide-area IVPNs include transportation, power, V2X networks, and large-scale enterprises with cross-regional operations. In terms of deployment architecture, 5G IVPNs can be categorized into three types: public network sharing, public network dedicating, and customized private network, which fulfill different customer requirements for security isolation, business quality assurance, and business service scope.

2. 5G Dual-domain Private Network

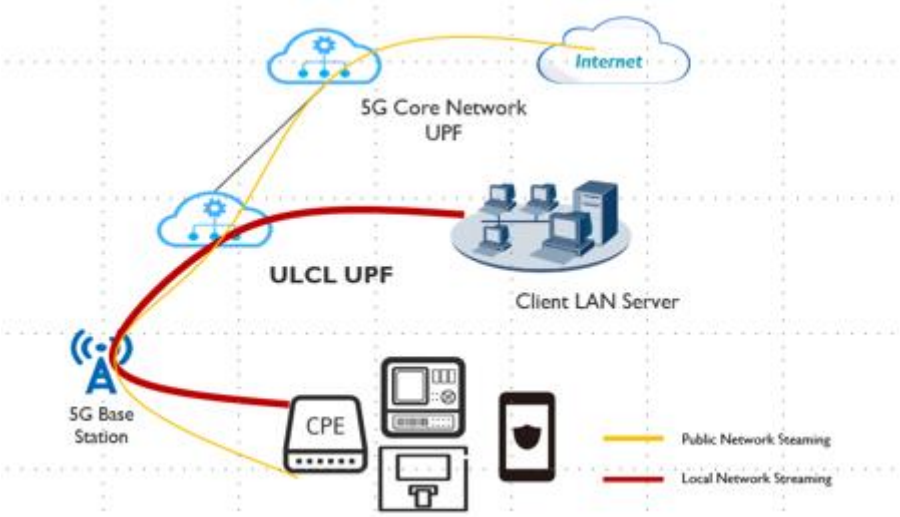


Figure 18 5G Dual Domain Private Network Architecture

The 5G dual-domain private network enables efficient and unconscious data splitting for users through the 5G network, allowing users to securely and unconsciously access both the enterprise intranet and the internet using their own 5G terminals without changing their SIM cards or phone numbers. This solution is based on 5G MEC (Multi-access Edge Computing) and utilizes technologies such as ULCL (Uplink Classifier) and dedicated DNN (Data Network Name) to provide local data traffic splitting and processing for specific customers. It addresses the issues of traditional intranet access, such as complex operations, poor security, high latency, and low speed. This solution is suitable for collaboration scenarios between intranets and the internet in industries, university teaching/research resource access, enterprise mobile office applications, hospital intranet access, and online inspections in industrial parks in scenarios such as education, government services, healthcare, and manufacturing.

4.Bangladesh 5G Application Evolution Path

Based on the international 5G application development experience and Bangladesh's current development situation and requirements, this report provides 5G ToC, 5G ToH, and 5G ToB application promotion suggestions.

4.1 5G ToC Application

4.1.1 5G ToC Application Analysis in Bangladesh

Right now, numerous 5G personal applications are developed and commercialized after 5G network commercialization. In work and study area, low latency online-meeting, remote cooperation, HD online class and various AR/VR/XR meeting already participate in daily work and study. Live shopping, AR map and Live calling are also starting commercialization in some area. Entertainment such as UHD gaming, video, cloud gaming and VR guidance has been widely acknowledged.

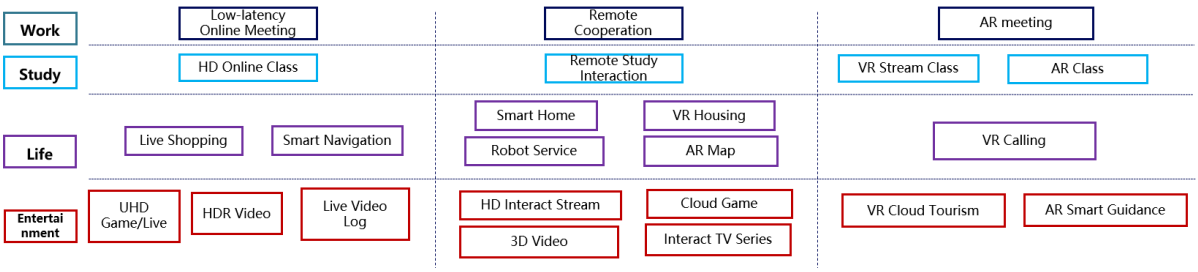


Figure 19 5G ToC Applications

Based on software and hardware innovation, 5G personal applications can be divided into three types including traditional video-based upgrade applications, new interactive applications, and XR-based immersive applications. **Traditional video-based upgrade applications** are traditional video applications such as short video, long video, and webcast. Based on the transmission capability of 5G networks, specific technologies are improved to optimize user experience, including high dynamic range (HDR) video, high FPS video, and HD video. **The new interactive applications** are based on smartphone terminals and innovate at the software

level. Compared with traditional video-based upgraded applications, users can interact with the application content by various ways. New interactive applications emphasize interactive experience and have high requirements on latency. The large bandwidth and low latency capabilities of 5G networks play a critical role in their development. **XR-based immersive applications** are created based on new terminals such as AR/VR, which change the current human-computer interaction mode of "human-mobile phone" and give users a truly immersive experience. Currently, global AR/VR applications have been explored and trialed, such as AR holographic video, AR bicycle, and VR live game viewing. Currently, the application fields are mainly in entertainment, industry, cultural and tourism, and medical industries.

Bangladesh has a good smartphone penetration rate, providing a good hardware and user base for promoting 5G applications. In recent years, the number of mobile phone connections in Bangladesh continues to grow. Indicated in Figure 20, according to GSMA data[17], Bangladesh cellphone connection keep increasing, reaching 183.06 million in 2023. Among which, smart phone connections reach 104.19 million, meaning 57% connection is from smart phone. In network, according to Speedtest data[18], Bangladesh mobile speed rank 89 globally, reaching download speed 27.76Mbps and upload 11.22Mbps. This 4G service can only meet limited requirements of HD video and limited service of classic application upgrade. In application area, even small screen smartphone is still most popular cellphone type in Bangladesh, video service is rapidly developing. Digital 2024: Bangladesh Report from Datareportal[19] show TikTok had 37.36M users aged 18 and above in Bangladesh in early 2024. TikTok ads reached 31.1 percent of all adults aged 18 and above in Bangladesh at the start of 2024. Overall, Bangladesh has a firm foundation of 5G HD video service and will rapidly develop forward with suitable guidance by government.

[17] GSMA database https://data.gsmaintelligence.com/data

[18] SpeedTest Global Index August 2024

[19] Datareportal Digital 2024: Bangladesh https://datareportal.com/reports/digital-2024-bangladesh

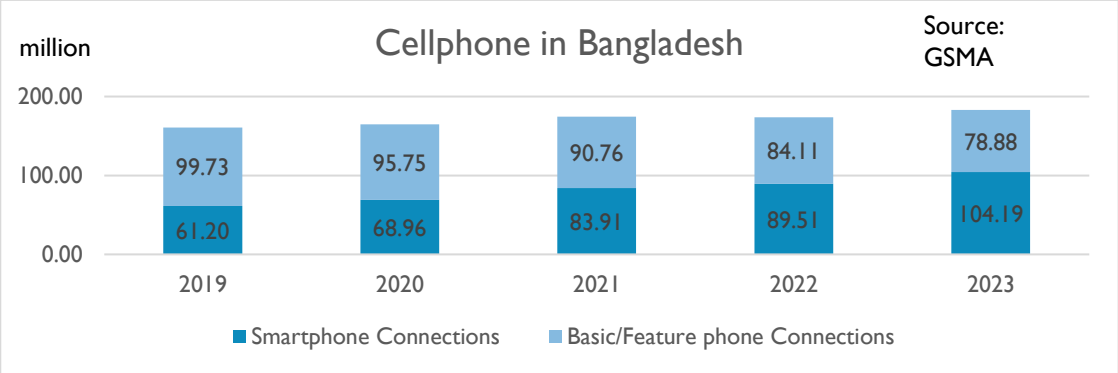


Figure 20 Bangladesh Cellphone Connections since 2019

4.1.2 Bangladesh 5G ToC Application Evolution Path

According to the current consumer application situation and industry development requirements of Bangladesh's consumer-grade market, it is suggested that Bangladesh's 5G consumer-grade applications be divided into a "three-step" development strategy of experience optimization innovation, interactive application innovation, and new terminal innovation.

- Phase 1

The first stage focuses on traditional application upgrade. This phase is estimated to be from 2025 to 2026. For mature applications developed in 4G, such as video applications, technology upgrade or optimization services will be performed based on 5G network features to improve user experience.

- Phase 2

The second stage is the new interactive application stage. This phase is estimated to be from 2025 to 2028. Based on the current mainstream smartphone terminals, innovative application models are used to meet the interaction requirements of users and application content and provide semi-immersive experience.

- Phase 3

The third stage is the new terminal innovation stage. At this stage, it is estimated that the outbreak will begin after 2029. As new terminal technologies such as AR/VR gradually mature

and the penetration rate increases, innovative applications based on 5G+new terminals will bloom on a large scale, revolutionizing the existing human-computer interaction mode.

4.2 5G ToH Application

4.2.1 5G FWA Service

5G ToH applications aim at the smart home market and provide smarter, high-speed, and prosperous home services for family life. Fixed Wireless Access is the most widely used service. Since the 4G era, mobile operators have gradually transitioned from providing only mobile network services to integrated broadband service providers, including mobile network services, residential broadband services, and commercial broadband services. The FWA service is the use of LTE and 5G networks by mobile operators to provide broadband services to areas where fiber optics cannot be deployed.

A rich FWA market ecosystem has been established. Currently, more than 554 operators in 186 countries provide FWA services and fixed broadband rate level network service. According to GSA statistics[20], the maximum rate of LTE FWA services can reach hundreds of Mbps, and the average maximum downlink rate is 173.3 Mbps. The downlink rate of 5G FWA ranges from 10 Mbps to 5,400 Mbps. The average maximum downlink rate has reached 1,077 Mbps, which is basically the same as that of fixed broadband. This scale and potential market are driven by FWA outstanding expectations. By 2023, the FWA data traffic will reach 30.3 EB/month, close to 19% of the world's mobile data traffic, and the number of FWA connections will reach 131 million. According to Ericsson's forecast[21], FWA data traffic will reach 159.3 EB/month by 2029, an increase of 525% compared with 2023. During the same period, global data traffic will grow by 351%. The number of FWA connections will reach 330 million. 5G FWA accounts for 83.6% of the FWA connections, and 2G/3G/4G FWA connections are only 16.4%.

[20] GSA: Fixed Wireless Access November 2023

[21] Ericsson Mobile data traffic outlook https://www.ericsson.com/en/reports-and-papers/mobility-report/dataforecasts/mobile-traffic-forecast

4.2.2 5G FWA Service Foundation in Bangladesh

The FWA service is an important part of Bangladesh's national network construction. Fixed network, especially fiber optical network, requires large investment in infrastructure and it cost more when considering FTTH. And this led to slow development of fixed broadband network in Bangladesh. According to world bank data[22], by 2022, the fixed broadband network subscriber per 100 people only reached 6.9 while mobile network subscribers reached 105.3. Meanwhile, fixed internet service in Bangladesh is also poor. According to Speedtest Global Index August 2024 data, the fixed network speed is around 48 Mbps level for both downlink and uplink, which rank 101 globally. Fixe broadband network status indicate Bangladesh fixed broadband network service is very inadequate and insufficient in Bangladesh.

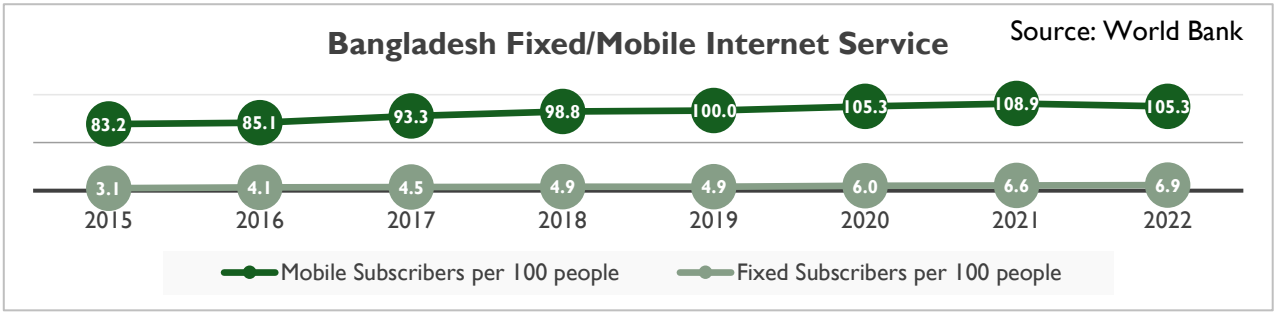


Figure 21 Bangladesh Fixed/Mobile Internet Service Subscribers per 100 People since 2015

Compared with fixed broadband, FWA has the following advantages: more flexible and not restricted by geographical and building conditions; The deployment speed is fast, and high-speed network access can be achieved almost instantly. Compared with the large-scale investment in fiber to the home, FWA is more cost-effective. According to GSMA analysis, FWA Service could provide fiber-level internet service with up to 80% cost saving, largely promote broadband service large-scale deployment and meet the requirement of full connectivity vision. Therefore, the extensive promotion of FWA service construction is an important part of Bangladesh's national network construction.

4.2.3 5G FWA Evolution Path in Bangladesh

[22] World Bank data https://data.worldbank.org/indicator/IT.CEL.SETS.P2?end=2022&locations=BD&start=2016

Considering efficiency and requirement of each vertical industry application, a vertical industry application deployment list given.

- Phase 0

Piloting in 2025, while still promoting legacy 4G FWA service, start 5G FWA commercial trail in large cities like Dhaka and Chattogram.

- Phase 1

Start 5G FWA commercial launch in Top 2 cities. FWA penetration rate reach 1% by 2026.

- Phase 2

Start 5G FWA commercial launch in Top 20 cities. FWA penetration rate reach 10% by 2028.

- Phase 3

Start 5G FWA commercial launch national wide in Bangladesh. FWA penetration rate reach 20% by 2030+. Initiate 5G-A based FWA^2 upgrade.

4.3 5G ToB Application

By generally analyzing market prospect, pain point, outcome of Bangladesh vertical industries, this report obtains pioneer vertical industries suit Bangladesh 5G application develop most: Smart City, Smart Medic, and Smart Agriculture.

4.3.1 5G+Smart City

4.3.1.1. Industry Analysis

The government of Bangladesh attaches great importance to the development of smart cities. Bangladesh release National Information and Communications Technology Policy in 2018 and build 7th largest national data center in 2021, jointly provide strong foundation of smart city. Dhaka South City Corporation (DSCC), one of the two municipal corporations in Dhaka, is committed to transforming Dhaka into a smart city. This includes managing solid waste, roads, sidewalks, dividers, street lights, markets, traffic signals, parks, playgrounds, cemeteries,

community centers, sports complexes, libraries, mosquito control, food hygiene, prevention and control of infectious diseases, disinfection efforts, and urban beautification projects.

In the traditional construction of smart cities in Bangladesh, several issues exist:

1. Infrastructure underdeveloped: Urban infrastructure development is relatively backward, with poor conditions in streets, drainage systems, information technology facilities, healthcare systems, and educational facilities. Highly developed infrastructure is necessary for the construction of smart cities, and current infrastructure poses difficulties in attracting investment and enhancing productivity.

2. Financial support: Smart cities involve not only technology but also electricity, water, transportation, and waste management etc, which require significant financial support. The current government budget and resources are insufficient to meet the growing demands of the large population, and measures need to be taken to stimulate investment from other sectors.

3. Urgent demands for urban security management: The government has an urgent demand for urban security management, especially in terms of personal safety, property safety, and vehicle safety. Currently, comprehensive linkage between perception, monitoring, and emergencies are not achievable, and the government lacks data support. The requirements to rely on digital technology to continuously enhance governance capabilities is very urgent.

The 5G network's large bandwidth, low latency, high reliability, and wide connectivity can accelerate industrial digital transformation and innovative business models. Smart city applications are diverse and have different requirements for network performance across various industries. The 5G network can provide customized network services through slicing technology and edge computing technology to meet user requirements. 5G can provide intelligent solutions for various applications such as smart security, smart transportation, smart environmental protection, and smart government affairs, thereby promoting industrial transformation, generating new businesses and forms, and improving the level of urban management, public service quality, and residents' quality of life in Bangladesh.

4.3.1.2. Typical 5G Application Scenario

1. 5G+Ultra HD Real-time Monitoring

Deploying 5G ultra HD cameras and panoramic cameras in cities, real-time transmission of collected data to a data center through 5G networks enables 3D monitoring. Combining this with AI and visual analysis technologies achieve intelligent identification and early warning, improving urban security efficiency.

2. 5G+Robot Patrol

Robots with multiple HD cameras to capture environmental videos, real-time transmission of these videos to edge and cloud platforms through 5G networks, and utilizing algorithms for facial and behavioral recognition assist the police in improving inspection efficiency and maintaining public safety.

3. 5G+Drone Patrol

Drones equipped with ultra-HD cameras transmit collected images and data information in real-time to the command center through 5G networks, providing staff with immediate on-site information and improving work efficiency.

4. 5G+AR Glasses Patrol

Law enforcement officers wearing 5G AR glasses capture facial image information, which is transmitted in real-time to an edge platform through 5G networks. Combining this with AI algorithms can compare the high-definition facial data captured by the glasses with a blacklist, enabling the timely identification of suspicious individuals and improving law enforcement timeliness.

5. 5G+Drone Environmental Monitoring

Drones equipped with 4K/8K ultra-HD cameras transmit HD video to management platform in real-time through 5G networks, enabling real-time monitoring of air, soil, water, and other

pollution conditions, achieving "no dead corner" inspection, improving inspection efficiency, and ensuring environmental protection in parks.

6. 5G+Smart Bus

Buses equipped with HD cameras, radars, and other sensors transmit collected data in real-time to edge/cloud platforms through 5G networks. Combining this with AI algorithms provides warnings for lane departure, forward collision, blind spot monitoring, etc. Generating driving models based on driving behavior allows for the analysis of drivers' driving skills, speed, safety factors, etc., improving bus safety management efficiency.

7. 5G+Digital Twins

Achieving comprehensive perception and intelligent interconnection of cities through technologies such as 5G and AI. Building a virtual reality space of the city based on BIM modeling, GIS maps, 3D modeling, etc., constructing a digital platform for the city that coordinates information resources to achieve global management and collaborative linkage within the city.

4.3.1.3. Suggestions

The urbanization process in Bangladesh is accelerating. With a total area of 1,47,570 square kilometers and a population of 170 million, approximately 25% of Bangladesh's population currently lives in urban areas. More than half of the urban population resides in eight major cities/regions, including Dhaka, Chattogram, and Khulna.

Dhaka, the capital of Bangladesh, serves as the political, economic, and cultural center of the country. The Dhaka South City Corporation (DSCC), one of the two municipal corporations in Dhaka, is committed to transforming Dhaka into a smart city by exploring improvements in various areas such as solid waste management, street lighting, markets, traffic signals, parks, playgrounds, cemeteries, community centers, gymnasiums, libraries, mosquito control, food hygiene, infectious disease prevention and sterilization work, and beautification of the cityscape.

At the same time, Dhaka is actively introducing advanced technologies to achieve intelligent urban management.

Chattogram, located on the northeast coast of the Bay of Bengal, is Bangladesh's largest port city and the second-largest city in the country. In 2022, the registered population of Chittagong exceeded 8 million. Chittagong accounts for 12% of Bangladesh's GDP, 80% of international trade, 40% of industrial output, and 50% of tax revenue. With the acceleration of urbanization, Chittagong City is also actively advancing the construction of smart cities to improve urban management efficiency and residents' quality of life. The city has already taken a series of measures such as improving infrastructure, promoting smart grids and renewable energy technologies, which provide a certain basis of experience for the development of 5G+Smart City.

In summary, both Dhaka and Chattogram are at the forefront of smart city development in Bangladesh. Through ongoing initiatives and technological advancements, these cities are striving to enhance urban living standards and management capabilities for their growing populations.

4.3.2 5G+Smart Agriculture

4.3.2.1. Industry Analysis

The economy of Bangladesh is primarily based on agriculture, with agricultural output accounting for approximately 25% of the country's GDP. Currently, the agricultural sector in Bangladesh is advancing towards agricultural informatization, exploring various aspects such as agricultural information platforms, mobile payments and financial services, agricultural IoT applications, agricultural e-commerce, and agricultural education and training. The application of digital technologies begins to use to monitor soil moisture, temperature to optimize crop cultivation conditions and improve agricultural productivity. However, the development of the integration of digital economy and agriculture is still in its experimental phase. With the continuous advancement of technology and the development of the digital economy, the

integration of agriculture and digital technology in Bangladesh will continue to progress, presenting significant development opportunities and potential in the future.

In the development of agriculture in Bangladesh, there are several challenges:

1. Traditional farming still relies heavily on manual labor, resulting in a lack of digitalization and low overall productivity.
2. Large agricultural parks and numerous terminal devices make it difficult to maintain traditional intelligent wired networks.
3. The sales path for agricultural products is limited, with low sales volume and low popularity.

5G technology, with its high-speed rates, low latency, and large number of connections, can bring new changes to agriculture by enabling intelligent and efficient agricultural production. Firstly, 5G can improve agricultural productivity by enabling farmers to achieve precise agricultural management, enabling more scientific planting, fertilization, and irrigation, reducing agricultural production costs and improving the quality of agricultural products. Secondly, 5G can promote agricultural technological innovation by allowing researchers to monitor field environmental parameters in real-time, providing richer data support for agricultural technological innovation. Thirdly, 5G technology provides strong support for rural infrastructure construction by accelerating broadband network coverage in rural areas to provide more convenient information services for rural residents. Additionally, 5G technology can provide infrastructure support for emerging industries such as IoT and smart agricultural equipment in rural areas, promoting the rapid development of rural agriculture.

4.3.2.2. Typical 5G Application Scenario

1. 5G+ Agricultural Product Live Streaming

5G's large bandwidth and low latency characteristics, along with the increasing number of platforms and applications, enable the incubation, support, and cultivation of a large number of rural live streamers. New models such as farmer anchors, live streaming of agricultural products, e-commerce of agricultural products, and agriculture subscription are constantly growing.

Through 5G technology, the production and sales process of agricultural products can be live streamed to consumers in real-time. Consumers can gain insight into the growth process and harvest timing of agricultural products through live streaming, increasing willingness to purchase. Meanwhile, the live streaming links provide convenient online purchase channels for consumers. By conducting activities such as 5G-assisted live streaming for farmers and 5G harvest festivals on e-commerce platforms, new promotion and revenue channels can be opened for farmers, supporting rural revitalization.

2. 5G+Agricultural Data Collection

Based on 5G's wide connectivity, various environmental data such as air temperature and humidity, light intensity, soil temperature and humidity, and CO2 level can be collected in real-time by connecting various sensors, HD cameras, and infrared cameras to the 5G network. Combined with AI and big data technologies, a data model of the entire crop growth process can be constructed to enable unmanned agricultural monitoring. After platform analysis of collected data, the occurrence of pests and diseases and extreme weather conditions can be predicted, reducing agricultural production losses. Additionally, by sending data to the command center, plant protection operations such as spraying, irrigation, and fertilization can be arranged.

3. 5G+Unmanned Aerial Vehicle (UAV)

The high-speed and low-latency characteristics of 5G technology enable UAVs to perform filed operating tasks more stably and efficiently. UAVs equipped with high-spectral cameras, laser cameras, high-definition cameras, infrared cameras, and visual sensors can capture images and collect data on crop yield, soil irrigation capacity, pest occurrence, and crop growth. The collected data is uploaded to the cloud platform via the 5G network. Through image processing and video processing in the backend, route planning and environmental information recognition are formed. Control information is transmitted to the control platform via the 5G network to quickly identify crop pests and diseases and accurately apply pesticides and fertilizers, improving the quality and efficiency of plant protection operations.

4. 5G+Agricultural Machine Remote Control

5G technology enables remote control and autonomous driving of agricultural equipment, improving the level of automation in agricultural production. The high bandwidth and low latency of 5G meet the requirements for autonomous driving, precise operations, real-time video transmission, and multi-vehicle coordination. By installing an autonomous driving system on agricultural machinery, full automation from cultivation to harvesting can be achieved, including seeding and transplanting. This application scenario can improve farmers' work efficiency and agricultural productivity compared to traditional mechanical operations.

5. 5G+Agricultural Product Traceability

By installing sensors at various stages of agricultural product production, processing, transportation, and sales, the quality and safety status of agricultural products can be monitored in real-time. Through the 5G network, these data can be transmitted to consumers in real-time, allowing them to understand the production information of agricultural products. Additionally, by combining blockchain technology and utilizing 5G's high reliability, agricultural product data can be uploaded to a distributed blockchain platform in real-time. This not only provides better security for user information and data exchange on the platform but also enables end-to-end value circulation, eliminating intermediate distribution costs.

4.3.2.3. Suggestions

It is recommended that Bangladesh carry out pilot applications of 5G+ smart agriculture to promote innovative applications of 5G technology in the field of smart agriculture. Initially, it is suggested to focus on promoting simple 5G application scenarios, such as 5G+ live streaming of agricultural products for direct sales, 5G+ ultra-high-definition video surveillance, and 5G+ collection of agricultural environmental data. Later, moderately promote integrated applications such as 5G+ pest and disease identification, remote automatic irrigation, and automatic feeding. Finally, scale up the promotion of smart scenarios to achieve transformative applications in unmanned farms.

4.3.3 5G+Smart Medic

4.3.3.1. Industry Analysis

By end of 2022, there were 5816 hospitals registered with Bangladesh Directorate General of Health Services (DGHS), of which 255 were public hospitals. The Bangladesh Medical & Dental Council (BMDC) registered 84,364 doctors, of whom 24,031 served in public hospitals, accounting for 28% of the total number of doctors. Public hospitals have lower costs but poorer medical conditions and can only treat common diseases. Private hospitals have better conditions but are very expensive.

The medical and pharmaceutical industry in Bangladesh still faces some challenges. First, the distribution of medical resources is uneven, with relatively well-equipped facilities in urban areas but weaker medical services in rural areas. Second, Bangladesh faces a shortage of medical talent. The current number of doctors and nurses is still insufficient to meet the growing demand, and further improvements are needed in medical education and training.

5G technology has characteristics such as high speed, low latency, and wide connection numbers. By integrating with big data, AI, cloud computing, and other technologies, it can enhance the digitization and intelligence level of healthcare. In the pre-diagnosis stage, through the 5G network of smart ambulances, medical equipment monitoring information, real-time vehicle location information, and video footage inside and outside the vehicle can be transmitted in real-time. Medical staff can conduct remote consultations and remote guidance, collect, process, store, transmit, and share pre-hospital emergency information, fully improving rescue efficiency and service quality while optimizing service processes and models. In the diagnosis stage, utilizing the massive connectivity of 5G, a hospital's medical IoT network can be constructed to organically connect a hospital's massive medical equipment and non-medical assets. This enables services such as hospital asset management, emergency dispatch within the hospital, management of medical staff and equipment status, access control and security, real-time patient monitoring, and in-hospital navigation, improving hospital management efficiency and patient experience. In the post-diagnosis stage, relying on 5G's low latency and precise

positioning capabilities, wearable monitoring devices can continuously report patient location information and securely and reliably transmit medical data to a remote monitoring center. Remote medical staff can make timely condition assessments and treatments based on the patient's current state in real-time.

4.3.3.2. Typical 5G Application Scenario

1. 5G+Remote Medical Consultation

This scenario utilizes 5G's large bandwidth and low latency to enable real-time transmission and interaction of large-volume imaging data such as patient pathology, CT scans, and ECGs, as well as 4K HD image information. It supports the provision of multidisciplinary remote real-time consultation services for patients with complex diseases at local hospitals, providing efficient assistance for frontline rescue work.

2. 5G+Remote Surgical Teaching

In this scenario, remote surgical equipment is deployed in the operating rooms and demonstration rooms of local hospitals. 4K ultra-HD surgical process images and data such as ultrasound and endoscopy are transmitted in real-time over the 5G network. Experienced doctors on the remote side can remotely control or guide local doctors based on real-time data. Additionally, the surgical process is broadcast online for other local hospitals to observe and learn, enabling real-time interaction between experts, local doctors, and other trainees.

3. 5G+Pre-hospital Emergency Care

5G-enabled standard ambulances integrate data from various devices such as multifunctional physiological monitors, ultrasound, and HD video consultations to achieve seamless connectivity between pre-hospital and in-hospital data. Real-time HD video communication between in-hospital experts and medical staff in the ambulance enables real-time tracking of patient status. This helps emergency doctors prepare for emergency rescue and surgery in the first instance. By bringing remote consultation, remote ultrasound, and monitoring indicators

that were previously only available in fixed locations to the ambulance, significantly enhancing pre-hospital emergency care capabilities.

4. 5G+Remote Ultrasound

Traditional remote ultrasound is operated by local doctors, and the diagnostic effect depends on professional manipulation techniques. Remote experts can only diagnose through ultrasound image videos but cannot perform inspections independently, resulting in suboptimal examination results. In this scenario, a robotic arm is mounted on the ultrasound probe at local hospitals, and medical equipment is connected to a 5G network. Based on the millisecond latency of the 5G network, real-time transmission is returned to the control room of the remote guidance hospital. Doctors can remotely control the robotic arm and conduct remote ultrasound examinations in real time. This scenario not only enables counterpart assistance and support between superior and subordinate hospitals and in remote areas but also enhances local medical service capabilities.

5. 5G+Umanned Delivery

This scenario relies on an unmanned business platform to achieve multi-category 5G terminal access for mobile medical robots, disinfection robots, unmanned logistics vehicles, and indoor delivery robots. Simultaneously, with the deep empowerment of 5G+Positioning technology, 5G intelligent terminals can achieve precise controllability, efficiently supporting personnel management and material distribution inside and outside the cabin. For example, a 5G mobile medical robot combines temperature monitoring with a traffic management system to perform non-contact temperature detection on incoming and outgoing personnel without perception, leaving a trace for access management personnel, and providing information inquiries to meet the needs of zero contact throughout the process and remote deployment. This achieves a localized closed loop for sensitive information such as facial recognition and ensures data security.

6. 5G+Remote Monitoring

Medical monitoring applications require real-time, continuous, and prolonged monitoring of patients' vital signs which require doctors to follow real-time ECGs, breathing patterns, blood oxygen levels, and other physiological signal sampling waveforms, parameter values, and alarm information. The timeliness of transmitting and reporting patients' vital signs and crisis alarm information determines the efficiency of patient treatment. 5G-based wireless medical monitoring reduces the need for connecting monitoring devices to medical sensors, allowing patients under monitoring to have more space of movement. In addition to providing doctors with more accurate measurement indicators, it also allows many medical tests to be completed on hospital beds, greatly facilitating patient visits and doctors' remote monitoring. Wireless monitoring significantly enhances hospital's modern information management and improves doctors' efficiency. Its high flexibility and scalability enable patients far from hospitals or other healthcare institutions to receive necessary medical monitoring at any time and consult with remote doctors when necessary.

4.3.3.3. Suggestions

It is recommended to support the selection of medical institutions in Bangladesh with pilot conditions to carry out 5G+Smart Medic piloting application. Initially, applications such as 5G+Remote Monitoring and 5G+Unmanned Delivery should be explored, and existing wireless or wired networks should be replaced with 5G to utilize its high bandwidth and extensive connectivity. Second, applications such as 5G+Remote Consultation, 5G+ Remote Ultrasound, and 5G+Pre-hospital Emergency Care should be explored to enable real-time voice and HD image communication, using remote Medicare to improve the efficiency of medical level in remote areas. Finally, applications such as 5G+Remote surgical Teaching and 5G+Remote Surgery should be implemented to achieve real-time human-machine interaction of tactile and visual information, allowing doctors to have an immersive feeling when operating remotely, making surgeries faster, more stable, and more accurate, addressing the issue of uneven medical resources across regions.

4.3.4 5G ToB Vertical Industry Promotion Summary

Combine 5G vertical industries characteristics and 5G application requirements level of Bangladesh pioneering industries, this report proposes Bangladesh 5G ToB industry application deployment priority:

- Phase 0

Priority deploy 5G+Smart Medic piloting project in Evercare Hospital in Dhaka before 5G commercialization to rapidly popularize the characteristics of 5G+Application to public.

- Phase 1: 30+ 5G+ Projects by 2025

Start 5G+Smart City project in Dhaka and Chattogram. Priority deploy 5G+Government Message service to utilize richer and colorful contents to enhance government influence;

Start 5G+Smart Agriculture. Priority deploy 5G+Sales Live Streaming service to effectively improve the sales of agricultural products;

- Phase 2: 200+ 5G+ Projects by 2028

Start 5G+Smart Medic service in Top 20 hospital. Priority deploys 5G+Remote Monitor and 5G+Ummanned Deliver service to improve Medicare efficiency and increase patience experiences;

Start 5G+Smart City project in Top10 cities. Priority deploy 5G+HD Video Monitor service, ensuring the safety of residents and tourists;

Start 5G+Smart Agriculture in most provinces. Priority deploy 5G+Agriculture Camera to ensure agricultural growth with digital technology;

Start 5G+Integrated Pilot Application, including 5G+Smart Harbor, 5G+Smart Education, 5G+Smart Manufacturing etc;

- Phase 3: 1000+ 5G+ Projects by 2030+

Start 5G+Smart City project in most cities and towns;

Start 5G+Smart Manufacturing in most manufacturing industries;

Start 5G+Smart Agriculture in all provinces and extended to villages level;

Start 5G+Integrated Scale Application, including 5G+Smart Harbor, 5G+Smart Education, 5G+Smart Manufacturing, 5G+Smart Electrical, 5G+Digital Ocean, 5G+Low-altitude Economy etc.

5.Bangladesh Mobile Network Suggestion

Based on the advanced experience in 5G exploration in major countries/regions around the world, this chapter provides short-term, mid-term and long-term development suggestions for Bangladesh's 5G development, and provides relevant suggestions for industry participants in terms of policies, networks, applications, and industries.

5.1 Short-Term Recommendations (2025-2026)

5.1.1 Policy

Develop the 5G development roadmap. The government should formulate a comprehensive 5G development strategy and plan, and specify the objectives, timetable, road map, and key development areas of 5G network construction. This will help guide industry investment and promote the R&D and application of 5G technologies.

Government departments and external experts jointly set up **the Bangladesh 5G Network and Application Expert Advisory Committee** to guide the decision-making on strategic and forward-looking issues during 5G network construction and application promotion.

Release 5G construction support policies. It is suggested that the government introduce various 5G network construction support policies and encourage telecom operators and related enterprises to increase investment in 5G network construction through financial subsidies, tax concessions, and loan support. Promote the openness and sharing of public facilities and resources, especially office buildings and other public building resources of government at all levels and subordinate units, to reduce the cost of 5G network construction.

Establish a 5G network evaluation mechanism. A 5G network assessment team was set up to comprehensively evaluate Bangladesh's 5G network construction progress, 5G network construction quality, and 5G network service quality through field surveys, carrier reports, and third-party data analysis, so as to ensure that government departments can understand the current situation of 5G network development in real time.

Establish **monitoring mechanism**. It is suggested that the government set up an assessment and inspection mechanism for 5G network subsidy funds, implement the rational use of special funds, and solve the problems existing in the process of using and allocating funds.

5.1.2 Networks

With spectrum auction, allocate 3500MHz and 700MHz to MNOs for both deep coverage and wide coverage. **Allocate a total of 360 MHz spectrum from 3340 to 3700 MHz** to four mobile operators. If the bandwidth is allocated to four operators, refer to the 100 MHz bandwidth for each of the three operators and 60MHz for one remaining operator. Allocate 2 45MHz bandwidth spectrum in 700MHz frequency point to four operators with each MNO own 10MHz+ bandwidth.

Establish the initial 5G network deployment mode, encourage operators to make full use of the existing 4G core network, **build 5G NSA networks**, and reduce the difficulty and cost of 5G network construction. Promote passive sharing in 5G network construction according to a baseline of two MNOs share one physical site in average while encourage MNO to build individual physical tower under guidance of its business requirement. MNOs are to be encouraged to deploy more In Building Solutions (IBS) and share Distributed Antenna System (DAS) among themselves to ensure faster rollout of 5G indoor services.

5G networks are preferentially deployed in urban hotspots, especially in transportation hubs (airports and ports), hospitals, schools, enterprise campuses, tourist attractions, and shopping malls. 5G networks connect hotspots to achieve continuous coverage in cities. Ensure the appropriate proportion of outdoor macro base stations and indoor distributed systems, promote continuous coverage, and enhance service quality in hotspot areas. For remote areas, strengthen the coverage of key areas such as tourism, and initially establish 5G benchmark demonstration zones for smart agriculture and digital villages.

It is recommended that **the government release 5G network construction indicators, 5G network quality standards, and 5G user penetration rate** to drive operators to improve the scale and quality of 5G network construction at the national level. The 5G network will further

improve the radio access capability of residents. The proportion of 5G users will increase to 10 percent by 2026.

5.1.3 Applications

Encourage carriers and enterprises to upgrade traditional applications and provide HD, HFPS, and HDR video services by upgrading existing video services.

Push operators to deploy FWA services and strengthen broadband network services in areas not covered by optical fibers. Keep legacy 4G FWA commercial launch and start FWA commercial trial in 2025. Start 5G FWA commercial launch in top 2 cities like Dhaka and FWA subscribers penetration rate 1% by end of 2026.

It is recommended that carriers, equipment vendors, and industry enterprises be encouraged to **conduct tests and pilot exploration in typical application scenarios** for Bangladesh's advantageous industries such as **smart city, medic, and agriculture**, starting with the **application scenarios of auxiliary production**, such as mobile inspection, and AI video supervision. Based on the 5G industry private network, gradually carry out 5G application incubation. **The number of virtual private networks in the 5G industry has reached 50 by 2026**.

It is recommended that **R&D enterprises and scientific research institutions strengthen R&D** in technical fields such as network slicing, edge computing, and artificial intelligence around the key upstream and downstream links of 5G applications. Encourage ICT enterprises and industry customers to jointly build 5G application joint labs to carry out 5G industry applications and 5G network tests, verification, and R&D commissioning.

5.2 Mid-term Recommendations (2027-2029)

The mid-term goal is to build a 5G network that basically covers the whole country and promote the commercialization of 5G applications.

5.2.1 Policies

Strengthen the policy of 5G construction and provide **policy incentives and financial subsidies** to operators with leading network construction progress. Set up special funds to subsidize operators to enhance 5G network coverage in rural areas.

Release 5G application development policies and establish guideline. Jointly launch the application implementation plan with multiple departments. Continue to guide local governments to formulate 5G network and application development policies based on their local industry characteristics.

It is suggested that the government convene all parties in the industry to **establish a 5G application development alliance and build a 5G application industry platform** to jointly promote the development of 5G technologies and industries and provide opportunities for both supply and demand sides. It is recommended that 5G industry application white papers and cases are released regularly to attract more vertical industries to learn about 5G. Encourage vertical industry requirement research based on the 5G Application Development Alliance, as well as 5G application industry promotion path and 5G application scenario research. In addition, it is recommended to build an international cooperation mechanism for 5G application alliances, build a bridge for sharing industrial ecosystem, and complement each other's advantages.

Encourage the government to **hold a nationally influential 5G application competition**, select 5G application projects that can be replicated and promoted, and use them as typical examples to promote the large-scale development of 5G To B applications.

5.2.2 Networks

Re-farming 2.1GHz and 2.6GHz after precisely evaluation and testing to further improve the usage of spectrum resources and improve the deep coverage capability in hotspot areas.

Continuously enhance the 5G NSA network construction mode and improve 5G network coverage. Deploy SA networks in 5G application scenarios to provide uRLLC and mMTC services for industrial users and explore industry requirements.

Promote full coverage of 5G networks in urban areas and extend them to rural areas, and eventually achieve full coverage of 5G networks in cities and basic coverage in rural areas. Strengthen the deep coverage of 5G networks in hotspot areas, increase the proportion of indoor distributed systems, and ensure network service quality. Track the released 5G network construction indicators and 5G network quality standards, and continuously improve 5G network quality. Finally, the proportion of 5G users will reach 30% by 2029.

5.2.3 Applications

Encourage operators and enterprises to **develop new 5G interactive application services**, such as new 5G calls, cloud gaming, and mobile AR/VR services, and further expand related enterprise services.

Continuously promoting the **coverage of FWA services in small and medium size towns** as well as **remote areas**. Promote 5G FWA commercial launch in top 20 cites of Bangladesh and FWA subscribers penetration rate reach 10% by 2029.

Encourage the promotion of 5**G piloting applications in leading industries such as cities, tourism, manufacturing, and agriculture**, and gradually apply 5G technologies to core process of the industry. Other industries apart from the leading industries (like healthcare, education, and ports), 5G integrated applications are to be explored regarding industry requirements. And based on the exploration experience in the leading fields, the application scenario promotion path is studied to promote the application and implementation of 5G applications in more diverse industries. T**he number of virtual private networks in the 5G industry will reach 500 by 2029.**

Encourage ICT enterprises and industries to **conduct joint research on 5G ToB industry application standards**, such as the adaptation of 5G performance to vertical industry network requirements. It is recommended to build a cross-industry R&D platform for 5G applications and encourage R&D enterprises and research institutions to carry out R&D and technical verification of lightweight virtual private network devices, low-cost and simplified module

terminals, and 5G application solutions in the 5G industry, laying a foundation for 5G application development.

5.3 Long-Term Suggestion (2030+)

The long-term objective is to build 5G deep coverage networks, promote large-scale deployment of 5G applications, and build a healthy industry ecosystem.

5.3.1 Policies

It is suggested to **build a systematic 5G policy promotion system**. 5G converged applications have cross-industry and cross-domain technologies and industry attributes. It is recommended to build a multi-dimensional policy system for collaborative promotion of industries from the national, industry, and local government levels and strengthen policy implementation.

It is suggested that the **government strengthen the training for local 5G application talents** in Bangladesh and create more 5G application talents.

5.3.2 Networks

It is recommended to study the requirements of public service networks and vertical industry networks, and allocate spectrum resources, such as 4.9 GHz, 6 GHz, and millimeter wave spectrum, to operators as required.

Promote the construction of 5G SA networks on a large scale. By building 5G core networks, we will provide true 5G services and provide a network foundation for the large-scale deployment of 5G applications across industries.

5G network continues to extend to rural areas and achieve full coverage of Bangladesh's 5G network. Deep coverage of 5G networks in cities. Continuously enhance network capabilities in the future and use 5G-Advanced technologies to enhance 5G network capabilities. By 2035, the proportion of 5G users will increase to over 60%.

5.3.3 Applications

Operators and enterprises are encouraged to develop immersive application services based on **new headset devices and integrate original 5G services** to provide full range of application services for public users.

Promote 5G FWA deployed national wide and reach 20% subscriber penetration rate by 2030+. Utilize 5G-A technology and upgrade FWA to FWA^2 to empower FWA service experience.

Promote the implementation of 5**G applications in cities, medic, and agriculture areas on a large-scale basis,** and explore the commercialization of 5G converged applications in other fields such as **harbor, education, electric power, and ocean**. Finally, achieve large-scale deployment of 5G in all fields. Conduct 5G-Advanced technology experiments for industry applications, such as high-precision indoor positioning, passive IoT, and integrated sensing & communication. Explore the application of 5G evolution technologies in new industry scenarios and form a virtuous cycle of application back-induction technology evolution. The number of virtual private networks in the 5G industry will reach 2000 by 2035.

Promote local vertical **industry application providers, 5G operators, 5G equipment vendors, application development enterprises, and scientific research institutions** to cultivate and incubate a number of excellent industry terminal and application solution providers. Encourage the government to build a database of application solutions and solution suppliers to strengthen the interconnection between supply and demand.

Part II Fixed broadband Network

6.Global Fiber Broadband Development Trends

6.1 Broadband Policies

Universal fiber coverage has become a global consensus，more than 170 countries around the world have released digital nation strategies, and optical network planning and development are important. 15+ countries issued policy or regulation of fiber deployment

In China, the government has been proactive in advancing fiber broadband through the "Broadband China" strategy. This initiative aims to enhance network coverage and service quality, thereby stimulating information consumption and economic growth. Through policy support and financial investment, there has been massive construction and upgrade of fiber broadband networks, particularly in rural and remote areas. Moreover, China has been vigorously promoting the growth of gigabit broadband users, surpassing 163 million by 2023.

The United States is also demonstrating a strong commitment to fiber broadband development. It includes three key funding programs: the Broadband Equity, Access, and Deployment (BEAD) Program, the Middle Mile Broadband Infrastructure Program, and the National Digital Equity Planning Grant Program. These programs are designed to ensure that all Americans have access to affordable and reliable high-speed internet by 2030. Major fiber service providers in the U.S. are actively expanding their fiber networks, with expectations of a significant increase in coverage by the end of 2025.

In Germany, efforts to streamline the approval process for broadband infrastructure and provide subsidies for mobile broadband network development are paving the way for ambitious connectivity goals. The nation aims to extend fiber-to-the-home (FTTH) coverage to over 50% of households and businesses by the end of 2025, with a vision to achieve universal FTTH and 5G service availability for all by 2030.

The European Union's fiber broadband development is progressing at a rapid pace, with the fiber broadband coverage rate in the European market reaching 70%. Between 2021 and 2023,

an average of 23 million additional households gained coverage each year, indicating a swift growth trajectory. Governments across Europe are also backing the expansion and application of fiber broadband through a range of policies and financial support measures.

South Korea unveiled the "K-Network 2030 Strategy," which serves as a detailed strategy under the "Korea Digital Strategy" published in September 2023, focusing on the development of the country's network technology and industry. South Korea plans to prioritize the construction of network infrastructure such as dedicated networks, backbone networks, and undersea cables. In terms of backbone networks, the speed will be doubled by 2026 and quadrupled by 2030 compared to the current rates. Regarding undersea cables, the capacity is set to be increased by 2030, from 200 Tbps in 2022 to 260 Tbps by 2030.

In Vietnam, national policies are steadfastly fostering home broadband growth. The 2020 Information and Communications infrastructure plan sets a target for 100% fiber coverage by 2025, with 90% of households achieving 200 Mbps speeds and urban areas seeing widespread connectivity with an average speed of 1 Gbps. By 2030, the plan envisions all users enjoying access speeds exceeding 1 Gbps. Building on this, the 2024 National Information and Communications Infrastructure Construction Plan by 2050 aims to provide 1Gbps connectivity to all tech parks, IT clusters, and R&D innovation centers nationwide.

The development trend of global fiber broadband is characterized by the following: strong government policy support, continuous improvement in fiber network coverage, ongoing technological innovation, and the growing demand for high-speed broadband services from users. Governments of various countries are formulating ambitious broadband plans and providing financial incentives to ensure their nations' competitiveness in the global digital economy. As technology continues to advance and costs gradually decrease, fiber broadband will be more widely applied and popularized worldwide.

6.2 Networks

Globally, the advancement of network technology is marked by a push towards universal fiber coverage, alongside an acceleration in gigabit connectivity. The “Dual-Gigabit” era represented by 5G and F5G gigabit optical networks. Development of fixed networks, currently entering the gigabit optical network era. This trend underscores the industry's commitment to leveraging strategic investments to achieve expansive broadband penetration with the aim of enhancing internet speeds and reliability.

The development of global broadband networks continues to advance, as of 2023, approximately 5.4 billion people, which is around 67% of the global population, are using the internet, and global FTTx ratio raised from 73% in 2023 to 78% in 2025. But the growth is not balanced. According to the ITU's report, the progress of global internet connectivity is steady but slow in low-income countries, highlighting the gap in the digital divide. Fixed broadband services still account for the dominant share of global internet traffic, at over 80%. However, due to high prices and a lack of infrastructure, there is only one fixed broadband subscriber per 100 people in low-income countries.

Internet usage is increasing worldwide, with about 5.4 billion people using the internet as of 2023, accounting for 67% of the world's population. However, the internet penetration rate in Africa is only 37%, and there is a clear urban-rural gap, with urban residents having a higher usage rate than those in rural areas. The gender digital divide still exists, with 70% of men worldwide using the internet and 65% of women, and women are disproportionately among the global population that does not use the internet.

China stands out in broadband network construction, with 96% of ports being optical ports and over 23 million 10GPON ports, providing gigabit fiber network coverage for more than 500 million households. In addition, China has 636 million broadband users, of which 163 million are gigabit broadband users, and the number of FTTR users has reached 12 million.

Overall, the construction of global broadband networks is accelerating, but more efforts are needed to address`` the unequal access to the internet, especially in low-income and rural areas.

6.3 Applications

Global broadband network development is characterized by a variety of applications and services that cater to different needs across the world. Here's an overview of the current state of broadband applications, development trends, and examples from various countries:

With a focus on fiber-optic infrastructure, China has one of the highest broadband penetration rates globally. Applications like e-commerce, online education, and telemedicine have seen significant growth, and the government continues to invest in network upgrades to support emerging technologies.

In the United States, a blend of fiber, cable, and DSL technologies supports a broad range of applications, from telework and online entertainment to smart home systems, with ongoing government efforts to enhance rural broadband access and network quality.

South Korea, recognized for its rapid internet speeds, boasts a substantial user base that benefits from broadband in gaming, streaming, and technological innovation, standing at the forefront of optical network services which facilitate applications like autonomous vehicles and sophisticated IoT systems.

As part of its digital agenda, Sweden aims to provide high-speed broadband to all households. Broadband is central to applications like smart city development, digital public services, and supporting the country's thriving startup ecosystem. With a focus on rural connectivity.

In summary, the global broadband network application landscape is diverse, with different countries focusing on leveraging broadband to support their unique economic and social needs. As technology advances, the potential for new applications and services continues to grow, driving further development and investment in broadband infrastructure.

7.Technical and Policy Tools to Speed-Up Development of Fiber Broadband Network——China Experiences

7.1 National Broadband Strategy

Broadband network is a strategic public infrastructure for economic and social development. In August 2013, the State Council issued the "Broadband China Strategy and Implementation Plan" to comprehensively promote broadband development and accelerate the construction of the next generation national information infrastructure that is broadband, converged, secure, and ubiquitous. It has become a strategic action program for guiding the country's broadband development. The "Broadband China" strategy specifies that the scope of broadband infrastructure mainly includes: network infrastructure such as 3G/4G mobile communication network and optical network, as well as application infrastructure such as Internet data center (IDC) and content delivery network (CDN). In recent years, with the acceleration of the new round of technological revolution and industry transformation, the development of 5G networks, gigabit optical networks, Mobile IoT, and cloud computing has accelerated, driving the iterative upgrade of broadband infrastructure.

The overall idea of the "Broadband China" strategy follows the law of broadband technology evolution, systematically solves key issues such as broadband network access speed, coverage, and application popularization, strengthens industry development and security assurance, and comprehensively improves the ability to support sustainable economic and social development. By 2015, the medium-term development goals will be achieved. A next-generation national information infrastructure will be initially built to meet the needs of economic and social development. Fiber to the building will be deployed in urban areas and broadband will be deployed in rural areas. The penetration rate of fixed broadband in households will reach 50%, and the penetration rate of 3G/LTE users will reach 32.5%. The broadband access rate in administrative villages reaches 95%, and the broadband access capacity of urban and rural households reaches 20 Mbit/s and 4 Mbit/s. By 2020, the long-term development goals will be

achieved. The gap between the development level of broadband network infrastructure and developed countries will be greatly reduced. People will fully enjoy the economic growth, service convenience, and development opportunities brought by broadband. The penetration rate of fixed broadband households will reach 70%, and the penetration rate of 3G/LTE users will reach 85%. The broadband access rate in administrative villages exceeds 98%. The broadband access capacity of urban and rural households reaches 50 Mbit/s and 12 Mbit/s respectively. In developed cities, the broadband access capacity of some households can reach 1 Gbit/s.

To achieve the above medium- and long-term development goals, the "Broadband China" strategy implements a number of policies and measures, mainly including three aspects: (1) Promoting market vitality: improving laws and regulations, clarifying the legal status of broadband networks as national public infrastructure, and strengthening the protection of personal information and network facilities. Chinese government strengthen the construction of a regulatory system, standardize the competitive environment, open broadband services to private capital, ensure fair access, and strengthen the supervision of the quality of inter-network communication on backbone networks and the measures for inter-network settlement. Deepening application innovation and promoting the opening up of public welfare information; (2) Optimize the network construction environment: Incorporate broadband network construction and reconstruction into the overall planning of urban and rural areas and land use. The broadband network is planned, constructed, and accepted simultaneously with other facilities. Release the FTTH construction standards and incorporate the required investment into the overall estimation. Ensure the right of way for broadband network facilities construction and deepen the joint construction and sharing of network facilities. (3) Support network investment: Increase financial support and improve the compensation mechanism for universal telecommunications services. Chinese government strengthen preferential tax support, improve investment and financing policies, and guide more investment in broadband networks to the western and rural areas.

Relevant central ministries and commissions have taken various measures to promote the implementation of the strategy, and cross-departmental collaboration has promoted the rolling succession of action plans. Over the past three years, the Ministry of Industry and Information Technology, Office of the Central Cyberspace Affairs Commission, and the National Development and Reform Commission have jointly participated in and made overall efforts to accelerate the formation of a national chess game. In March 2021, the Ministry of Industry and Information Technology released the "Dual Gigabit" Network Coordinated Development Action Plan (2021-2023) to promote the coordinated development of 5G and gigabit optical networks. In April 2023, the Ministry of Industry and Information Technology, the Central Cyber Information Office, and the National Development and Reform Commission issued the Implementation Opinions on Promoting the Evolution and Innovation of IPv6 Technology and Application, promoting the creation of an industry ecosystem in which IPv6 technology, networks, device applications, and security are coordinated and mutually promoted. Build new advantages in innovation and development of the next generation Internet. In May 2023, the Ministry of Industry and Information Technology, Ministry of Education, Ministry of Public Security and other 14 other departments jointly issued the "Implementation Opinions on Further Deepening the Sharing of Telecom Infrastructure and Promoting the High-quality Development of "Dual Gigabit" Networks" to further expand the scope of cross-industry sharing and optimize the layout of infrastructure. Improve the level of co-construction and sharing of telecom infrastructure. In October 2023, the Ministry of Industry and Information Technology, the Central Cyber Information Office and other six departments jointly issued the Action Plan for High-quality Development of Computing Infrastructure, focusing on improving the comprehensive supply capacity of computing power, efficient carrying capacity, and flexible support capacity, and continuously enhancing the effectiveness of computing enablement. In September 2024, the Ministry of Industry and Information Technology, the Central Cyber Information Office and other 11 departments jointly issued the Notice on Matters Related to Promoting the Coordinated Development of New Information Infrastructure, focusing on

improving the systematic and coordinated development of infrastructure such as 5G, gigabit optical network, satellite network, artificial intelligence, and computing power.

7.2 Broadband Universal Service

There is an objective gap between rural and urban development. The challenge of broadband network construction in remote rural areas needs government policy support and guidance. The implementation of broadband telecommunications universal service is an important measure to narrow the digital divide between urban and rural areas and is also a common international practice. According to the statistics of the International Telecommunication Union, more than 159 countries and regions around the world have issued national broadband plans, most of which consider universal telecommunications services. The specific forms include the establishment of a universal service fund, the addition of universal service clauses to licenses, cross-subsidization of losses, and reasonable allocation of universal service costs. China has deployed nine batches of universal telecommunications services. So far, it has supported the construction of optical fiber networks in 130,000 administrative villages and 79,000 4G and 5G base stations in rural areas, and has achieved broadband network coverage in all remote villages, islands and border areas. The network coverage level of public service places such as education and medical care has been effectively guaranteed. Primary and secondary schools (including teaching points) across the country have achieved 100% broadband access, and schools that have not been connected have been dynamically cleared. Telemedicine covers all poverty-stricken counties in rural areas and poverty-stricken areas, effectively consolidating basic medical security.

The implementation of universal telecommunications services in China is generally guided by the central government's financial funds, coordinated support by local governments and promoted by enterprises. At present, the central government has invested more than 20 billion CNY to support the construction of optical fibers and 4G and 5G base stations, and has fully mobilized local enthusiasm through regional subsidies. On the one hand, local telecommunications administrations (the vertical management unit of MIIT in each province)

play an important role, organize telecommunications enterprises in each province to promote the smooth implementation of pilot projects in each province, especially the project for broadband access to poor villages, and actively coordinate relevant local departments to incorporate broadband access to poor villages into local poverty alleviation work. Chinese government work together with industrial stakeholders to promote poverty alleviation through the network. On the other hand, Chinese government effectively mobilize the participation of local governments, give priority to supporting areas with strong willingness to develop policies and measures in land requisition, electricity use, planning, and compensation, and specify that the pilot work can be carried out by the province in a coordinated manner, in conjunction with the regular publication of provincial popularity rankings. Promote local governments to pay high attention to it. At the same time, Chinese government always uphold the dominant position of enterprises, fully mobilize the enthusiasm of basic telecommunications enterprises through competitive bidding, and encourage telecommunications enterprises to offer preferential network tariff packages for poor areas and groups. For example, China Telecom has launched low-threshold packages for poor areas in many provinces, which are generally about 20% lower than urban prices. China Mobile offers customers in poor areas an additional amount of traffic or call duration per month. China Unicom gives 30% discount to poor people on the basis of standard tariffs.

Relevant policies and systems have been continuously improved and institutional mechanisms have been continuously innovated to effectively support the effective implementation of the pilot projects for universal telecommunications services. After the approval of the pilot cities, the Ministry of Industry and Information Technology and the Ministry of Finance publicized the list of the pilot cities nationwide, requiring all provinces to publicize the list of the pilot administrative villages in the province, and conducting special inspections on all the pilot provinces in accordance with the principle of "double random and one disclosure". Publicize the inspection results to the public in a timely manner, strengthen the media publicize, and identify problems in a timely manner through supervision by public opinion. To continuously improve the efficiency of policy implementation, the universal telecom service project focuses

more accurately and supports administrative villages (the smallest administrative unit in China). The construction acceptance standards are more clear. Optical fiber network and 4G/5G network signals cover at least major public institutions such as village committees, schools, and health centers. The access capability reaches 12 Mbit/s or higher for fixed broadband and 10Mbit/s for mobile broadband, and the tariff cannot be higher than that in other areas.

7.3 Fiber Infrastructure Planning and Sharing

On December 25, 2012, the Code for Design of Optical Fiber to the Home Communication Facilities in Residential Areas and Residential Buildings and the Code for Construction and Acceptance of Optical Fiber to the Home Communication Facilities in Residential Areas and Residential Buildings were released and formally implemented nationwide on April 1, 2013. The release and implementation of the two national standards for fiber to the home provide the technical foundation and construction basis for the fiber to the home project in residential areas and residential buildings. It is an important foundation for solving the problems of broadband construction in residential areas, promoting the comprehensive realization of fiber to the home in residential buildings, and promoting the co-construction and sharing of communication facilities in residential areas.

The two compulsory national standards for FTTH mainly include three aspects: (1) In the urban areas at county level and above where the public telecommunication network has realized the optical fiber transmission, the communication facilities of newly built residential areas and residential buildings shall be constructed in the FTTH mode, and it is specified that the new residential buildings shall be constructed in the FTTH mode directly in the future. Instead of using copper cables; (2) The design of the fiber-to-home communication facilities in residential areas and residential buildings must meet the requirements of equal access by multiple telecommunications service operators and free selection of telecommunications service operators by users, which is conducive to breaking the monopoly of operation. (3) Underground communication pipelines, distribution pipe networks, telecommunications rooms, equipment rooms and other communication facilities in newly built residential areas and residential

buildings must be constructed and accepted simultaneously with residential areas and residential buildings, and communication facilities must be placed in the same position as water, electricity and gas. Demarcated the real estate development enterprises and operators of the construction of the boundary.

The implementation of the standards still needs to be continuously followed up. Through publicity and training, supervision and inspection, and experience exchange, we need to actively promote the implementation of the two national standards for fiber to the home. At the same time, the central government should take the lead in improving mechanisms, and establish and improve mechanisms for cross-government coordination and cooperation between central government departments and provinces. Construction drawings and design documents review institutions in the design review, all local housing and urban-rural construction departments when issuing construction permits to strictly check; The central government departments guide and promote the establishment and improvement of the FTTH acceptance management mechanism in all localities.

8.Broadband Network Evolution Path in Bangladesh

8.1 Current Status of Broadband Network Development in Bangladesh

8.1.1 Policy Development

In terms of ISP regulatory licensing, there are four types of ISP concessions in Bangladesh: national (allowed to operate anywhere in Bangladesh) and regional. (Permitted to operate within the administrative area of a specific division) 2. County and township/town ISP licenses. In terms of fixed broadband rates, the "minimum speed" of fixed broadband Internet is 20 Mbps according to the decision of the Bangladesh Telecommunications Authority (BTRC), and ISPs unable to maintain the minimum speed standard will not be classified as broadband providers according to the latest decision in November 2021.

8.1.2 Network construction

According to the data provided by BTRC[23], as of October 2024, the total number of ISP and PSTN users in Bangladesh has reached 13.74 million, of which the number was 12.49 million in October 2023, with an annual growth rate of 10%. The total fiber optic deployment has reached 173,845 km, and the total network bandwidth has reached 6,600 Gbps.

In terms of overall traffic, Bangladesh's fixed broadband data traffic has been increasing gradually in recent years. BTRC reports that traffic totaled 7,340 PB in 2019, growing to 11,766 PB in 2021 and 13,271 PB in 2022[24].

In terms of broadband speed, the "minimum speed" for fixed broadband Internet is set at 20 Mbps, according to the BTRC decision, raising the existing official threshold guidelines of 10 Mbps (fixed). According to the latest decision in November 2021, ISPs and mobile operators unable to maintain minimum speed standards will not be classified as broadband or 4G service providers. According to the Speedtest data by August 2024, the average fixed broadband rate

[23] SAPIX-WSRTT/INP-26 Enhancing Digital Transformation in South Asia-Perspective Bangladesh

[24] https://btrc.gov.bd/site/page/347df7fe-409f-451e-a415-65b109a207f5/-

of Bangladesh[25] is 48.14 Mbit/s in the downlink and 47.31 Mbit/s in the uplink, ranking No. 99 in the world.

8.1.3 Competition

Bangladesh has 2,715 ISPs as said by BTRC[23]. According to the "List of the top 20 organizations with the largest IP allocations in Bangladesh" by the DB-IP[26], some major ISPs are Link3, BDCOM, BRACNet etc.

8.2 Network Development Status in Bangladesh

8.2.1 Late Start, Slow Growth

Bangladesh's telecommunications industry started late and initially did not receive sufficient attention from the government, resulting in slow development. It was not until 2009 that the government began to strengthen support for the telecommunications sector through policies and funding, leading to the launch of ADSL services that catered to the actual tariffs of small businesses and residential users. Fiber to the Home (FTTH/B) services were introduced around 2015. However, due to political, economic, and pandemic-related factors, the growth in the number of fixed broadband users in Bangladesh has slowed in recent years, with the penetration rate remaining almost unchanged.

8.2.2 Low Connection Rate, and The Broadband Technology Needs to Be Updated

The fixed broadband rate is low. Take the broadband rate provided by the ISP in Bangladesh as an example. The downstream rate provided by BTCL is from 1 Mbps to 20 Mbps based on DSL and from 5 Mbps to 30 Mbps based on GPON.

8.2.3 Low User Penetration Rate

[25] https://www.speedtest.net/global-index/bangladesh

[26] Internet Service Providers in Bangladesh https://db-ip.com/country/BD

According to BTRC, by the end of October 2024, the number of ISP and PSTN users in Bangladesh was 13.74 million[24]. Fixed broadband subscriptions in Bangladesh was reported at 12.9 million in 2023, according to the World Bank collection of development indicators, compiled from officially recognized sources[27]. Based on the total household number provided by World Bank, 38,294,131, the fixed broadband subscription rate is up to 35.9%. There is still some increment room for development compared with the average rate of 50.04% of Asia-east area according to the data from point-topic[28].

8.2.4 Appropriate service price

There are many ISPs in Bangladesh's broadband telecommunications market, the competition among carriers is not strong and the overall service quality is low. According to the tariff description of Bangladesh telecom operators and service providers, fixed broadband services are quite reasonable. In the fiscal year 2022-2023, the per capita income of Bangladesh is about 270,400 taka/year. For the 10Mpbs lowest limit broadband service, 800 taka/month is calculated[23], which is 3.55% of the average monthly revenue.

8.3 Evolution Path of Broadband Fiber Network

8.3.1 Fixed Broadband Access Technology

The development of fixed networks is driven by service requirements and supported by technology development. Its development has experienced the narrowband era (64Kbps) represented by PSTN/ISDN technology, the broadband era (10Mbps) represented by ADSL technology, and the VDSL technology. The ultra-broadband era (30–200 Mbit/s) and the ultra-100 Mbit/s era (100–300 Mbit/s) represented by the GPON/EPON technology are now entering the gigabit ultra-broadband era represented by the 10G PON technology. ETSI proposes the industry vision of "Fiber to Everywhere" based on the F5G standard group. Three main features of F5G, such as enhanced fixed broadband (eFBB), all-optical connectivity (FFC) and

[27] https://databank.worldbank.org/reports.aspx?source=2&country=bgd

[28] https://www.point-topic.com/post/global-broadband-subscribers-q1-2024

guaranteed quality of experience (GRE), are proposed. The following describes the main fixed broadband technologies.

1. Asymmetric Digital Subscriber Line (ADSL)

A technology that uses the existing telephone transmission line to transmit digital information at a high bandwidth. Its maximum rate is 8 Mbit/s for downstream signals (from the end office to the user) and 1 Mbit/s for upstream signals (from the user to the end office). ADSL can make full use of the existing local copper lines for data transmission, but there are problems such as large distance limit, low rate, large gap between upstream and downstream bandwidth, high line quality, high construction and maintenance achievements, and poor compatibility with more advanced broadband access.

2. Fixed Wireless Access

Fixed Wireless Access (FWA) uses wireless signals instead of physical lines to connect to a home or enterprise network. The FWA provides radio signal coverage through a mobile communication base station, and a user receives signals through a CPE (Customer Premises Equipment, client equipment) installed in a residence or business place, thereby implementing broadband access. The CPE provides both Wi-Fi and wired Ethernet access. With the development of 5G technologies, FWA can provide speeds close to fiber broadband, with peak rates up to Gbps.

3. Optical fiber access network

Optical fiber access network refers to the transmission media between the central office and the user. The main support technology is the passive optical network (PON) technology. A PON system is generally composed of an OLT located at the central office, an ONU located at the user side, and a passive optical distribution network connecting the OLT and ONU. Depending on the distance the optical fiber extends to the user, that is, the location of the optical network unit (ONU), the optical access network has many application forms, including the fiber to the

cabinet (Fiber-To-The Cabinet, FTTCab), fiber to the building (FTTB), fiber to the office (FTTO), fiber to the curb (FTTC), fiber to the home (FTTH), fiber to the village (FTTV).

The following table lists the evolution of PON technologies. The XG-PON technology can be regarded as a direct evolution of the GPON technology. The XG-PON technology and the XG-PON technology can coexist on a same ODN, allowing the network to be upgraded to a higher rate step by step. 10G PON can also be smoothly upgraded to 50G PON. 10G EPON is the next generation technology of EPON. 10G EPON and 10G EPON use the same upstream wavelength and can coexist on the same ODN in TDMA mode.

The PON technology, especially the new generation 10G PON and 50G PON, can provide a bandwidth of up to 10 Gbit/s or even 50 Gbit/s, far exceeding the bandwidth of xDSL and FWA. In addition, PON technology reduces the maintenance cost due to its passive feature. Especially when the number of users increases, the cost per user is lower. Optical splitters enable efficient sharing of optical fiber resources and improve resource utilization. The PON technology supports dynamic bandwidth allocation and provides differentiated service assurance based on different types of traffic. In addition, the PON network is stable and reliable due to low environmental impact. It is recommended that the broadband construction in Bangladesh should be implemented from GPON to 10G PON and then to 50G PON, which can be smoothly transferred and the existing investment can be protected.

Table 8 Evolution of the PON technical standard system

Technical system	**Uplink/downlink rate**	**ITU-T**
First-generation GPON/EPON	1.25G/2.5G	GPON (ITU-T G.984)
Second generation **10G PON**	2.5G/10Gbps 10G/10Gbps	XG-PON/XGS-PON (ITU-T G.987/G.9807)

Third generation 50G-PON	12.5G/50Gbps 25G/50Gbps	50G-PON (ITU-T G.9804)

8.3.2 Bangladesh Broadband Network Construction Roadmap

1. Short-term (2027)

Newly built areas can flexibly adopt the "thin coverage" construction mode that reduces the port ratio and improves the port utilization rate based on the actual market and occupancy rate. Focus on accelerating the reconstruction of densely populated areas, key cities, and hotspot areas with optical fibers. The GPON technology can be deployed based on the existing infrastructure and the technical preference of the operator. According to different scenarios and conditions, the construction route is shown in Table 9.

Table 9 Short-term construction plan

Scenario	Scenario Condition	Construction mode
city	Optical cable resources do not have the conditions for entering the home and do not have the integrated cabling residential.	FTTB
city	Common residential areas where optical cable resources are not available for home access but integrated cabling is available	FTTB or FTTH
city	Residential area with optical cable resources and home access conditions	FTTH
Sub urban	Optical cable resources do not meet the requirements	FTTB

	for home access, and users are concentrated but scattered.	
rural areas	-	FTTV

2. Medium-term (2031)

Deploy the GPON technology for basic broadband coverage and upgrade to the higher-rate PON technology. "Light-in copper retreat" in old areas; Newly built areas adopt the FTTH construction solution. According to different scenarios and conditions, the construction route is shown in Table 10.

Table 10 Medium-term construction program

Scenario	Scenario Condition	Construction mode
City- Existing Connection	FTTB	Upgrade to FTTH
City- Existing Connection	FTTH	Keep or upgrade bandwidth
City-new connection	-	FTTH
Sub-urban	-	New/Upgraded FTTH
Rural- Existing Connection	Existing FTTH	Hold or upgrade bandwidth
Rural-new connection	-	FTTH

3. Long-term (2041)

The PON technology is used for FTTH construction. Select PON technologies at different rates according to user service requirements. The construction route is shown in Table 11.

Table 11 Long-term construction plan

Scenario	Scenario Condition	Construction mode

City- Existing Connection	Existing FTTH	FTTH Speed Up / Upgrade to FTTR
City-new connection	-	FTTH/FTTR
Sub-urban	- -	FTTH Speed Up / Upgrade to FTTR
Rural- Existing Connection	Existing FTTH	FTTH Speed Up / Upgrade to FTTR
Rural-new connection	-	FTTH/FTTR

9.Fixed Broadband Suggestions

9.1 Development Goal

1) Strengthen network capability development for distance education and healthcare, expand network coverage, improve network coverage for primary medical institutions, and promote dedicated network resources to cover Bangladesh of key schools and hospitals.

   In the short term (2027), over 30% of primary and secondary schools will have broadband fiber access, 75% of universities will have broadband fiber access, and 30% of medical institutions will have broadband fiber access. Over 50% of enterprise buildings and campuses have broadband access.

   In the medium term (2031), over 75% of primary and secondary schools will have broadband fiber access, and over 100% of universities will have fiber access. Medical institutions have achieved more than 50% of broadband optical fiber access. Over 80% of enterprise buildings and campuses have broadband access.

   In the long term (2041), over 95% of primary and secondary schools and over 100% of universities will have broadband optical access. Medical institutions have achieved more than 90% broadband optical fiber access. The percentage of enterprise buildings and campuses that have broadband access is 100%.

2) Fulfill the gap between the development of network infrastructure and other countries in the Asia-Pacific region, and fully enjoy the convenience of the network. By 2031, broadband networks will cover both urban and rural areas.

   In the short term (2027), the broadband penetration rate of urban households will reach 30%, and that of rural households will reach 10%. Among them, 80% of urban broadband users have a broadband access capacity of 50 Mbit/s or higher, and 85% of rural broadband users have a broadband access capacity of 20 Mbit/s. The FTTH coverage rate reaches 40%.

In the medium term (2031), the fixed broadband penetration rate of urban and rural households will reach 65% and 30% respectively. The broadband access capability of urban households basically reaches 100 Mbit/s, that of some households in developed cities reaches 300 Mbit/s, and that of rural households reaches 50 Mbit/s. The FTTH coverage rate reaches 85%.

In the long term (2041), we will basically build a broadband network infrastructure that covers both urban and rural areas, provides convenient services, is fast and smooth, and is technologically advanced. The fixed broadband penetration rate of urban and rural households reaches 95% and 80% respectively, and optical networks cover urban households. The broadband access capability of urban and rural households reaches 300 Mbit/s and 100 Mbit/s respectively. The broadband access capability of some households in developed cities can reach 500-1000 Mbit/s. The FTTH coverage rate reaches 100%.

3) Reduce network service tariffs and improve network quality and service experience.

In the short term (2027), for urban household users, ISPs can provide bandwidth services ranging from a minimum of 20 Mbit/s to a maximum of 300 Mbit/s. The high bandwidth tariff does not exceed 8% of the per capita GNI. For rural home users, ISPs can provide bandwidth services with a minimum of 5 Mbit/s and a maximum of 50 Mbit/s. The high bandwidth tariff does not exceed 3% of the per capita GNI.

In the medium term (2031), for urban households, ISPs can provide bandwidth services ranging from 50 Mbit/s to 500 Mbit/s. The high bandwidth tariff does not exceed 5% of the per capita GNI. For rural home users, ISPs can provide bandwidth services ranging from a minimum of 20 Mbit/s to a maximum of 100 Mbit/s. The high bandwidth tariff does not exceed 2% of the per capita GNI.

In the medium term (2041), for urban household users, ISPs can provide bandwidth services with a minimum of 100 Mbit/s and a maximum of 1 Gbit/s. The high-bandwidth tariff does not exceed 3% of the per capita GNI. For rural home users, ISPs can provide bandwidth

services with a minimum of 50 Mbit/s and a maximum of 500 Mbit/s. The high bandwidth tariff does not exceed 1% of the per capita GNI.

9.2 Policies Suggestion

1) Strengthen the top-level design. The Bangladesh Telecommunications Authority (BTRC) introduced a series of policies to support the development of broadband networks and remove existing policy barriers. In the short term (by 2027), the minimum national broadband rate will be raised to over 30 Mbit/s. In the medium and long term (2031), the minimum national broadband rate will be raised to over 100 Mbit/s, and we will strive to reach the second tier (G1 -> G2).

2) Strengthen policy guidance. Encourage operators to invest in PON network construction. Formulate reasonable policies on the use of pipelines and optical networks to reduce carriers' operating costs. Formulate mandatory standards for pre-deployment of optical fibers in residential and commercial areas to improve carriers' construction efficiency. Promote telecom infrastructure enterprises and ISPs to expand fiber networks, especially in urban areas with high demand for high-speed connections. Supports deployment of fixed wireless access in remote areas.

3) Raise the rules for issuing broadband ISP licenses, reduce the number of ISP licenses, and combine and recycle the existing more than 2000 ISP licenses. Mobile operators are allowed to hold the qualification for fiber network construction, develop full-service operators, and improve the broadband infrastructure deployment level of operators.

4) Strengthen capital investment to Encourage local governments to support the deployment of broadband network infrastructure through policies and funds, promote the development of FTTH home users, promote the construction of professional networks in industries such as education private networks, healthcare, and transportation, and encourage enterprises to deploy FTTB and FTTH broadband connection capabilities. Launch policies on universal

services to promote the construction of optical fiber networks in rural areas and other remote areas.

5) Improve technical capabilities. Public and private enterprises and academia are encouraged to cooperate, tax and exemptions for broadband technology research, intellectual property protection, procurement of innovative solutions, and financial subsidies for start-ups are established.

6) Strengthen data statistics and quality supervision. Establish a network data reporting and service quality supervision system, establish a broadband network data platform, collect statistics on network construction and operation data of ISPs in China, and regularly collect statistics on indicators such as the number of network users, average upstream and downstream rates, number of FTTx ports, and network quality satisfaction. Provide data support for orderly improvement of network quality and user service level.