The 5G Spectrum Standardization

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The rapid increase in data traffic caused by the proliferation of smart devices has spurred the demand for extremely large-capacity wireless networks. Thus, faster data transmission rates and greater spectral efficiency have become critical requirements in modern-day networks. The ubiquitous 5G is an end-to-end network capable of accommodating billions of linked devices and offering high-performance broadcast services due to its several enabling technologies.

5G spectrum communication

1. Introduction

The International Telecommunication Union (ITU) was founded in 1865 as a result of a global agreement between the private and public sectors on the visibility of enabling the connection of communication networks, allocation of radio frequency bands, and development of international technical communication standards [1]. The main responsibility of the ITU is to create standards for unified communications that will allow networks and technologies to be integrated globally, thus enabling unrestricted access to telecommunications services. In relation to IMT systems, the ITU regulates each element of the radio communication system. The ITU is also in charge of harmonizing and standardizing the frequency band requirements for mobile communication technologies to promote cross-platform interoperability between current and emerging technologies. The ITU oversees, assesses, and develops the requirements for 5G technology [2].

The ITU Radio regulations outline the spectrum assignments that ITU-R has been working on over the years for various applications and other services. There are several spectrums identified for IMT systems. A list of these bands and the corresponding radio communication conference that approved them are contained in [3]. Although some preferences are being established, 5G theoretically can be deployed in any of the specified bands.

The USA is willing to use the 3.5 GHz (3550–3700 MHz) shared band as well as the 600 MHz licensed spectrum (617–652/663–698 MHz). The radio frequency below 1 GHz that Europe has selected for 5G is the 700 MHz band (694–790 MHz), but the leading pioneering 5G spectrum should be 3.4–3.8 GHz. To enable more downlinks, the 1.5 GHz band (1427–1452/1492–1518 MHz) is also being considered [4][5]. Other nations are investigating the optimal band to roll out their 5G services. Japan is considering the frequencies of 3600–4200 MHz and 4400–4900

MHz for the testing 5G deployment. Nigeria is considering the 3500 MHz and 26,000 MHz frequencies, while in China, the frequencies being considered are the 3300–3600 MHz and 4800–4990 MHz bands [3][6][7].

Due to the steadily increasing data traffic, more spectrum resources are required to support upcoming mobile communication networks. Furthermore, it is significant to remember that each nation will have different specifications for its national spectrum. Therefore, this section covers discussions on the different spectrum allocations and assignments for the 5G network and the sub-6GHz and above-6GHz frequencies. Furthermore, the worldwide trials and the different deployment modes of the 5G network are presented.

2. Spectrum Allocation and Assignment

A sufficient radio spectrum in the low-, mid-, and high-frequency bands is essential for the deployment of a 5G network to support the many use cases and applications. The 5G standard separates two carrier frequency ranges known as FR1 (sub-6GHz with TDD and FDD), and FR2 (mmWave band, 23–53 GHz with TDD) [5][8]. While some of these frequencies will be allocated particularly for the deployment of the 5G network, other frequencies will need to be obtained from existing communication services. In [3], the comprehensive list of available frequency ranges for the 5G FR1 and FR2 frequencies are presented, where frequencies in FR1 support TDD, FDD, and Supplemental Downlink/Uplink (SDL UL/DL); frequencies in FR2 support only TDD, which uses the same frequencies for transmission from both the device and the base station but are coordinated to transmit at different times to reduce interference. By contrast, with FDD, the base station and the device each transmit data using a separate frequency.

3. The FR1 Band

In addition to supporting wide areas and indoor/outdoor coverage, 5G also offers high data rates. As a result, the spectrum below 6 GHz is critical to the 5G solution [7][9]. Over 1200 MHz of the spectrum in Europe’s frequency range between 694 MHz and 3800 MHz has already been harmonized for mobile broadband. The key frequency band appropriate for the launch of 5G in Europe even before 2020 is in the 3400–3800 MHz range, which has been harmonized for mobile networks and has up to 400 MHz of the continuous spectrum. This spectrum could allow Europe to be a global leader in 5G or pre-5G deployment [10].

4. The FR2 Band

High data speeds expected from 5G will require substantially wider bandwidths than in the past. Only higher frequency bands (above 6 GHz) have those extraordinarily high data rates. In order to provide faster data speeds and lower latency, it is projected that new wireless solutions at higher frequencies—millimeter wave bands—would be introduced. To fulfill all of the 5G performance goals, such as multi-gigabit-per-second data rates, frequency bands even over 24 GHz must be implemented. Very low latency has implications for millimeter wave deployments because of their small cell sizes and highly directional antennas [6][7].

5. Worldwide 5G Trials

Commercial 5G networks have already begun operating in several nations worldwide. Other nations that have not achieved full implementation have likewise advanced in their deployment of the network. **Table 1** lists the regions and operators for each of the current global 5G deployments. However, virtually every Asian country has also invested in 5G technology. The first 5G network was deployed in South Korea, and it is projected that the country will continue to lead the way in the adoption of the technology. Other nations have likewise advanced in their deployment of 5G technology recently.

Table 1. Global 5G Deployment Statistics (source: GSA).

Region	Country	Sub-Region	Operator	Status	Launch Date	Freq. MHz
AFRICA	Nigeria	West Africa	MTN	Live	Aug. 2022	3500
	South Africa	Southern Africa	Vodacom	Live	May 2020	3500
ASIA	Saudi Arabia	Western Asia	Zain	Live	Oct. 2019	
	Hong Kong; SAR China	Eastern Asia	3 (CK Hutchison)	Live	Apr. 2020	
	Hong Kong; SAR China	Eastern Asia	China Mobile	Live	Apr. 2020	
	Japan	Eastern Asia	SoftBank	Live	Mar. 2020	2500
	Japan	Eastern Asia	KDDI	Live	Mar. 2020	
	Japan	Eastern Asia	NTT DOCOMO	Live	Mar. 2020	3700/4500/28,000
	Hong Kong; SAR China	Eastern Asia	csl (HKT)	Live	Apr. 2020	3300
	Thailand	Southeastern Asia	TrueMoveH (True Corporation)	Live	Mar. 2020	2600
	Thailand	Southeastern Asia	Advanced Wireless Network (AIS)	Live	Mar. 2020	2600
	Saudi Arabia	Western Asia	STC	Live	Sep. 2019	3500

Region	Country	Sub-Region	Operator	Status	Launch Date	Freq. MHz
	Philippines	Southeastern Asia	Globe Telecom	Live	Feb. 2020	
	Qatar	Western Asia	Ooredoo	Live	Jan. 2020	
	China	Eastern Asia	China Unicom	Live	Oct. 2019	
	China	Eastern Asia	China Mobile	Live	Oct. 2019	
	China	Eastern Asia	China Telecom	Live	Oct. 2019	
	Qatar	Western Asia	Vodafone	Live	Aug. 2019	
	Maldives	Southern Asia	Dhiraagu (Batelco)	Live	Aug. 2019	
AMERICA	United States of America	Northern America	GCI	Live	Apr. 2020	
	Canada	Northern America	Rogers	Live	Mar. 2020	
	United States of America	Northern America	T-Mobile (Deutsche Telekom)	Live	Apr. 2020	
	United States America	Northern America	US Cellular (TDS)	Live	Mar. 2020	
EUROPE	Netherlands	Western Europe	Vodafone-Ziggo (Liberty Global/Vodafone) (Liberty Global/Vodacom)	Live	Apr. 2020	1800
	Hungary	Eastern Europe	Magyar Telekom	Live	Apr. 2020	3600
	Belgium	Western Europe	Proximus	Live	Apr. 2020	
	Norway	Northern Europe	Telenor	Live	Mar. 2020	
	United Kingdom	Northern Europe	3 (CK Hutchison)	Live	Feb. 2020	

Region	Country	Sub-Region	Operator	Status	Launch Date	Freq. MHz
	Finland	Northern Europe	DNA	Live	Jan. 2020	
	Austria	Western Europe	A1 Telekom	Live	Jan. 2020	3500
	Latvia	Northern Europe	Tele2	Live	Jan. 2020	3500
	Romania	Eastern Europe	Orange	Like	Nov. 2019	
	Ireland	Northern Europe	eir	Live	Oct. 2019	
	United Kingdom	Northern Europe	O2 (Telefonica)	Live	Oct. 2019	
	Hungary	Eastern Europe	Vodafone	Live	Oct. 2019	3600
	Finland	Northern Europe	Telia	Live	Oct. 2019	4500
	Austria	Western Europe	3 (CK Hutchison)	Live	Oct. 2019	
	Ireland	Northern Europe	Vodafone	Live	Aug. 2019	

vices over ectures to [11] etwork for agement, out an end-to-end 5G network i e this method for the rapid and cost-effective deployment of 5G networks. Deploying a 5G network in NSA mode can provide faster data speeds but cannot guarantee all of the 5G objectives. However, with the assistance of an existing 4G network, operators can implement 5G, promoting early adoption of the technology, which is why the 3GPP released a preliminary set of NSA requirements before the full 5G standard was released. A cell in the NSA approach performs the control plane activities, while the user plane connection is provided jointly by both the LTE eNodeB and the 5G gNodeB [6][12]. NSA architecture will allow mobile operators to start 5G deployment since the 4G infrastructures can be retained for deployment and, thus, reduce network operation time. The cost of network deployment will also be reduced since operators can rely on existing 4G infrastructures. However, it is important to note that the NSA design is incapable of matching the exceptional performance of 5G networks in terms of speed, low latency, high data rate, and other factors.

- Standalone (SA): The 5G NR Standalone mode differentiates between LTE and 5G networks by defining a separate core and radio access network for each network. This enables the true realization of 5G goals and end-to-end 5G connectivity. A simpler core network with lower operating costs is possible with 5G. The ability to arrange different types of UEs in separate network slices, each with a different QoS and set of rules, is a new feature in the 5G core network when compared with the 4G core network. Because UEs with lower resource requirements can be placed on a separate network slice, systems with the same capacity can handle more UEs more effectively than if a single policy was used for all UE types. This prevents the allocation of unnecessary resources. This is especially helpful in facilitating significant IoT installations. Since most IoT devices are sensors that do not need very low latency or high data rates, these UEs can be placed in a different network slice. Critical Internet of Things deployments can be placed in a different network slice with low latency [13]. The SA deployment method ensures operators can achieve the highest level of performance promised by 5G implementation. The revolutionary nature of 5G is a result of the fast data transfer rates and extremely low latency it offers, among many other enhancements. This mode was created to function on the 5G FR2 frequency since the entire SA architecture is made up of 5G infrastructures. This will ensure the 5G network aimed at extremely low latency and large data speeds is achieved. Huge infrastructure costs associated with the SA roll-out are a significant obstacle since telecommunication service providers would need to completely redesign their current LTE networks.

7. Application and Device Benchmarking in 5G Networks

In a typical 5G network, application developers and device manufacturers should be able to test and benchmark new mobile applications, devices, and services. A critical aspect of the mobile communications market is to guarantee the correct and efficient behavior of dense applications and massive devices to satisfy the requirements of end users. Although these mobile devices have been standardized, there is no adequate consensus on the benchmarking or testing methodologies at the application level. Thus, the need to identify reference deployment scenarios and the definition of new KPIs and QoE metrics becomes imperative.

It is worthwhile considering three distinct areas for testing and benchmarking. These include applications, devices, and mobile network operators. Interestingly, Small and Medium Enterprises (SMEs) provide these applications and often find accessing various testing processes in real-time wireless networks difficult. Another critical challenge for SMEs is understanding the requirements of standardized testing schemes and their associated products. Unfortunately, the enormous testing costs and the need for technical expertise often discourage SMEs from conducting robust tests.

A typical testbed scenario is shown in **Figure 1**. The architecture comprises the Orbit Management Framework (OMF), Orbit Measurement Library (OML), and OMF Experiment Description Language (OEDL). The OMF controls the experimental execution in testbeds. The OEDL technically describes the execution of an experiment and specifies the results in readable formats. Also specified is the Experiment Controller (EC) that interprets and orchestrates the OEDL scripts. Finally, the Resource Controller (RC) manages each resource in the testbed, and there are RCs for managing smartphones, among others.

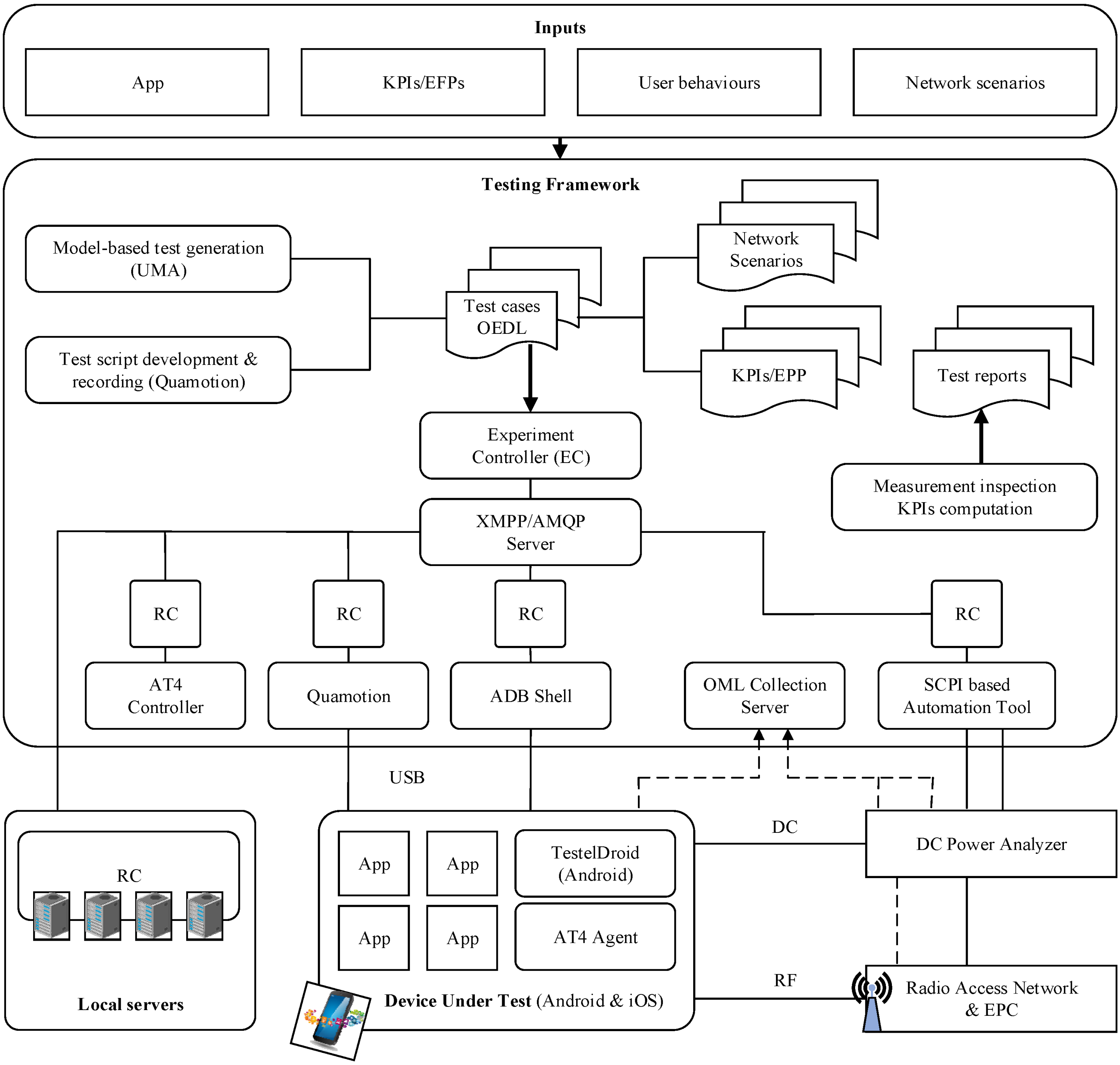

Figure 1. 5G Network Testbed and Benchmarking Scenario.

Last, the Advanced Message Queuing Protocol (AMQP) manages communication between the EC and RCs and measures data obtained through the OML. Finally, the test automation platform manages the DC power analyzer and the eNodeB emulator for design verification and signaling testing. In comparison, the DC Power Analyser helps to characterize power consumption in mobile devices.

References

1. ITUR. P.1814 Prediction Methods Required for the Design of Terrestrial Free-Space Optical Links; International Telecommunication Union Radiocommunication Recommendations: Geneva, Switzerland, 2007.
2. ITU. Provisional Final Acts. In Proceedings of the World Radiocommunication Conference 2019, Sharm El-Sheikh, Egypt, 28 October–22 November 2019; 2019.
3. Union, A. Report of the 3rd Ordinary Session of the Specialized Technical Committee on Communication and ICT, Sharm El Sheikh, Egypt, 25–26 October 2019. 2020. Available online: https://au.int/en/documents/20191025/ministerial-report-3rd-ordinary-session-african-union-specialized-technical (accessed on 5 December 2022).
4. Lee, J.; Tejedor, E.; Ranta-aho, K.; Wang, H.; Lee, K.-T.; Semaan, E.; Mohyeldin, E.; Song, J.; Bergljung, C.; Jung, S. Spectrum for 5G: Global Status, Challenges, and Enabling Technologies. IEEE Commun. Mag. 2018, 56, 12–18.
5. Sowande, O.A.; Idachaba, F.E.; Ekpo, S.; Faruk, N.; Uko, M.; Ogunmodimu, O. Sub- 6 GHz 5G Spectrum for Satellite-Cellular Convergence Broadband Internet Access in Nigeria. Int. Rev. Aerosp. Eng. (IREASE) 2022, 15, 85.
6. Morgado, A.; Huq, K.M.S.; Mumtaz, S.; Rodriguez, J. A Survey of 5G Technologies: Regulatory, Standardization and Industrial Perspectives. Digit. Commun. Netw. 2018, 4, 87–97.
7. Shafi, M.; Molisch, A.F.; Smith, P.J.; Haustein, T.; Zhu, P.; De Silva, P.; Tufvesson, F.; Benjebbour, A.; Wunder, G. 5G: A Tutorial Overview of Standards, Trials, Challenges, Deployment, and Practice. IEEE J. Sel. Areas Commun. 2017, 35, 1201–1221.
8. Dilli, R. Analysis of 5G Wireless Systems in FR1 and FR2 Frequency Bands. In Proceedings of the 2020 2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA) 2020, Bangalore, India, 5–7 March 2020.
9. Faruk, N.; Bello, O.W.; Sowande, O.A.; Onidare, S.O.; Muhammad, M.Y.; Ayeni, A.A. Large Scale Spectrum Survey in Rural and Urban Environments within the 50 MHz–6 GHz Bands. Measurement 2016, 91, 228–238.
10. Ancans, G.; Bobrovs, V.; Ancans, A.; Kalibatiene, D. Spectrum Considerations for 5G Mobile Communication Systems. Procedia Comput. Sci. 2017, 104, 509–516.
11. Liu, G.; Huang, Y.; Chen, Z.; Liu, L.; Wang, Q.; Li, N. 5G Deployment: Standalone vs. Non-Standalone from the Operator Perspective. IEEE Commun. Mag. 2020, 58, 83–89.
12. Salami, G.; Faruk, N.; Surajudeen-Bakinde, N.; Ngobigha, F. Challenges and Trends in 5G Deployment: A Nigerian Case Study. In Proceedings of the 2019 2nd International Conference of the IEEE Nigeria Computer Chapter (NigeriaComputConf) 2019, Zaria, Nigeria, 14–17 October 2019.

13. Kumar, S.; Kumar, A. 5G New Radio Deployment Modes. Int. Res. J. Eng. Technol. (IRJET) 2020, 3419–3422.