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Overview of the implementation of 5G spectrum and services in urban areas

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ABSTRACT

The development of 2G, 3G, 4G, WiFi, and other improvements that provide improved reliability and wide coverage and are focused on high data rates and low latencies has led to the development of 5G technology. We must, however, overcome a number of obstacles before we can deploy 5G in Indonesia, particularly in terms of choosing the appropriate frequency. This assessment can help in assessing and resolving issues with spectrum, infrastructure, and other technical factors while also helping to understand the demands and characteristics of urban areas and determine the best spectrum allocation to fulfill the increasing demand for connectivity in urban areasThis study's methodology include a qualitative literature evaluation and mini-review of related studies. This study attempts to review 5G technology and discuss the difficulties and barriers that must be overcome for it to be used in urban settings. The findings of this study point to significant difficulties and barriers in the deployment of 5G networks in Indonesia. If rules are in place to support them, particularly those regarding the frequency band designated for 5G, all hurdles and obstacles will turn into possibilities. The primary frequency range used for 5G implementations—namely, the 700 MHz (low band) frequency, 3.3–4.2 GHz (mid band), and 24.2–29.5 GHz (high band)—must be accessed by 5G in order to meet the demands expected of 5G implementations. In order to increase outdoor capacity in cities with high user concentrations, high-band radio frequency offers convenience in satisfying user needs according to user density and area distribution. for instance, near other public areas, the major business district, and train and bus stations. In comparison to high band radio frequency, low band and medium band radio frequency have a greater coverage area, making them more suitable for use in rural areas with low population densities but strong demand for network services. The requirement for network infrastructure has the same issues as 4G network services, including a lack of coverage for all of Indonesia. Urban areas have more internet users than rural areas, therefore there is a need for suitable infrastructure to expand the reach of 5G technology, which has extremely low latency, address network capacity issues, improve coverage, and offer superior 5G NR services.

Keywords: 5G; 5G implementation; spectrum; urban areas; 5G challenges and obstacles

1. INTRODUCTION

Telecommunications technology has developed rapidly, especially with the presence of fifth generation cellular technology or 5G NR which was launched in 2020. 5G NR technology is a new generation of radio system and network architecture that will deliver broadband, ultra-reliable, ultra-low latency and massive network connectivity for people and the Internet of things [1]. Thus 5G technology rests on significant improvements in speed, range and reliability. The consequences of this 5G technology require network change solutions in the form of developing existing networks and implementing new potential networks, new distribution models including small cell dimensions, appropriate network infrastructure that can include interconnections between wireless networks and fiber optics, and access to spectrum. different frequency. This technology was developed to address the increasing demand for telecommunication services [2]. Currently, telecommunications services have become a basic human need. The availability of access to information that is very fast and reliable can help human activities and improve the quality of life. For this reason, the 5G NR technology standard is an important issue in every 5G mobile network implementation.

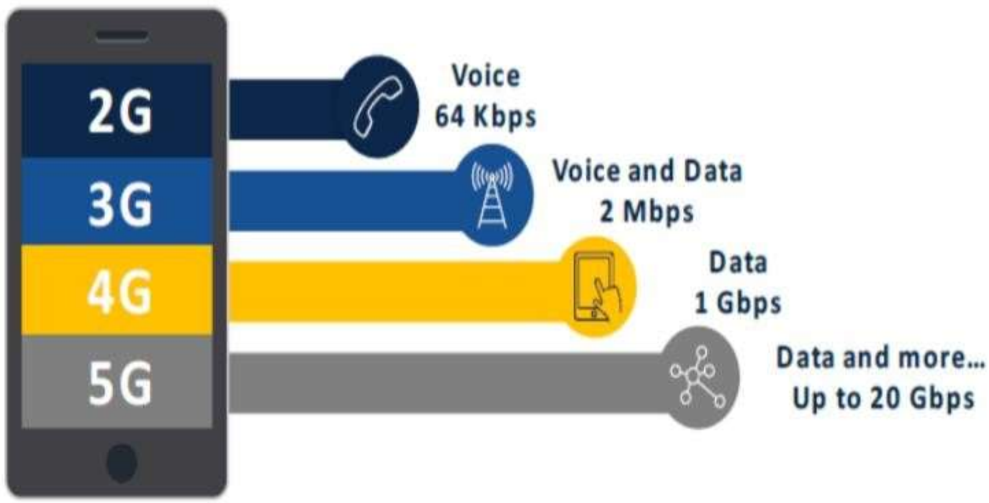

Figure 1. Evolution of mobile data speed

Figure 1 explains the evolution of cellular data based on its generation, namely:

a) Generation 2G (GSM): Data rates offered in 2G generally range from 9.6 kbps to 384 kbps.
b) 3G Generation (UMTS, HSPA): 3G data rates can reach 2 Mbps (megabits per second), which enables better use of internet, video streaming, and data based applications.
c) 4G Generation (LTE): 4G brings significant improvements in data rates with download speeds reaching tens to hundreds of Mbps or even more. This enables the use of high-quality video streaming applications, video conferencing, and various data services that require high capacity.
d) 5G Generation: The fifth generation (5G) offers very high data rates, reaching several gigabits per second (Gbps) or even more. It enables blazing-fast data transfers, supporting highly complex applications such as virtual reality (VR), augmented reality (AR), Internet of Things (IoT), and large numbers of simultaneously connected devices.

In the long term, 5G is expected to provide connectivity tailored to meet the specific demands of different groups of users, including certain industries (so-called 'verticals'). Verticals may require data connectivity both to be used internally for their own operations and to be embedded in the products and services they provide to their customers. Radio spectrum availability including a spectrum management framework and flexibility to allow operators to configure spectrum to achieve their business goals is also critical to achieving optimal 5G service [3].

In 5G networks, spectrum availability is one of the main challenges to support the huge traffic demands. Currently, the spectrum is already scarce and dense. Especially in very dense deployments, higher frequencies will be required and use a larger portion of the free spectrum spectrum. What frequency bands are available, will help determine the business case for 5G [4].

Table 1. Indonesia's 5G network frequency spectrum

Layer	Frequency Spectrum
Low	700/800/900 MHz
Middle	1,8/2,1/2,3/2,6/3,3/3,5 GHz
High	26/28 Ghz

The Indonesian government through the Ministry of Communication and Informatics has set a 5G network frequency spectrum in Indonesia which is prepared for low band at 700 MHz frequency, medium band at 3.5 GHz and 2.6 GHz frequency, and high band at 26 GHz and 28 GHz frequency.

In the application of the frequency spectrum for urban areas, you can use the 26 GHz frequency spectrum, which is a frequency that is categorized as a high high frequency because the 26 GHz frequency has a higher data rate characteristic. High band frequency spectrum will be more appropriate to be used to increase outdoor capacity in urban (urban) areas with a very high number of users. While the frequencies of 2.3 GHz, 2.6 GHz and 3.5 GHz are frequencies that are categorized in the medium band spectrum, this frequency spectrum has advantages in terms of capacity and coverage. This spectrum is more suitable for providing smooth cellular network coverage in urban areas and along highways. Mid-band spectrum also has speeds in the hundreds of megabits per second for several miles, so users can have 5G access, both outdoors and indoors. The use of these two spectrums is expected to produce a combination of maximum data rates and phenomenal capacity increases throughout the metropolitan area.

To address the various requirements of 5G usage scenarios in urban areas, 5G needs access to "high", and "low" frequencies. A certain amount of harmonic spectrum in each layer must be available for mobile operators to provide optimal 5G services to customers.

2. METHOD

The research method used is a mini-review and descriptive qualitative research method. Researchers conducted a literature study on related research, identification of titles, screening of abstracts, selection of full articles, and mini-reviews [5]. Next is described to describe 5G technology, challenges and obstacles to 5G implementation for urban areas in Indonesia.

3. RESULTS AND DISCUSSION

In the discussion section, it is broken down into several subtitles which explain the spectrum of 5G technology, Implementation Scenarios and challenges and obstacles in implementing 5G networks in Indonesia in urban areas.

3.1 The 5G technology spectrum

The new generation of mobile broadband technology is 5G. With higher data rates than previous technologies, 5G offers the highest-speed mobile broadband services ever and provides alternatives to long-distance access, such as fiber-optic-to-home (FTTH) connections [4].

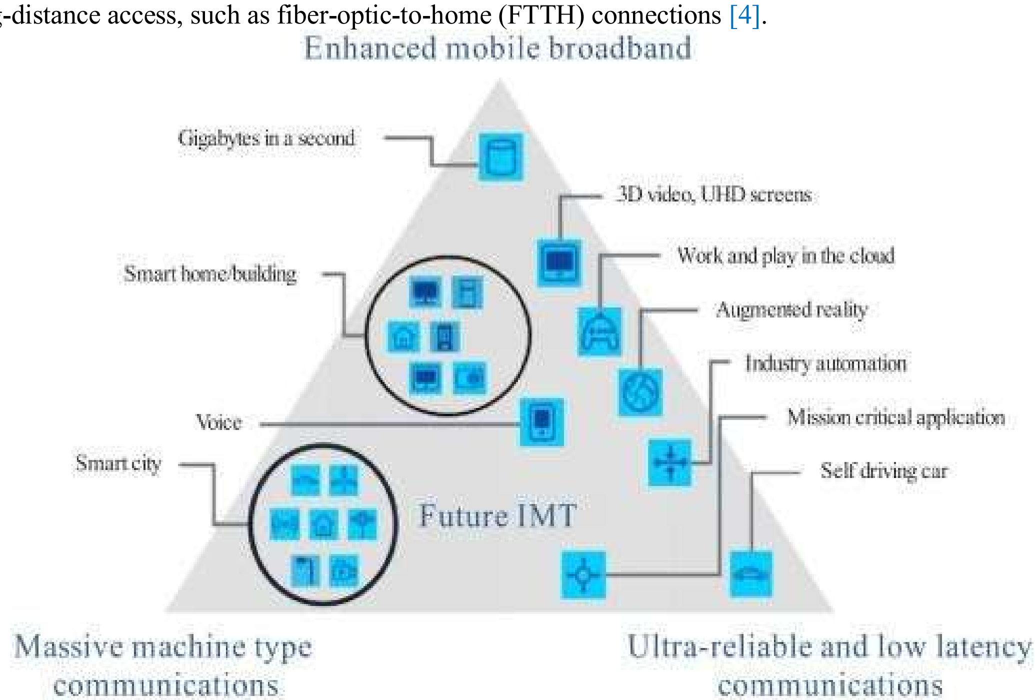

Figure 2. 5G Key usage scenario

Figure 2 describes 5G services and their applications can be grouped into three usage scenarios [6]:

a) Enhanced mobile broadband (eMBB): 5G is supposed to result in faster and more reliable mobile broadband, offering users a richer application experience.
b) Highly reliable and low latency communication (URLLC): The highest priority for this usage scenario is the latency and mobility parameters.
c) Massive machine communications (mMTC): This deployment scenario is illustrated with very large scale or large Internet of Things (IoT) applications.

5G will create opportunities for network operators to leverage new revenue streams by developing infrastructure that can deliver a wide range of innovative services for enterprises, including IoT (Internet of Things) applications and deep integration of connectivity [7]. The general target of 5G technology is as follows:

a) High data rates (1-10 Gbps);
b) Has a latency below 1 ms;
c) Cost and energy efficiency;
d) 1000x current capacity;
e) Extensive coverage using heterogeneous networks;
f) Stable connectivity.

As a wireless communication technology, frequency spectrum is one of the fundamental aspects of 5G requirements. The GSMA has classified this spectrum into three categories, each of which is more suitable for different 5G implementation scenarios [8].

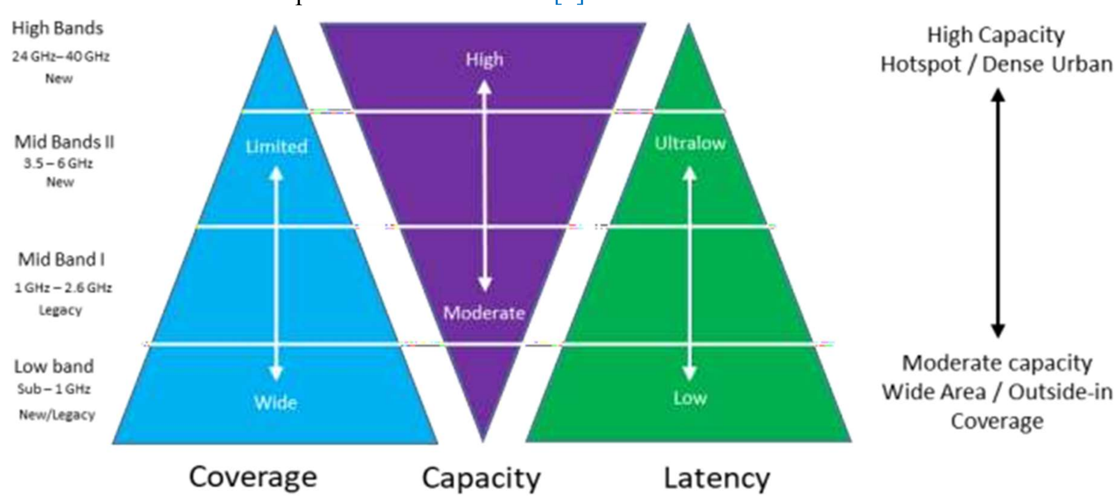

Figure 3. Frequency characteristics

Figure 3 explains the classification of the spectrum stated by GSMA in 3 categories namely:

a) *Sub 1 GHz.*
The spectrum in this category is very suitable to meet the needs of broad coverage and is suitable for use in rural areas. However, the weakness of spectrum bands in this category is that they cannot provide sufficient bandwidth.

b) *Sub 1-6 GHz.*
For the range between 1 GHz to 2.6 GHz, many spectrum bands have been utilized for mobile communications. When 5G is ready to roll out, some bands above 2.6 GHz can also be used. Although the bands in this range have advantages in terms of coverage and capacity, they are considered insufficient to support the 5G vision in terms of data rate without performing spectrum aggregation (carrier aggregation).

c) *Sub > 6 GHz*
Meanwhile, the spectrum in the other categories has a very wide channel, so it can meet the needs of high data rates. However, the coverage area of this spectrum is inversely proportional to its

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frequency, so its use is limited to small areas in urban areas and inside buildings. Rural areas still require lower spectrum to fulfill services. The spectrum above 6 GHz is very vulnerable to natural conditions and has difficulty penetrating buildings, so it is necessary to install an indoor antenna to serve customers inside the building.

The 5G technology spectrum includes different frequency bands to support different communication needs. This includes the sub-6 GHz spectrum, which covers the frequency range below 6 gigahertz (GHz), and the mmWave (Millimeter Wave) spectrum, which covers higher frequencies in the range of a few tens to several hundred GHz [9].

The sub-6 GHz spectrum is used to provide broad coverage and good penetration, so it can be used to provide wider and more stable 5G services in urban areas. This spectrum also enables better connectivity within buildings and areas with physical barriers [10].

On the other hand, mmWave spectrum offers very high data rates and large network capacities. However, these higher frequencies have more limited coverage and can be affected by physical obstacles such as buildings or vegetation. Therefore, mmWave spectrum is typically used in high-density environments such as city centers, train stations, or stadiums, where high data rates and large capacities are required [11].

To address the various requirements of 5G usage scenarios, 5G requires access to "high", "medium" and "low" frequencies. A certain amount of harmonic spectrum in each layer must be available for mobile operators to provide optimal 5G services to subscribers.

Figure 4. Benchmark of 5G deployment frequency plan

Figure 4 explains that many countries have planned to roll out 5G services using 3 main frequencies, namely:

a. Frequency 700 MHz for Low Band
b. Frequency 3.4 – 3.8 GHz for Mid Band
c. Frequency 26 – 28 GHz for High Band

In addition, based on **Figure 5**, it describes the 5G device ecosystem that supports these 3 main frequencies. Many 5G devices will start to be released on the market starting in the second half of 2019. Following are some of the key elements of the 5G device ecosystem as shown in **Figure 5** [12]:

a) Network Operator: Network operator is the party that provides 5G infrastructure and services to end users.
b) Device Manufacturers: Device manufacturers, such as smartphones, tablets and IoT devices, play an important role in providing hardware compatible with 5G technology.
c) Software Companies: Software companies play a role in developing applications, platforms and software solutions that support 5G deployments.

d) Content Providers: Content providers provide digital content that can be accessed via 5G networks.
e) Governments and Regulators: Governments and regulators have an important role in regulating and overseeing the use of frequency spectrum, issuing licenses, and setting policies related to security, privacy, and setting technical standards for 5G networks.
f) End Users: End users, such as consumers and enterprises, avail 5G services and applications provided by network operators and content providers. They can access the internet at much higher speeds, experience lower latencies, and take advantage of new features such as AR/VR (Augmented Reality/Virtual Reality) and IoT.

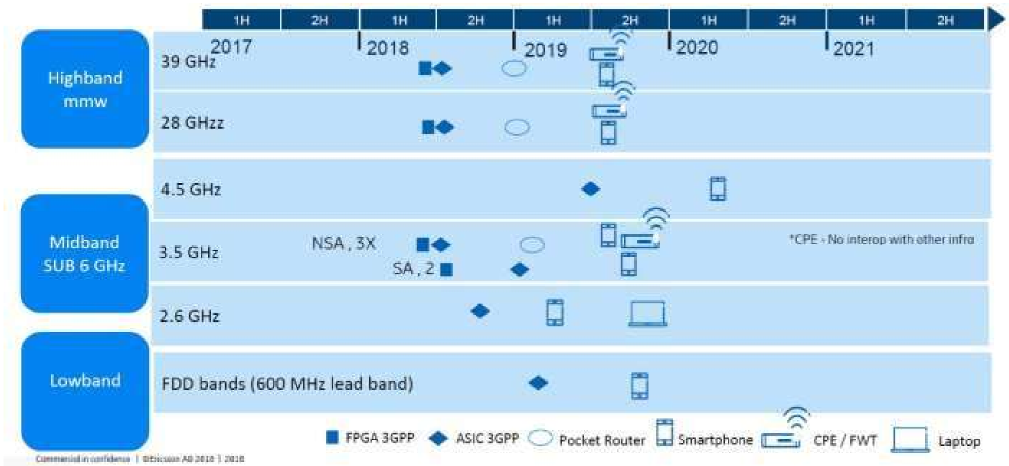

Figure 5. 5G device ecosystem

3.2 Scenarios for implementing 5G networks in urban areas in Indonesia

The 5G network will be implemented through various scenarios, and for that it is necessary to understand the vision and requirements needed to face the new era in networks. In the future, IoT and mobile Internet will become a core part of mobile communication technology. The advantage of 5G will lie in its ability to support very high data usage, such as playing online games, augmented reality, virtual reality, high-quality video streaming, and more. To meet these requirements, several things need to be improved in 5G implementation, such as virtualization, millimeter wave, beamforming, small cell, low latency, massive MIMO, and others. Nonetheless, if operators succeed in overcoming all these challenges, further preparations must be made so that 5G implementation can be widely successful in Indonesia, especially in urban areas.

Prior to implementing a 5G network, it is important to carry out careful mapping and planning. This includes identifying optimal cell tower (base station) locations, selecting appropriate frequencies, and mapping user population density to ensure adequate network coverage and capacity [13][14].

5G cell towers (base stations) need to be installed in strategic and optimal areas to provide wide coverage. In urban environments, 5G cell towers can be placed on tall buildings, street light poles, or other urban infrastructure to ensure optimal coverage [15].

Small cells are an additional solution used to increase the capacity and coverage of 5G networks in dense urban areas [16]. Small cells can be placed in small buildings, light poles or other facilities to ensure reliable and fast connectivity [17].

To support the high speed and low latency offered by 5G, extensive fiber optic provision is required to connect 5G cell towers with the core network [18]. This enables fast and stable data transfer between devices and network servers [19].

In dense urban areas, optimizing 5G network capacity is important to maintain service quality [20]. This involves using techniques such as MIMO (Multiple-Input Multiple-Output), frequency aggregation, and the use of a wider frequency spectrum [21].

If the 5G Network is successfully implemented widely in Indonesia, there will be a significant increase in mobile broadband and support the development of the Internet of Things (IoT) in various situations. The 5G network is perfect for improving broadband quality in urban areas in a cost-effective manner, so that it can handle the increasing demand for broadband. In an effort to achieve this goal, there are three approaches to getting more broadband.

First, increasing the transmit power or reducing noise will allow for increased signal levels or reduced interference in 5G networks. This will facilitate the use of better modulation techniques by increasing the signal to noise ratio (SINR). This more efficient modulation can be used by multiple users located close to the access point.

Second, the addition of frequency spectrum will support the 5G Network upgrade requirements. In this case, the Federal Communications Commission (FCC) may release a higher frequency spectrum (6 GHz to 80 GHz) to support higher capacities and data transfer rates. Global standardization and licensing will be required to implement 5G in the future.

Lastly, reducing the number of users per cell will also increase the overall capacity of the system. This can be achieved by bringing cells closer to each other, enabling better coverage capacity within a single cell by means of a workable channel radio. In addition, device manufacturers need to collaborate to expand MIMO (Multiple Input & Multiple Output) capabilities in order to develop successfully. With these steps, the 5G Network has the potential to bring significant improvements in mobile broadband in Indonesia, support the development of IoT, and meet the demand for high-quality connectivity in the coming era.

Figure 6. Acceleration of infrastructure development in 10 new urban strategic areas

Figure 6 describes strategic urban areas whose development is accelerated in line with the government's plan to move the national capital outside Java Island. This was done by the government to reduce the development gap between western and eastern Indonesia, as an example of a comparison of the highest coverage of 4G signal reception in the Java region, namely in Central Java province with 7765 or 12.54% of villages/kelurahans, and the least in North Kalimantan province with 227 or 0.37% village/kelurahan [22]. The government also provides themes for 10 areas that will be developed into metropolitan cities.

a. Medindingro (Medan City, Binjai City, Deli Serdang Regency, and Karo Regency) with a focus on the relationship between urban and rural areas.
b. Statue of Liberty (Palembang City, Banyuasin Regency, Ogan Ilir Regency, Ogan Komering Ilir Regency) with an emphasis on the role of a production and distribution center.

c. Jabodetabekpunjur (DKI Jakarta, Bogor Regency, Bogor City, Depok City, Tangerang Regency, Tangerang City, South Tangerang City, Bekasi Regency, Bekasi City, Cianjur Regency) with a focus on developing smart and resilient areas.
d. Bandung Basin (Bandung City, Bandung Regency, West Bandung Regency, Cimahi City) with the theme of digital creativity.
e. Kedungsepur (Kendal Regency, Demak Regency, Semarang City, Ungaran Semarang Regency, Salatiga City, and Purwodadi Grobogan Regency) with an emphasis on cultural and compact aspects.
f. Gerbangkeratosusila (Gresik Regency, Surabaya City, Sidoarjo Regency, Mojokerto Regency, Mojokerto City, Lamongan Regency, Bangkalan Regency) with the theme of green mixed used area development.
g. Banjar Bakula (City of Banjarmasin, City of Banjarbaru, District of Banjar, District of Barito Kuala, District of Tanah Laut) with a focus on urban agriculture (urban agriculture).
h. Sarbagita (Denpasar City, Badung Regency, Gianyar Regency, Tabanan Regency) with the theme of international tourism.
i. Mamminasata (Makassar City, Maros Regency, Gowa Regency, Takalar Regency) with an emphasis on developing urban seafront areas.
j. Bimindo (Manado City, Bitung City, North Minahasa Regency) with a focus on the fishery industry.

From this scenario, it appears that the government will focus on infrastructure development in urban areas as part of the implementation of the 5G Network in Indonesia. Thus, 5G will be applied especially in urban areas that have high population density and large network demands. One of the urban strategic areas that serves as an example is the candidate for the new State Capital (IKN) in Indonesia. The development of this IKN has the potential to become a model for implementing the smart city concept in Indonesia. However, the implementation of 5G in rural areas will be less effective due to the small population and the low level of demand for 5G networks.

3.2 Challenges of 5G network implementation in urban areas

Currently, many countries through their respective telecommunication operators are launching 5G networks and conducting tests before they are implemented, this is important considering the many challenges that will be faced in implementing 5G. Among these challenges, the biggest challenge is implementation in urban areas which have more complex challenges such as the presence of tall buildings in urban areas can be a challenge in providing consistent and robust coverage for 5G networks [23]. High-frequency 5G signals are more susceptible to interference from buildings and construction materials [24].

Urban areas often have limited spatial planning for the placement of 5G cell towers (base stations) [25]. Larger traditional cell towers may not be sufficient, requiring solutions such as small cells and DAS (Distributed Antenna Systems) [26].

The use of limited frequency spectrum and dense spatial planning in urban areas can make it difficult to allocate and manage spectrum for 5G networks [21]. Efficient spectrum coordination and allocation is necessary to ensure optimum network capacity and quality [27].

Extensive implementation of 5G networks in urban areas can result in high energy consumption [28]. The number of cell towers required, user density and high data demand can lead to increased energy consumption which needs to be managed efficiently [29].

While still seeing the development of this new generation connection. Operators will benefit from establishing new types of services, as discussed earlier, thereby providing opportunities to increase revenue. And from the point of view of the community as users, they can improve the economy through the use of internet technology. According to Grijpink's analysis, there will be a 60% increase in CAPEX in 2020-2025. In order to meet the performance parameters that have been determined in the 5G Network, technology, development, and infrastructure development are things that must be done by operators in Indonesia. On the basis of this huge economic opportunity, the government issued several policies to realize 5G technology in Indonesia, the government as a regulator has prepared 5 policies which were presented in the press release of the Ministry of Communication and Information in April 2022, namely: regulations, efficient and flexible business models, availability of radio frequency spectrum, reliable infrastructure, availability of equipment, ecosystems and digital talent. However, there are several challenges and obstacles that need to be underlined by the government.

First, the Ministry of Communication and Information has not yet touched on cyber security aspects after the implementation of the 5G network. Based on the BSSN traffic anomaly data report (2021), throughout 2020 Indonesia experienced cyber attacks reaching 495.3 million, an increase of 41 percent from the previous year 2019 which amounted to 290.3 million. The potential for cyber attacks will be even higher as 5G develops. Where changes in the ecosystem trigger the emergence of new attack patterns, as well as take advantage of super fast access to the 5G network. In this case, industry and all stakeholders must ensure safety standards in the application of the latest technology and provide security guarantees for the interests of the people and nation of Indonesia. One of the intended security guarantees is the fulfillment of device security certification that refers to global standards and the rules of the Indonesian National Standard (SNI).

Second, accelerating the fulfillment of radio frequency spectrum needs for 5G internet networks. Currently, the 5G networks deployed by the three cellular operators have different coverage and frequency bands. Telkomsel is deploying 5G at the 2.3GHz frequency band (50 MHz bandwidth), Indosat Ooredoo at 1.8 GHz (20 MHz bandwidth), and XL Axiata at 1.8 GHz (20 MHz bandwidth). In fact, the bandwidth needed for optimal 5G services is at least 80-100 MHz. In addition, the frequency spectrum used is also not the optimal spectrum for use as a 5G network. The spectrum that can be said to be mature for 5G networks is in the 700MHz, 2.6 GHz and 3.5 GHz frequencies. Therefore it is important for the government to immediately follow up on the refarming process in these 3 radio frequency spectrums in order to accelerate the implementation of 5G as a whole. Mainly related to the analog switch off (ASO) program which has been postponed several times. Third, the digital divide is still wide. This is because 4G cellular coverage is still concentrated in commercial areas such as Java, Sumatra and parts of Kalimantan. The availability of broadband access is not evenly distributed throughout Indonesia which can hinder digitalization in all sectors. The government must continue to work to eliminate the digital divide in Indonesia, for the sake of realizing overall people's welfare, not only in urban areas, or even on certain islands.

3.3 Barriers to 5G implementation in urban areas

Not only does it have challenges, 5G technology also has drawbacks, including the lack of penetrating power. Unlike its predecessor technology which can penetrate the barrier better. For urban areas that have many obstacles such as walls and concrete, the performance of 5G technology will be less than optimal to penetrate barriers.

Implementing 5G in urban areas requires a robust and complex infrastructure, including base stations, fiber optic networks, and reliable backhaul. However, procurement, installation and maintenance of this infrastructure can pose significant technical and logistical challenges [30]. Urban areas often have limited spatial planning for the placement of 5G network infrastructure, such as cell towers and supporting equipment [31]. This can make it difficult to obtain the necessary permits and space to build a 5G infrastructure [32].

5G requires access to a wide spectrum of frequencies to support high speeds and capacities. However, in dense urban areas, spectrum availability can be limited and requires efficient management and proper allocation [33]. Tall buildings, concrete buildings and other urban structures can hinder the propagation of 5G signals that use high frequencies [34]. This can reduce coverage and signal quality in dense urban areas [35].

The high frequencies used in the mmWave spectrum can face greater signal propagation challenges, especially in urban areas with tall buildings and other physical barriers. Interference between adjacent base stations can also affect signal quality [36].

Urban areas tend to have high population densities and large network demands. To address this need, a larger number of base stations and careful network planning are needed to handle high user volumes and ensure good quality of service [37]. Managing user density and ensuring sufficient network capacity is a barrier to 5G implementation in urban areas [38].

In 5G technology, the resulting bandwidth is indeed increasing, but the area served can be reduced. Likewise, it is believed that devices operated on 5G technology are not as wide as the range of 4G. So that the coverage area that can be served by 5G towers is narrower. Likewise, millimeter waves on 5G in urban areas have low power. Under these conditions it will be difficult to pass through buildings, trees, walls and other obstructions without any disturbance at all [39].

Apart from the drawbacks above, radio frequency in urban areas is very congested, this is a separate obstacle for the use of 5G technology. The 3G and 4G technologies that were the predecessors of 5G have made up the full radio spectrum available today. Coupled with the implementation of 5G technology, the full spectrum is available. The full use of the radio frequency spectrum is a new problem [39]. However, in the future, improving the performance of 5G technology in Indonesia will be very important [40]. However, privacy security issues are also one of the drawbacks that 5G technology has to face. Privacy and security issues on the internet are crucial because the world's dependence on the internet network is increasing [39].

According to the latest data from OpenSignal, it is easier for urban areas with high population density in Indonesia to access 4G internet network compared to rural areas which have a smaller population [41]. OpenSignal uses data from the Central Bureau of Statistics (BPS) to classify areas based on population density, and although 89% of these areas have access to 3G and 4G networks, when viewed from the number of areas, the availability of 3G and 4G networks only reaches 52% throughout Indonesia. While the availability of 4G networks in Indonesia is high, the speeds are low, especially in urban areas with a population density of more than 1,000 people per square kilometer, where 4G connections account for only 89.7% of the total time connected to the network (4G availability). Meanwhile, areas with the lowest population density, which is 50 people per square kilometer, can only reach the 4G network for 76% of the total time connected to the network. The difference between the two types of areas reaches 13%. This will be an important consideration in dealing with the potential reach of 5G technology in the future. Several cities that have the potential to implement 5G networks include Jakarta, Surabaya and Medan [42].

4. CONCLUSION

The implementation of 5G in urban areas has great potential to deliver high connectivity, faster data rates and innovative services such as IoT, AR and VR. This will open up new opportunities for digital transformation. Further research can be conducted to review new opportunities for digital transformation from implementing 5G in cities related to 5G technology for increasing economic growth, and improving the quality of life in cities. It is also necessary to review further about regulations that have not been explained in detail in this study because good regulations and supportive policies are very important to support 5G implementation in urban areas. This includes adequate spectrum allocation, efficient licensing, and a clear framework for collaboration between network operators, governments, and other stakeholders. Strong cooperation is required in terms of infrastructure planning, spectrum allocation, investment, and management of potential conflicts to achieve successful implementation. It is also necessary to review future research on 5G investments that have been carried out by both network operators and the government, especially in urban areas that require significant investment in infrastructure, technology and human resource training. Proper investment in network, spectrum, and operational capabilities will be key to ensuring the successful implementation of 5G networks in urban areas.

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