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Research Article

Challenges and Possible Solutions of Implementing 5G Mobile Networks in Bangladesh

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Recently, fifth-generation (5G) mobile connectivity has been launched in Bangladesh on a trial-run basis. 5G is a super-speed mobile network that is much faster than the existing fourth-generation (4G) technology. It is excruciatingly hard to deploy a fully functioning 5G in any country regardless of its available resources and technological advancements because of some apparent technological complexity and limitations. In addition, when deploying this technology in developing countries such as Bangladesh, the costs come into play. To cope with the world's advancement in science and technology, Bangladesh is planning to implement 5G covering the whole country. In this paper, we present the major challenges in implementing a wide area 5G network in Bangladesh and find some possible solutions. This research work has also tried to get a clear picture of the service quality of the existing 4G cellular communication by analyzing some of the mobile operators' download speeds over 24 hours. In addition, this paper presents the current comparison of Internet facilities in Bangladesh with those of other countries across the globe. To the best of our knowledge, there is no publicly available study that has focused on the deployment of the 5G network in Bangladesh after assessing the current state of the cellular network. Therefore, this study could serve as a guiding resource, providing valuable information for decision-making.

1. Introduction

These days, 5G technology, or the fifth-generation standard for the broadband cellular network, is a buzzword worldwide. Some countries have already deployed 5G technology, and others will adopt it soon. A developing country such as Bangladesh is also taking steps to start using 5G technology. 5G will be many times faster than the existing 4G technology. More specifically, 4G has an average speed of 10 Mbps and 5G has an average speed of 10 Gbps. According to the Bangladesh Telecommunication Regulatory Commission (BTRC), some cities in Bangladesh promised to be covered by the 5G network by 2022. However, no such initiatives have occurred to date, except for a short period of limited trials by GP (Grameenphone) in some major cities. LTE subscriptions already exceeded 6.2 billion by the end of 2021 [1]. Mobile services based on 4G LTE (services) are steadily expanding across the global market, providing subscribers with the type of responsive Internet browsing experience previously only possible with wired broadband connections [2]. The growth rate is tremendous and will further increase over the next decade. IoT (Internet of Things) devices are also believed to eventually reach hundreds of billions with a connection density of 10 million

devices per km^2 by 2030 [3]. Figure 1 shows the general network architecture of fifth-generation (5G) mobile technology. 5G will bring a revolutionary change in science and technology, healthcare, agriculture, communication, entertainment, business, real-time simulation, and gaming. The widespread applications of the IoT in various fields, e.g., industry, agriculture, medicine, and traffic, have spurred explosive growth in the number of IoT devices [5]. The following five key research areas will have an immense impact on progressing 5G: dense small cell deployment, massive multiple-input multiple-output (massive MIMO), device-to-device (D2D), machine-to-machine (M2M), and millimeter wave (mmWave) communications [6]. By considering the socioeconomic conditions of Bangladesh, first, 5G connectivity will start in the agriculture, health, and education sectors. These rapid changes are in response to the capacity demands resulting from the massive data growth over the last ten years, posed mainly by video. The video resolution capability is also increasing, and handsets supporting 4K video will need a data rate of 15.4 Mbps per user (using H.265 profile 5.1, 4K resolution at 64 fps, and chroma ratio 4 : 4 : 4) [7, 8]. However, it is a daunting task to implement 5G infrastructure all over Bangladesh. The major challenges in implementing a 5G network in Bangladesh include the cost of spectrum, equipment, cost, deployment coverage, lack of supported devices, high consumer VAT (value-added tax), short length propagation of mmWave, security, and privacy. This paper will also present the current Internet speed in Bangladesh. Although Bangladesh will start 5G connectivity soon, the existing 4G and 3G standards are not so good here. The most significant issues faced by the users are call drops and Internet buffering.

On the other hand, compared to a few subcontinental countries, the Internet price is higher than average in Bangladesh. Nevertheless, as a developing country, Bangladesh's Internet price should be reduced to ensure better Internet facilities and availability for its people. This paper will also compare the data prices of Bangladesh with those of other countries. Therefore, this paper can provide reliable instructions for the authority and operator companies that are currently operating in Bangladesh.

The remainder of the paper is organized as follows. Section 2 presents the methodology of this study. Section 3 presents the challenges of implementing 5G networks in Bangladesh. Section 4 comprehensively describes the current 4G speeds of different telecom operators in Bangladesh. A description of the Internet speed around the world is provided in Section 5. Section 6 discusses some possible solutions for implementing 5G networks in Bangladesh. Finally, the conclusion of our study is drawn in Section 7.

2. Methodology

Despite an exhaustive search of specialized databases, no articles that provide a comprehensive overview of the current state of the mobile wireless communication industry in Bangladesh were located. They function as a valuable resource for guiding the implementation of 5G in Bangladesh or investigating viable alternatives in the realm of cellular networks. In this context, their insights and data can significantly contribute to decision-making processes. The present investigation employed a comprehensive methodology to collect data, utilizing both primary and secondary sources. Experiments were conducted to collect primary data, while secondary data, including diagrams, were meticulously extracted from numerous research publications and official websites. To ensure the accuracy and reliability of the information, a comprehensive literature review was performed. Accessing and analyzing the official websites of various mobile operators and the BTRC were required to compile data, and other pertinent sources were conducted with utmost care.

A part of the research was performed to know the average download speed for different mobile operators in Bangladesh, e.g., GP, BL, and Robi in Nurpur, Pabna district (Figure 2), for two consecutive days. To record the best possible real-life scenario, it is essential to conduct precise measurements of the data transfer rate offered by cellular networks.

Traditional methods of analyzing network speed include using third-party websites, which may or may not accurately reflect the real performance that users experience. In order to work around this limitation, the research presented here suggests an alternate methodology that entails downloading the actual files themselves from the Internet. This method provides a more accurate representation of the effective data speed observed by customers. After completing the network data speed measurement collection process, a comprehensive data analysis was carried out. The sizes of the downloaded files and the times that each download took were logged, making it possible to compute the data transfer rates. The data collected were subjected to statistical analysis to determine whether or not there were any significant differences in the transfer rates of data across the various mobile service providers (GP, BL, and Robi) at the various time slots spanning a period of 24 hours. During the data acquisition process for this experiment, large and small files were set to download to minimize the apparent error with a stationary cellular device outdoors in an urban area, maintaining a 2 km distance from the experimental site of the cell base. The data samples were collected every hour for 24 hours by downloading mp4 videos and keeping notes of the downloading times carefully and precisely.

All experimental data are organized in Tables 1–3 for further calculations to determine the 4G data download speed. Furthermore, for the convenience of comprehending the significance of the calculated 4G speed at different times of the day and for comparing them among the operators, these data are visualized by appropriate bar diagrams in Figures 3–6. The entire process is depicted in Figure 7 as a flowchart. Data speed in Tables 1–3 was calculated by using the following formula:

$$\text{Data Speed (Mbps)} = \frac{\text{Total bits}}{\text{Total time in seconds} \times 1024} = \frac{\text{Downloaded file size in MB} \times 1024 \times 8}{\text{Total time to download in seconds} \times 1024}. \quad (1)$$

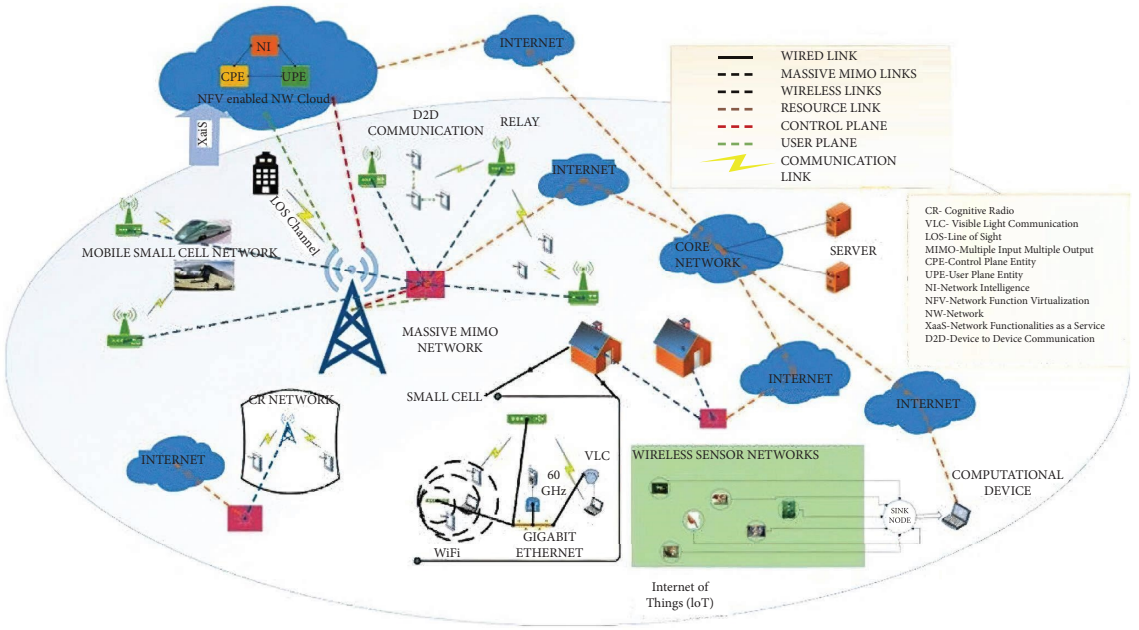

Figure 1: General network architecture of fifth-generation (5G) mobile technology [4].

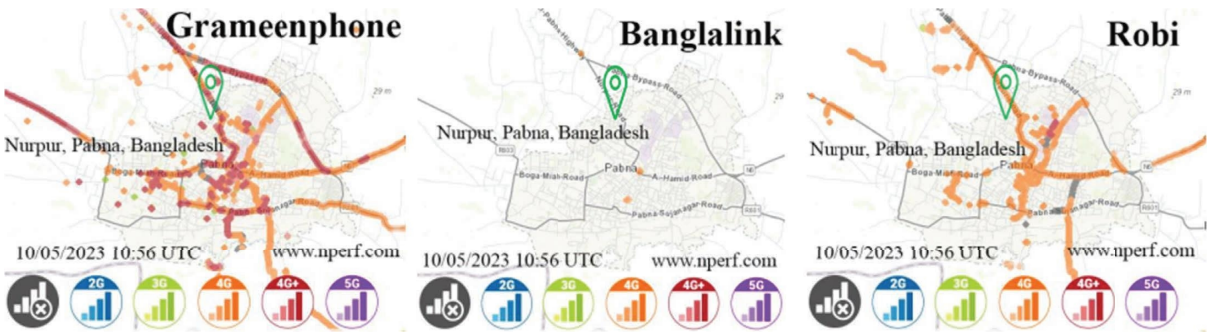

Figure 2: Site location of data acquisition at Nurpur, Pabna, Bangladesh.

Data in Table 4 were calculated by using the following formula:

$$\% \text{ Network Speed Reduction} = \frac{\text{Difference in Network Speed between Both Halves}}{\text{Network Speed in the First Half}} \times 100. \quad (2)$$

3. Challenges of Implementing 5G Networks in Bangladesh

Undoubtedly, 5G technology heralds a revolutionary change in science and technology. This section delves into the primary challenges associated with the nationwide implementation of 5G networks.

3.1. Cost of Spectrums. In October 2012, Bangladesh began offering 3G Internet access. The BTRC auctioned the 3G spectrum in the 2.1 GHz band on September 8, 2013 (BTRC, 2013). Four of the leading telecom providers in Bangladesh participated in the auction, which concluded after three rounds of bidding. BTRC fixed the reserve price for the 1 MHz spectrum at $20 million [9]. Compared to other countries, the cost of spectrum is very expensive. Therefore, mobile operators ended up having to purchase an expensive spectrum, resulting in inadequate purchases by mobile operators and leaving some available spectrum unused. The three leading operators, GP, Robi, and, BL recently purchased 27.4 MHz of 4G spectrum for a whopping 7634 crores, Taka, over 15 years, which is astronomically expensive compared to neighboring countries.

Table 1: 4G download speed of Grameenphone networks.

No. of observations	Time (hours)	File size (MB)	Download time (sec)	Speed (Mbps)
1	01:00	53.87	72	5.984
2	02:00	15.35	20	6.144
3	03:00	15.35	40	3.072
4	04:00	55.87	40	11.176
5	05:00	29.25	73	3.208
6	06:00	53.87	55	7.832
7	07:00	53.87	59	7.304
8	08:00	19.14	18	8.504
9	09:00	53.87	72	5.984
10	10:00	53.87	74	5.824
11	11:00	53.87	95	4.536
12	12:00	53.87	69	6.248
13	13:00	19.14	19	8.056
14	14:00	19.14	80	1.912
15	15:00	19.14	97	1.576
16	16:00	19.14	33	4.64
17	17:00	53.87	147	2.928
18	18:00	53.87	250	1.72
19	19:00	19.14	48	3.192
20	20:00	19.14	54	2.832
21	21:00	19.14	51	3
22	22:00	19.14	225	0.68
23	23:00	19.14	397	0.384
24	24:00	19.14	91	1.68
				$\sum$ Speed = 108.96

Table 2: 4G download speed of Banglalink networks.

No. of obs	Time (hours)	File size (MB)	Download time (sec)	Speed (Mbps)
1	01:00	15.35	24	5.12
2	02:00	15.35	20	6.144
3	03:00	15.35	13	9.448
4	04:00	53.87	131	3.288
5	05:00	15.35	30	4.096
6	06:00	15.35	16	7.672
7	07:00	15.35	27	4.552
8	08:00	37.28	79	3.776
9	09:00	37.28	51	5.848
10	10:00	15.35	24	5.12
11	11:00	37.28	71	4.2
12	12:00	15.35	27	4.552
13	13:00	37.28	258	1.152
14	14:00	37.28	51	5.848
15	15:00	37.28	102	2.92
16	16:00	53.87	103	4.184
17	17:00	15.35	30	4.096
18	18:00	37.28	26	11.472
19	19:00	37.28	67	4.448
20	20:00	53.87	67	6.432
21	21:00	37.28	33	9.04
22	22:00	53.87	80	5.384
23	23:00	5.65	286	0.16
24	24:00	53.87	59	7.304
				$\sum$ Speed = 126.24

Consequently, telecom operators in Bangladesh raised the data price, making it unaffordable for many subscribers. Similarly, it can be extrapolated that the 5G spectrum will be significantly more expensive than the existing 4G spectrums. Therefore, there is no doubt that the data pricing for 5G at the consumer level will be higher than before. Figure 8 illustrates the cost of each megahertz spectrum in various nations.

Table 3: 4G download speed of Robi network.

No. of obs	Time (hours)	File size (MB)	Download time (sec)	Speed (Mbps)
1	01:00	5.65	156	0.288
2	02:00	15.35	27	4.552
3	03:00	15.35	16	7.672
4	04:00	7.63	11	5.552
5	05:00	15.35	21	5.848
6	06:00	7.63	19	3.216
7	07:00	7.63	13	4.696
8	08:00	7.63	8	7.632
9	09:00	37.37	30	9.968
10	10:00	15.35	90	1.368
11	11:00	37.28	35	8.52
12	12:00	15.35	15	8.184
13	13:00	37.28	63	4.736
14	14:00	1.4	191	0.056
15	15:00	7.63	6	10.176
16	16:00	7.63	18	3.392
17	17:00	7.63	15	4.072
18	18:00	6.64	44	1.208
19	19:00	7.63	12	5.088
20	20:00	37.37	39	7.664
21	21:00	7.63	32	1.904
22	22:00	1.99	95	0.168
23	23:00	7.63	8	7.632
24	24:00	7.63	12	5.088
				$+\sum$ Speed = 118.56

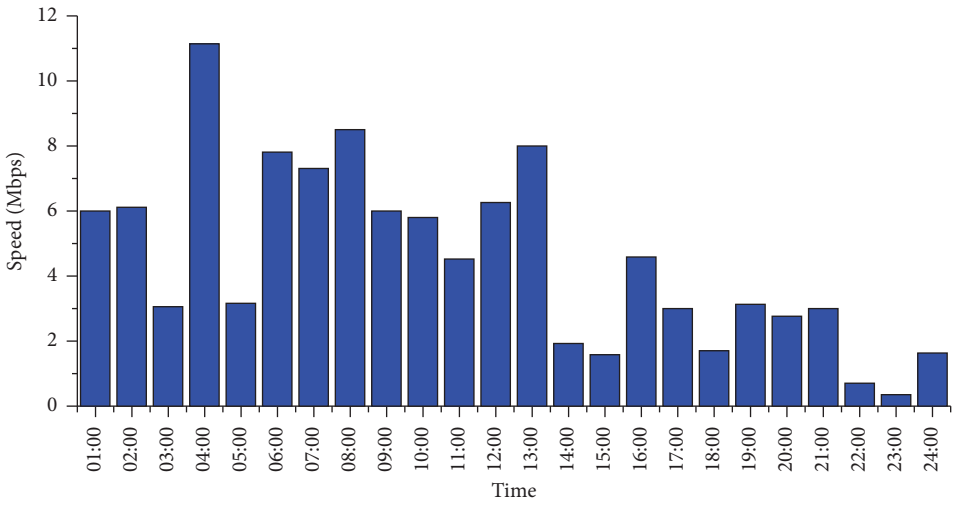

Figure 3: Grameenphone's 4G download speed sampled hourly over a 24-hour period.

3.2. Equipment Cost. In the 5G network, supporting customized slicing demands requires the reconstruction of radio and core networks in terms of utilizing new technologies such as software-defined networks (SDN), network functionality virtualization (NFV), and microcells [11]. The spectrums' cost and the types of equipment used in 5G networks are also costly. One crucial aspect to consider in the 5G paradigm is the transport network segment, which carries data traffic between radio base stations and the core part of the network. Transport networks must be able to deliver in a flexible and cost-efficient way. The connectivity needed to accommodate 5G services (i.e., parts of which may now also be cloud-based) and to provide enough capacity to support the many-fold increase in data traffic [12, 13], millimeter wave (mmWave) communications have been proposed to be an essential part of the 5G mobile network to provide enhanced mobile broadband (eMBB) services such as virtual reality (VR) and ultra-high-definition video (UHDV) [14, 15]. The rapid demands of mobile data and smartphones create unprecedented challenges for wireless service providers to overcome a global bandwidth shortage [16, 17]. However, the high-frequency millimeter wave cannot travel much higher than a kilometer. Therefore, the number of antennas will be increased massively in 5G

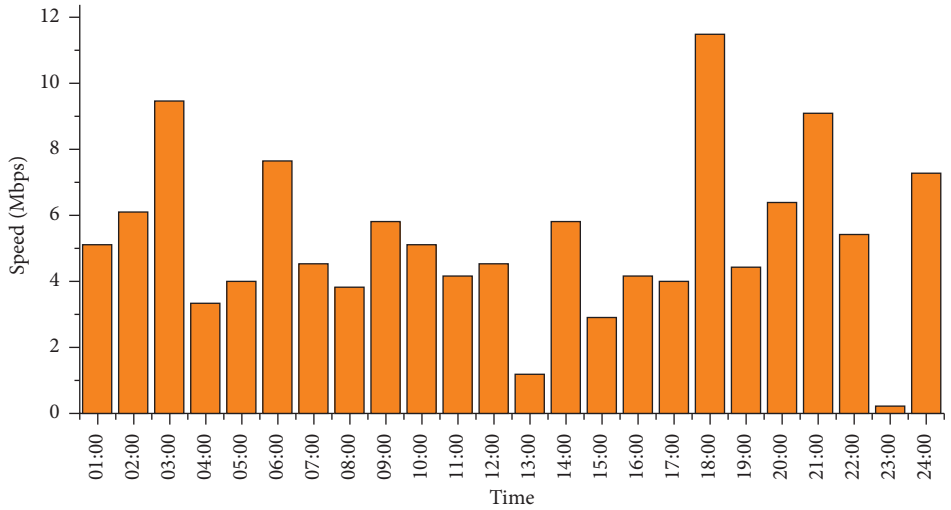

Figure 4: Banglalink's 4G download speed sampled hourly over a 24-hour period.

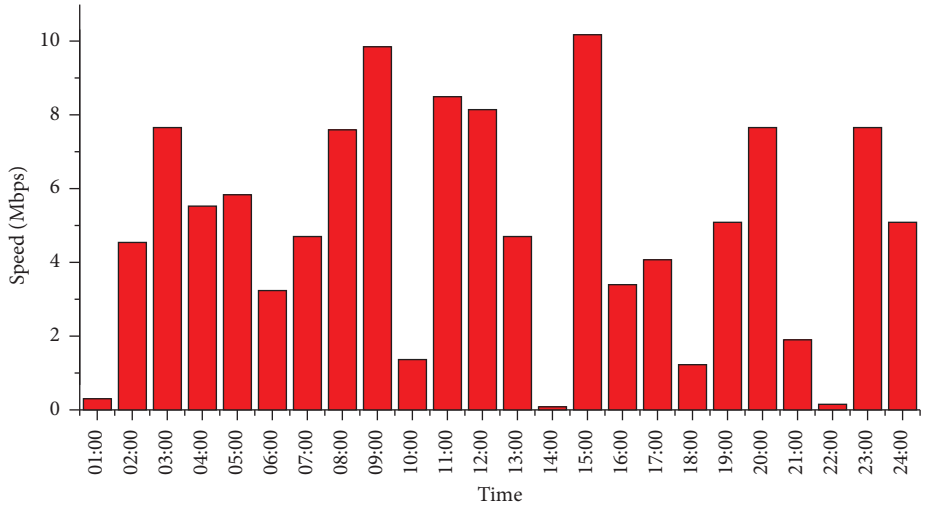

Figure 5: Robi's 4G download speed sampled hourly over a 24-hour period.

networking. The antenna will be placed on the roof, streetlight, and electric pole. The larger the number of antennas, the greater the cost. The length of the optical fiber will also be increased because of the increasing number of antennas.

3.3. Deployment Coverage. Although Bangladesh is on the verge of introducing 5G networks, many people cannot access existing 4G network facilities due to a shortage of supported or expensive devices, sufficient network coverage, and the required skills. The overview of the telecom sector in Bangladesh is as follows:

(i) 9 crore unique mobile subscribers

(ii) 17 crore mobile connections

(iii) 10 crore mobile Internet connections

(iv) 3.23 crore active mobile financial service (MFS) accounts

(v) Tk 17,795 crore average daily transactions through MFS [18].

At this moment, four telecom operator companies are serving a total of 158.438 million Bangladeshi mobile subscribers. In addition, 86.268 million subscribers use the mobile Internet [19]. According to the Global System for Mobile Communications Association (GSMA) report, around 47% of the country's mobile connections still rely on the 2G technology, which only provides voice call and messaging services. 2G is a rudimentary mobile communication system, and this obsolete technology prevents its users from digital inclusion. Compared to Bangladesh, 32% of mobile connections in India still utilize 2G, which is 20% in Sri Lanka. Besides, 63% of Indian subscribers use 4G technology, which gives the country more opportunities for digital inclusion [20]. Where 47% of people use a 2G network, 5G is like a daydream for rural communities. Figure 9 shows the network coverage area of Grameenphone, Banglalink, and Robi mobile operators.

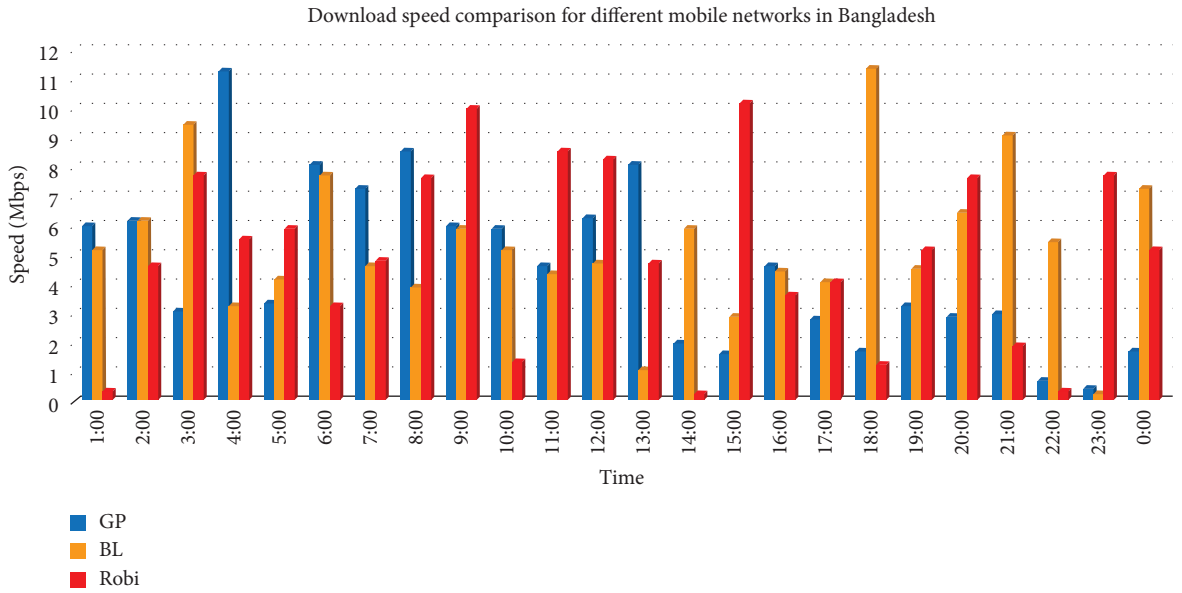

Figure 6: Download speed comparison for various mobile networks sampled hourly over a 24-hour period.

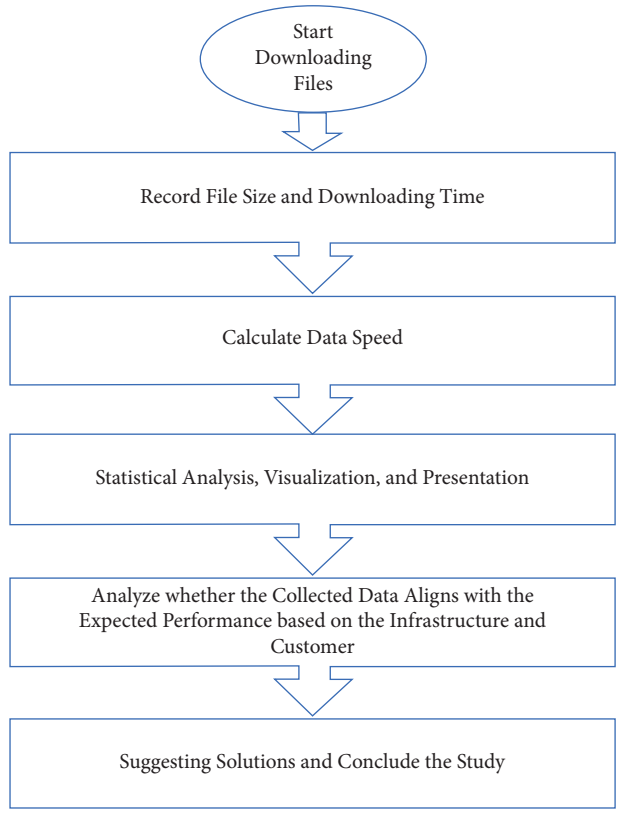

Figure 7: Steps of the experiment.

3.4. Lack of 5G-Supported Devices. In Bangladesh, 5G-supported mobile phones are rare in number. Since the infrastructures for 5G are yet to be deployed in Bangladesh, another possible reason is unaffordability because 5G mobile devices are more expensive than their 4G counterparts. The price list of 5G mobile phones is given in Table 5. The prices are arranged ascendingly from the top of the table.

Table 4: 4G download speed comparison for GP, BL, and Robi mobile networks.

Operators name	Network speed in the first half (01:00 to 12:00 hours) (Mbps)	Network speed in the second half (13:00 to 24:00 hours) (Mbps)	Average speed (Mbps)	% network speed reduction in the second half
GP	6.32	2.72	4.54	57
BL	5.32	5.20	5.26	2.16
Robi	5.62	4.27	4.94	24.17

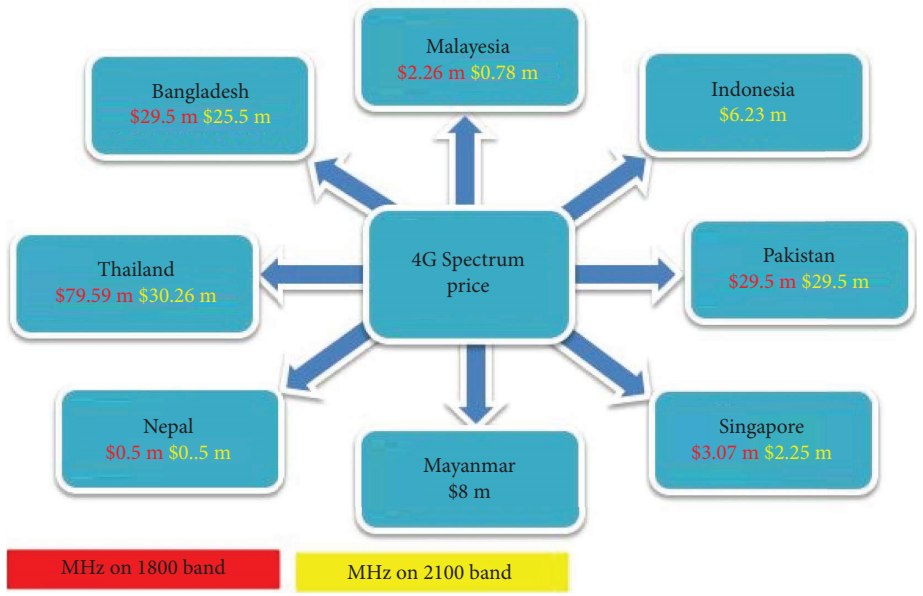

Figure 8: Spectrum prices in different countries [10].

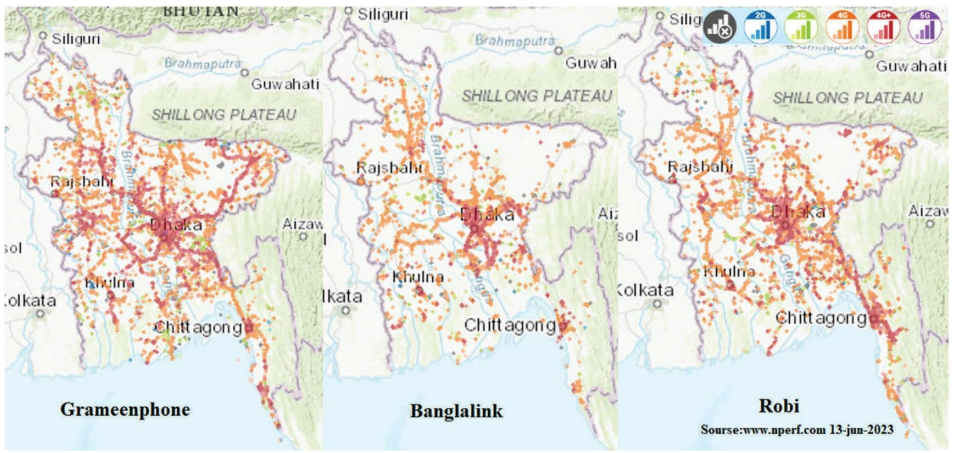

Figure 9: Grameenphone, Banglalink, and Robi's network coverage [19].

On the other hand, IoT devices suitable for 5G are not available in Bangladesh. The variety of radio access technologies (RATs) and wireless devices is growing in numbers. In the 5G era, many devices use multiple RATs and modes ranging from D2D communications based on wireless fidelity (Wi-Fi), direct, or LTE direct to short-range mmWave technologies such as Wireless Gigabit (WiGig) and even new body area networks oriented toward wearable devices [21].

3.5. High VAT from Consumers. The VAT, tax on mobile phone imports, subscriber identity module (SIM), and Internet data costs are increasing in Bangladesh. Today, without Internet data, the tax is 33.25%, and in the case of Internet data, the tax is 21.75%. Even when buying a SIM, 200 Tk VAT must be given. The VAT on imported products is also increasing in Bangladesh. So, the dealers are not interested in importing the 5G-enabled devices due to the high VAT. As a result, high VAT may affect the 5G revolution in Bangladesh.

Table 5: Approximated 5G-supported cellular phone price in Bangladesh.

Brand	Price (Taka)
Realme Q5i	18,000
Nokia G300	20,000
Realme v11s	20,000
Realme Q5	29,500
Realme 8s	28,000
Samsung Galaxy M32	23,000
OPPO K9s	23,990
Motorola Moto G50	26,000
Vivo iQ00 Z5	26,000
Nokia G50	30,000
OnePlus Nord CE	34,990
Vivo V21	35,000
Meizu 18x	35,000
Infinix Zero X Pro	40,000
Xiaomi Civi	40,000
Realme GT Neo2	42,990

3.6. Will 5G Hamper 4G? When 3G was launched here in Bangladesh, the data speed instantly improved. Video calling and YouTubing were smooth. However, after launching 4G, it was experienced that video calling and YouTubing were not as smooth as before. Sometimes, making a video call on 3G was impossible, and the download was disrupted when it was in the 3G network. A stable 1 Mbps of speed was commonly found when 3G was first launched. However, after the 4G cellular network deployment, the people using 3G-supported devices faced difficulty getting proper speed in 3G mode. People had to upgrade to 4G and buy 4G-supported devices to get back to reliable Internet service. So, now a question arises whether the scenario will be similar to 4G if 5G is launched commercially in Bangladesh. If 5G disrupts the speed of 4G, the 4G-supported mobile phones will have to be upgraded to 5G-supported mobile devices, resulting in an additional cost for the customer who is satisfied with the 4G service and has no use case for the 5G network.

4. Current 4G Speed in Bangladesh

4.1. Current 4G Download Speed of Grameenphone Networks. Considering the number of active subscribers and the amount of acquired spectrum, GP is the most dominating entity in the telecommunication industry in Bangladesh [22]. GP is currently providing its 4G service to its 31.5 m active Internet users [7] in Bangladesh by acquiring a 60 MHz spectrum from the 2.6 GHz band [5].

The data in Table 1 show the current 4G speed of GP, and the calculated 4G network speed is illustrated in Figure 3. By analyzing those tables and figures, it can be interpreted that the Internet speed fluctuated notably throughout the 24 hours. This experiment found the highest downloading speeds of 11.176 Mbps, 8.504 Mbps, and 8.056 Mbps at 04:00, 08:00, and 13:00 hours, respectively. Similarly, the lowest-performing downloading speed of 0.38 Mbps, 0.68 Mbps, and 1.576 Mbps was found at 23:00, 22:00, and 15:00 hours, respectively. The average (arithmetic mean) download speed during the experimental period was 4.54 Mbps. During the period from 14.00 to 24.00 hours, the data speed degraded noticeably with an average (arithmetic mean) data speed of 2.72 Mbps; whereas, before that period from 01.00 to 13.00 hours, the 4G download speed of GP maintained an average speed of 6.318 Mbps.

$$\begin{aligned}\text{Average download speed} &= \frac{\sum \text{Speed}}{\text{Total number of experiments}} \\ &= \frac{108.96}{24}\ \text{Mbps} \\ &= 4.54\ \text{Mbps}.\end{aligned} \tag{3}$$

4.2. Current 4G Speed of Banglalink Networks. BL is Bangladesh's third most dominating mobile operator according to the number of active users [3]. BL is currently providing its 4G service to its 13.3 million active Internet users [3] in Bangladesh by acquiring a 40 MHz spectrum from the 2.3 GHz band [2, 5]. The data in Table 2 show BL's current 4G speed. In addition, the calculated 4G network speed is illustrated in Figure 4. This experiment found the highest downloading speeds of 11.472 Mbps, 9.448 Mbps, and 9.04 Mbps at 18:00, 03:00, and 21:00 hours, respectively. Similarly, the lowest-performing download speed of 0.16 Mbps, 1.152 Mbps, and 2.92 Mbps was found at 23:00, 13:00, and 15:00 hours respectively. Moreover, the average (arithmetic mean) downloading speed during the experimental period was 5.26 Mbps. During the period from 13.00 to 17.00 hours, the BL 4G network performed comparatively worse with an average (arithmetic mean) data speed of 3.64 Mbps, whereas, after that period, from 18.00 to 22.00 hours, the 4G download speed of BL maintained an average speed of 7.36 Mbps.

$$\begin{aligned}\text{Average speed} &= \frac{\sum \text{Speed}}{\text{Total number of experiments}} \\ &= \frac{126.24}{24}\ \text{Mbps} \\ &= 5.26\ \text{Mbps}.\end{aligned} \tag{4}$$

4.3. Current 4G Download Speed of Robi Networks. Robi is considered the second leading mobile operator in Bangladesh according to its number of active users [6]. In addition, Robi holds a 60 MHz spectrum in the 2.6 GHz band for its 26.3 m 4G network subscribers [6]. Table 3 represents the data collected to quantify Robi networks' current 4G speed. The calculated speed is presented in the last column of the table, and the bar diagrams in Figure 5 illustrate the 4G speed throughout the day (24-hour period). This experiment found the highest downloading speeds of 10.18 Mbps, 9.97 Mbps, and 8.52 Mbps at 15:00, 09:00, and 11:00 hours, respectively. On the contrary, the lowest-performing

download speed of 0.056 Mbps, 0.17 Mbps, and 0.29 Mbps was recorded at 14:00, 22:00, and 1:00 hours, respectively. In addition, the average (arithmetic mean) download speed during this full-length experimental period was 4.94 Mbps. The most stable network speed was recorded from 02.00 to 09.00 hours with an average (arithmetic mean) data speed of 7.77 Mbps, whereas throughout 18.00–22.00 hours, it was the low performing time for the network when it maintained an average speed of 3.2 Mbps. This fluctuation can be easily noticed in Figure 5.

$$\begin{aligned}\text{Average speed} &= \frac{\sum \text{Speed}}{\text{Total number of experiments}} \\ &= \frac{118.56}{24}\,\text{Mbps} \\ &= 4.94\,\text{Mbps}.\end{aligned} \tag{5}$$

4.4. Download Speed Comparison for Various Mobile Networks. This section will analyze the 4G network performance of GP, BL, and Robi comparatively. These compared data are summarized in Table 4. Suppose the 24-hour experimental period is split into two time slots, denoted as the first half (01:00 to 12 hours) and the second half (13:00 to 24:00). In that case, the network speed can be analyzed to evaluate the stability of the network speed at two different times of the day. For GP, in the first and second half of the day, the average data speed was 6.32 Mbps and 2.72 Mbps, correlatively, resulting in a 57% degradation in data speed. For BL, in the first and second half of the day, the average data speed was 5.32 Mbps and 5.20 Mbps, respectively, and the data speed degradation was minimal with a 2.16% reduction. Finally, for Robi, the first half network speed was 5.62 Mbps, and the second half network speed was 4.94 Mbps; therefore, a 24.17% reduction in data speed was recorded. BL has the best average data speed of 5.26 Mbps among the three operators and provides the best data speed stability. This is justifiable because this operator has the leading radio frequency infrastructure per million users [2]. In the first 12 hours, GP had the highest average speed than the two other operators; however, this speed dropped dramatically in the second half of the day, consequently making it the worst-performing operator in the second half of the day compared to the other two operators. According to the recorded average 4G Internet speed in the 24-hour duration in this research, BL has the highest speed of 5.26 Mbps, Robi has the second best 4G Internet speed of 4.94 Mbps; finally, GP has the lowest average 4G speed of 4.54 Mbps. It should be noted that GP has 5.2 million [6, 7] more 4G subscribers than Robi; however, these operators serve the customer with the same amount of allocated 4G frequency spectrum. Figure 6 shows the 4G download speeds comparison for various mobile networks sampled hourly over a 24-hour period.

4.4.1. Limitations of Our Experiment. The limitations of our experiment are as follows:

(i) All experiments are performed by using the brand Oppo A15s device. The device may influence mobile speed; the download speed may differ for different devices

(ii) The experiment is performed in places within 2 km of the base area

(iii) The experiment is performed only for urban areas

5. Internet Speed around the World

The bar graphs presented in Figure 10 compare the current (in 2022) 4G and 5G data speeds illustrated in reference [23]. If the 4G Internet speed is analyzed first, South Korea and the USA have the most impressive 4G Internet speeds of 66.6 Mbps and 60 Mbps, respectively. Sweden is in the third place with a cellular 4G data speed of 47.7 Mbps. Qatar and New Zealand share 4G Internet speeds with similar ranges of 41.2 Mbps and 40.7 Mbps, correlatively. UAE and Taiwan, these two countries have 4G Internet speeds of around 37 Mbps; for Kuwait and Saudi Arabia, the range is around 30 Mbps. The UK and Malaysia maintain a 4G speed of 20 Mbps and 15 Mbps, respectively. In this list, Bangladesh has an overwhelmingly low 4G Internet speed of 5 Mbps. By inspecting the 5G data speed in the provided bar diagram in Figure 10, it can be noticed that South Korea's current (in 2022) 5G speed secures the top spot in the graph with 432 Mbps speed and 382.2 Mbps speed, while Malaysia is at the second place. Sweden and UAE have maintained their 5G speed higher than 300 Mbps, more specifically 333.9 Mbps and 315.9 Mbps, respectively.

In comparison, Qatar and Taiwan have almost a tie in their 5G data speed, 275.9 Mbps and 274.2 Mbps, respectively. Kuwait and New Zealand are the two countries that have crossed the mark of 250 Mbps cellular data speed, specifically 267.6 and 256.6 Mbps, respectively. Saudi Arabia and the UK have Internet speeds of 237.9 Mbps and 200 Mbps, respectively. The last country on the list to have the Internet speed crosses the 200 Mbps mark. Finally, the USA has 5G Internet speeds of 141.4 Mbps. Bangladesh has yet to implement its 5G network; as a result, no data are listed regarding the speed.

6. Possible Solutions

In this section, we will discuss some possible solutions for implementing 5G networks in Bangladesh.

6.1. Reducing the Price of the Spectrum. As previously discussed, the spectrum prices in Bangladesh are notably high. The ITU has designated the spectrum for 5G in Bangladesh, prompting telecom companies to expedite the implementation of 5G technology. Nevertheless, certain operators have raised concerns, alleging that the government aims to maximize profits by selling the 5G spectrum. It is suggested that the government consider pricing the spectrum competitively, aligning it with the rates observed in neighboring countries.

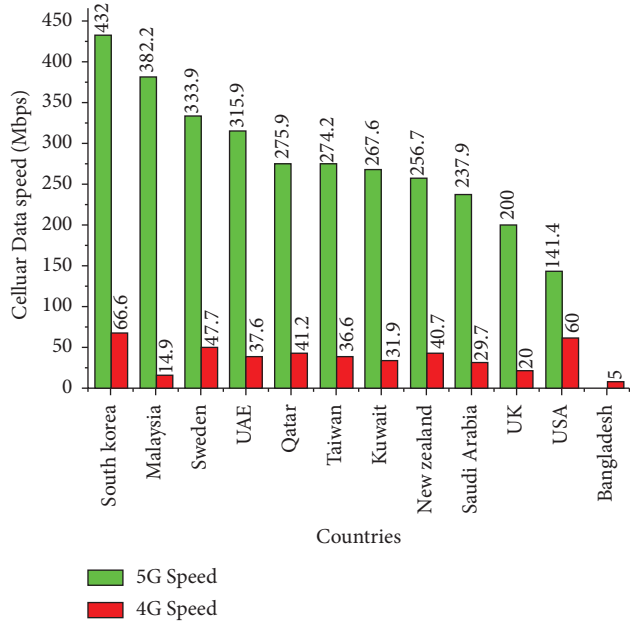

Figure 10: Comparison of 4G and 5G data speeds for different countries [23].

6.2. Increasing the Optical Fiber Instead of Microwave Communication. Optical fiber communication is vital in developing high-quality and high-speed telecommunication systems. Today, optical fibers are used in telecommunication links, on the Internet, and in local area networks (LAN) to achieve high signaling rates [24]. Bangladesh needs more optical fiber for the base transceiver station (BTS) connections. Conventionally, it uses microwave wireless connection among most of the BTS, and thus the signal attenuates due to absorption in the rain and other natural disasters. So, the operator company should provide optical fiber communication instead of microwave communication. Figure 11 shows microwave and optical fiber communication.

Bangladesh is currently using 1.3 terabytes per second (TB/s) of bandwidth; among them, 0.9 TB/s is from SEE-ME-WE-4 (South-East Asia-Middle East-Western Europe 4), SEE-ME-WE-5, and the rest is imported from India. Bangladesh is going to sign a memorandum for SEE-ME-WE-6. If the project is implemented in Bangladesh, the total national (domestic) bandwidth will reach 5 TB/s. It will be such a large amount of bandwidth for Bangladesh that it is expected that Bangladesh will be able to export some bandwidth to other countries. So, to implement 5G in Bangladesh, signing in SEE-ME-WE-6 is a must.

6.3. Decreasing the VAT and Taxes. The impediment to implementing 5G in Bangladesh lies in the high VAT and taxes. An increase in VAT may deter operator companies from purchasing the spectrum, leading to a potential rise in data prices if operators decide to pass on the additional VAT costs. Consequently, the affordability of 5G services for the general population in the post-COVID-19 economy could be compromised.

6.4. Establishing the 5G Mobile Manufacturing Industry. Due to the high costs associated with importing mobiles from other countries, Bangladesh has initiated the production of smartphones locally, including brands such as Walton, Vivo, Oppo, Tecno, and the Indian brand Lava. It is advisable to encourage these companies to venture into manufacturing 5G mobile phones, as this would streamline the process of implementing 5G in Bangladesh.

6.5. Cooperation with the Operator Companies. Given the limited travel range of high-frequency mmWave in 5G networks, multiple antennas or BTS installations are necessary. To accommodate this, operator companies may deploy antennas on various structures such as lamp posts, electric poles, or rooftops. Collaborating with these companies by providing suitable locations for BTS setups can contribute to effectively implementing 5G.

6.6. Reducing the Price of Data. Although data price is on the cheaper side in Bangladesh compared to other countries. The regular data price for GP is given in Table 6. Here, if we consider, for example, the peak occupancy data, then we can obtain the average data price per GB data as price = 599/45 = 13.31 Taka = 13.31/101.87 = \$0.131. However, combining all operators in Bangladesh, according to some international reports [25], the nation's average Internet price is \$0.32, which is the 12th cheapest in the world. Figure 12 shows the data price per GB for different countries. The bar diagram in Figure 12 represents the per GB Internet price in some countries in the world. For a reasonable comparison with Bangladesh, the list is mostly made with some Asian countries where Bangladesh, India, Nepal, Sri Lanka, and Pakistan are situated in South Asia.

Here, Saudi Arabia has the highest price on the list; moreover, it is almost five times higher in price than Bangladesh (\$.32) and almost nine times higher than India and Kyrgyzstan which are the second-highest Internet prices in the chart costing \$0.17 per GB mobile Internet. According to this bar diagram, per GB, Internet prices in Nepal and Sri Lanka are congruent which is \$0.27. Likewise, with costs of \$0.32 and \$0.36 per GB of Internet, Bangladesh and Pakistan show a similar price point. The United Kingdom is the last country to have a per GB cellular data price under \$1, which is \$0.79. Finally, Israel has the cheapest Internet in the world at \$0.04.

6.7. Strict Law for Cybercrime. Cyber-dependent crimes (or "pure" cybercrimes) are offenses that can only be committed by using a computer, computer network, or other forms of information and communications technology (ICT) [26]. A generalized definition of cybercrime may be "unlawful acts wherein the computer is either a tool or a target or both" [27]. The computer may be used as a tool in the following kinds of activity: financial crimes, the sale of illegal articles, pornography, online gambling, intellectual property crime, e-mail spoofing, forgery, cyber defamation, and cyberstalking [28]. When 5G is deployed, people will keep much

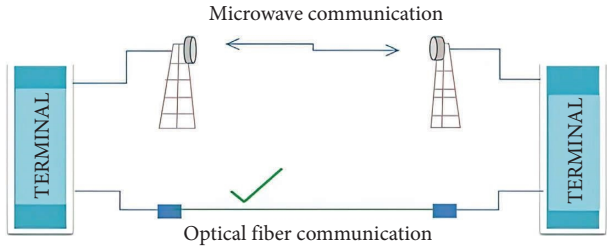

Figure 11: Concept of microwave and optical fiber communications.

Table 6: Internet data price in Bangladesh (GP).

Data amount (GB)	Occupancy (day)	Price (Taka)
1.5	3	57
4	3	84
8	3	98
4	7	129
8	7	148
15	7	179
8	30	348
18	30	448
45	30	599

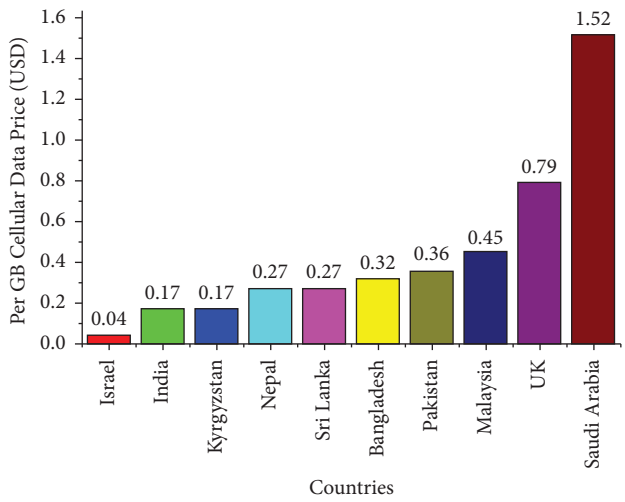

Figure 12: Price of per GB data in different countries (in USD) [25].

data on the Internet. As a result, there will be a security issue. Cybercrime has already increased in Bangladesh. According to the constitution of Bangladesh (Chapter IX: Section 66), punishment for tampering with computer source documents whoever intentionally or knowingly conceals, destroys, or alters, or intentionally or knowingly causes any other person to conceal, destroy, or alter any computer source code used for a computer, computer program, computer system, or computer network when the computer source code is required to be kept or maintained by any law for the time being in force, shall be punishable with imprisonment of either description for a term which may extend to three years, or with fine which may extend to Taka of two lakhs, or with both [29]. The government of Bangladesh should make more strict laws for cybercrime for the smooth implementation of the 5G network. The users also have to be conscious of cybercrime. We should avoid keeping such information in our social media, which may harm us if disclosed. We should update the antivirus in our devices to protect it from viruses and malware.

6.8. Global Performance Gaps in 4G and 5G, Cost Analysis, and Implications for Bangladesh. This study found that the 4G speed in Bangladesh is below the standard (the average data speed of GP, Banglalink, and Robi found in this study are 4.54 Mbps, 5.26 Mbps, and 4.94 Mbps, respectively), and other studies conducted in other countries indicate that there are significant performance gaps between the advertised 5G mobile access bandwidth and the actual bandwidth delivered in the field [30]. According to this study [30], the primary reasons behind these discrepancies can be attributed to various factors. These factors include the influence of user devices, the allocation of radio resources, insufficient investment in infrastructure, and the rapid advancements in specific areas of cellular technology that may not be fully compatible with older technologies [30].

The preceding analysis leads us to conclude that there is no favorable scenario for 5G deployment in Bangladesh. Therefore, Bangladesh Telecommunication Regulatory Commission (BTRC) ought to concentrate on providing high-speed Internet coverage throughout the entirety of Bangladesh in order to establish the ideal environment for future 5G deployment. Since 4G and 5G will coexist for very long [30, 31], our research findings also stand for the cost-effective enhancement of existing LTE infrastructure. For example, we recommend expanding the use of LTE-Advanced technology as suggested by a similar study [30]. The reasons behind their suggestion were that LTE-Advanced utilizes a suite of innovations, including carrier aggregation, multiantenna technology, enhanced MIMO, and mobility, to significantly increase LTE bandwidth [32–34]. Consequently, LTE-Advanced can theoretically achieve up to 2 Gbps of bandwidth, comparable to the bandwidth of today's commercial 5G, whereas conventional LTE can only maintain 150 Mbps. LTE-Advanced is also technically mature, simple to deploy, and cost-effective [32–34]. In their study, it was determined that LTE-Advanced can maintain an average speed of 403 Mbps when speeds range from 53 Mbps to 813 Mbps. [30]. Moreover, the LTE-Advanced carrier aggregation feature can assist in combining noncontiguous channels (single carrier) [34], resulting in effective migration of spectrum fragmentation and enhancement of the reframing effect.

When Bangladesh begins deploying 5G, Bangladesh Telecommunication Regulatory Commission (BTRC) should take measures to prevent the aggressive migration of radio resources. The aggressive migration of radio resources from 4G to 5G has quantifiable effects on both 4G and 5G access bandwidths [30, 33]. Spectrum reframing is typically viewed as unavoidable during the evaluation of cellular technologies, but it should be executed with moderation and forethought to minimize negative consequences. In context with the rapid evolution of cellular networks, we propose more effective

band defragmentation and reframing strategies, such as flexible band trading [35] and dynamic spectrum allocation [36], to facilitate improved spectrum resource utilization.

Although the use of the millimeter Wave (mmWave) spectrum at 24, 28, 37–39, and 60 GHz has been proposed, the primary frequency band for 5G deployment is the midband (3.4–3.6 GHz), which has been allocated by the ITU WRC-15 and is used by broadband cellular communication systems [37–39]. This decision was made to overcome obstacles and shortfalls associated with propagation that could hinder network deployment. Compared to mmWave bands, which are still in the developmental stage for short-range indoor connections [40], the midband provides greater area coverage with less propagation loss.

However, using the 3.5GHz technology can still be expensive. For instance, taking into account a cell density of 256 cells per square kilometer and a capacity of 30.6 Gbps per square kilometer, the estimated annual cost per square kilometer is approximately £1.8 million [41] and it is £2.2 million in today's currency after adjusting for inflation [42]. This cost includes only the radio access network (RAN) and would be significantly higher in densely populated cities such as Dhaka. To make 5G more accessible to subscribers, including those in underserved or economically disadvantaged areas, it is necessary to implement specific cost-reduction strategies. Initially, 5G deployment costs can be reduced through measures such as network sharing and spectrum aggregation. Exploring new revenue streams, such as augmented reality (AR) and virtual reality (VR), can generate additional revenue. These strategies have the potential to make 5G expansion viable [41].

7. Conclusion

The study reveals that none of the major operators in Bangladesh meet the 4G performance standard. Similar results have been discovered in other nations, indicating that the advertised 5G bandwidth is not being delivered. Therefore, the current conditions in Bangladesh do not support favorable 5G deployment. Instead, emphasis is placed on achieving pervasive high-speed Internet coverage and enhancing existing LTE infrastructure with LTE-Advanced technology, which is capable of achieving speeds comparable to commercial 5G. When deploying 5G, care should be taken to avoid aggressive migration of radio resources and to implement effective band defragmentation and reframing strategies to optimize spectrum resource utilization.

When Bangladesh is entirely prepared for 5G deployment, it is recommended to survey to determine the areas where 5G should be prioritized, in order to reduce costs, and avoid redundancy. Moreover, network operators should collaborate and share 5G infrastructure to assure rural service coverage while minimizing costs. Government investment must be substantial, and measures such as reducing spectrum costs and VAT for 5G services can be advantageous. Incentivizing the local assembly of 5G devices and equipment in Bangladesh can further reduce costs.

Abbreviations

2G:	Second-generation
3G:	Third-generation
4G:	Fourth-generation
5G:	Fifth-generation
BL:	Banglalink
BTRC:	Bangladesh Telecommunication Regulatory Commission
BTS:	Base transceiver station
D2D:	Device-to-device
eMBB:	Enhanced mobile broadband
Gbps:	Gigabit per second
GP:	Grameenphone
ITU:	International Telecommunication Union
LTE:	Long term evolution
LTE-A:	Long term evolution-advanced
MB:	Megabyte
Mbps:	Megabits per second
MFS:	Mobile financial service
mmWave:	Millimeter wave
NFV:	Network function virtualization
QoS:	Quality of service
RATs:	Radio access technologies
SDN:	Software-defined network
SEA-ME-WE-6:	South-East Asia-Middle East-Western Europe 6
SIM:	Subscriber identity module
TB/s:	Terabytes per second
UAE:	United Arab Emirates
UK:	United Kingdom
USA:	United States of America
USD:	US dollar
VAT:	Value-added tax.

Data Availability

The data used to support the findings of the study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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