Evolution of mobile networks and seamless transition to 5G

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Abstract. The evolution in mobile networks continues with the next 5G technology, which is already released in 2020, and also has a distinct advantage from its predecessor. This difference also results in measurements of Quality of Service (QoS) and Quality of Experience (QoE) which are very diverse because there is no specific standard on 5G technology. This paper gives a review of an approach in the measurement as part of the process of QoS and QoE. In addition, this paper provides measurements on how to predict the availability of new 5G. The measurement process is related to the location and conditions, where 5G technology will be implemented.

1. Introduction
The first mobile cellular networks of the fifth generation 5G are expected to be available to the end user in 2020. The technology will be a combination of different networks, technologies and applications, and there will be no one universal 5G network. It is expected to have a set of different frequency spectra with different access options for different needs. Wider bandwidths will be used, the connection time is expected to be between 1 and 5 ms, ensuring full availability of radio coverage. 5G should provide real-time communication of time-dependent applications, transmission speeds in the DL direction up to 20 Gbps and up to 10 Gbps in the UL direction, complete reliable communication, improved energy efficiency, direct communication between mobile devices, etc. [1, 2,3]

The standardization of 5G technologies and solutions should be completed by 2021, so 5G currently means only fragmented solutions, which in the future will become part of the overall IMT2020 solution. Such solutions have already been implemented in various countries, but they are still local and test in nature and don’t provide all the planned functionality of IMT2020 networks. [4,5]

5G networks significantly extend the limited functionality of previous generations of mobile networks (figure 1) [6]. The main functional characteristics of 5G networks can be summarized to:
- Enhanced Mobile Broadband (eMBB);
- Ultra-Low Latency Reliable Communication (ULLRC);
- Massive IoT/IoT, mMTC (massive Machine Type Communication).
Technical characteristics and parallel between the generations of mobile cellular systems, mostly related to data transmission are presented in the article [3].

The paper describes characteristics of gNodeB and UE main parameters, measurements on how to predict the availability of new 5G in Sofia, measuring the important data [7, 8, 9].

2. 5G mobile networks

5G provides the ability to upgrade through cognitive radio technology, which includes various important features, such as the ability of devices to identify their geographical location, as well as time, temperature and more signals in its work environment. In addition, it timely distinguishes changes in its environment and responds accordingly to ensure continuous quality of service (QoS).[10, 11] Figure 2 shows the 5G system model, which is entirely IP based, designed for wireless and mobile network.[2]
The 5G network architecture has been developed for the exchange of all types of data and the provision of various services using technologies such as network virtualization Network Function Virtualization (NFV) and software defined networks Software Defined Networking (SDN) [12, 13]. The new technology is mainly characterized by ultra-broadband mobile access improved mobile broadband, eMBB, URLLC, mass connection of various sensors and devices from the world of Internet of Things (IoT), mMTC [14, 15].

The system consists of a main user terminal and then a number of independent autonomous radio access technologies. Each of the radio technologies is considered as an IP connection to the outside world. IP technology is designed to provide sufficient control data for the appropriate routing of IP packets associated with certain application connections, i.e. sessions between client applications and servers somewhere on the Internet. In addition, in order to make packet routing available, it must be fixed in accordance with the given user policies (shown on figure 2).

The main idea of NanoCore is the combination of three innovation technologies:

- All IP Network (AIPN);
- Nanotechnology;
- Cloud Computing.

As shown in figure 2, the 5G NanoCore is a convergence point for other technologies that have their own impact on the existing wireless network. Interestingly, its design makes it easier for NanoCore to work in parallel multimode, including all IP network modes and 5G network mode. In this mode (as shown in the image below), all RAN network technologies and different access networks (DAT) are controlled. Because the technology is compatible and manages all new deployments (based on 5G), it is more efficient, less complex and more powerful. [2]

Each service mode can be opened under a 5G new deployment mode such as World Combination Service Mode (WCSM). WCSM is a wonderful feature of this technology; for example, if a professor writes on a whiteboard in a country, it can be shown on another whiteboard in any part of the world except a conversation and a video. In addition, a new service can be easily added via a parallel multimode service [4, 16].

3. Experimental results

Compared to the generation used for mobile coverage, different coverage is achieved, and with each more modern generation, the coverage area decreases, at the expense of the services used. The coverage is in accordance with a decision of the Communications Regulation Commission [8], as the admissible levels according to the decision of CRC are presented in table 1 and are shown on figure 3.

| Level of coverage | 2G network (GSM) X-level of the signal (RxLev) | 3G network (UMTS) X-level of the signal (CPICH RSCP) | 4G network (LTE) X-level of the signal (RSRP) | Color |
|-------------------|---------------------------------------------|-----------------------------|-----------------------------|-------|
| Bad coverage      | $X \leq -104 \text{ dBm}$                 | $X \leq -105 \text{ dBm}$   | $X \leq -110 \text{ dBm}$   | White |
| Not good enough   | $-85 \text{ dBm} < X < -104 \text{ dBm}$  | $-85 \text{ dBm} < X < -105 \text{ dBm}$ | $-110 \text{ dBm} < X < -100 \text{ dBm}$ | Green |
| Good              | $-85 \text{ dBm} \leq X < -65 \text{ dBm}$| $-85 \text{ dBm} \leq X < -65 \text{ dBm}$ | $-100 \text{ dBm} \leq X < -80 \text{ dBm}$ | Yellow|
| Very good         | $X \geq 65 \text{ dBm}$                   | $X \geq 65 \text{ dBm}$     | $X \geq 80 \text{ dBm}$     | Red   |

The mobile coverage of 5G now (September 2020), is still a confidential project and there is no official information about the coverage and capacity of base stations in Bulgaria. In order to be able to present practical results, officially presented results are presented from city, where 5G technology for mobile coverage works in the same frequency range in which it will work in the future in Bulgaria - 3.3GHz - 3.8GHz.

The presented results show forecast data, which will most likely be valid for Bulgaria as well. The presented data show analysis and measurements of coverage in tests of 5G technology [7, 8].
Figure 3. Coverage of 2G, 3G and 4G in Sofia

Figure 4. Prediction of NR coverage

The main parameters for main gNodeB are presented in table 2, there are presented Cell Edge Rate in Mbps. The thresholds of NRSRP are for area probability 90% and 75% for edge probability.
Table 2. 5G NR Link Budget.

| Data Channel Type | PUSCH (UL) | PDSCH (DL) |
|-------------------|------------|------------|
| NR Duplex Mode    | TDD        |            |
| System Frequency Band | n78 (3500MHz) |      |
| System Bandwidth  | 60         |            |
| Min MCS requirements | 16 QAM     | 64 QAM |

| Transmitter gNodeB |
|--------------------|
| Max Tx power per port (dBm) | 23 | 43 |
| Tx Antenna Gain (dBi) | 2 | 24.7 |

| Receiver (UE) |
|---------------|
| Minimum SUNR (dB) | -0.54 | -2.29 |
| Receiver Sensitivity (dBm) | -107.23 | -91.97 |
| gNodeB Antenna Height (m) | 27.77 |
| Area probability | 90% |
| Edge Probability | 75% |

A Rohde & Schwarz NR [9, 16] measuring instrument and a broadband measuring antenna were used to test the considered 5G coverage [4]. The device registers data from points in single input mode, single output (SISO) in more than 30 km in the surrounding streets. The second test is a stationary bandwidth test using a 5G UE (consumer equipment) placed through the window in the back of the car.

The UE used 2x2 Multiple Input, Multiple Output (MIMO) and speed tests were performed using a TCP based speed testing service on a smartphone connected to the UE via 5 GHz Wi-Fi network.

Figure 5. Coverage of 5G compared to the RSRP levels by numerical methods
Figure 5 shows the coverage of 5G compared to the RSRP levels by numerical levels. The figure 6 shows the same coverage but with applicable measurements. The results are in normal relative differences.

The performed measurements of RSRP levels, compared to the needed values, allow a seamless introduction of the new technology. The 5th generation communications are compatible with the current location of base stations, and modern technologies allow the implementation of 5G modules in now existing ones.

4. Conclusion
The experimental results shown by the used equipment of different generations and analysis of existing coverage by mobile operators is possible to use a common collocation area for the equipment of different generations of cellular networks. The technology for mobile communications of the 5th generation are compatible with the current location of base stations, and modern technologies allow the implementation of 5G modules in existing ones.

From the presented solutions for coverage of different generations of mobile networks, currently operating on the territory of the Republic of Bulgaria, a complete idea can be obtained about the coverage provided by mobile operators.

References
[1] Iliev T, Mihaylov G, Bikov T, Ivanova E, Stoyanov I and Radev D 2017 LTE eNB traffic analysis and key techniques towards 5G mobile networks," 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, 2017, pp 497-500, doi: 10.23919/MIPRO.2017.7973476
[2] Mihaylov G, Iliev T, Bikov T, Ivanova E, Stoyanov I, Keseev V and Dinov A 2018 Test cases and challenges for mobile network evolution from LTE to 5G, 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia 2018, pp 449-452, doi: 10.23919/MIPRO.2018.8400085
[3] Lopa V 2015 Evolution of mobile generation technology: 1G to 5G and review of upcoming wireless technology 5G. *International journal of modern trends in engineering and research* 2.10, pp 281-290
[4] Iliev TB, Mihaylov GY, Stoyanov IS and Ivanova EP 2020 LTE and 5G NR – Coexistence and Collaboration, 43rd International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia, pp 389-392, doi: 10.23919/MIPRO48935.2020.9245123

[5] Iliev T, Nikolaev N, Mihaylov G, Ivanova E, Stoyanov I and Radev D 2018 A Critical View of the NFV Dataplane Implementations for 5G Networks, 26th Telecommunications Forum (TELFOR), Belgrade, 2018, pp 1-4, doi: 10.1109/TELFOR.2018.8611980

[6] https://www.rohde-schwarz.com/id/solutions/test-and-measurement/mobile-network-testing/stories-insights/article-real-5g-ue-measurements_252646.html

[7] Angelov K and Sadinov S 2019 Investigation of the Reliability of Service Equipment in Communication Networks, 27th National Conference with International Participation (TELECOM 2019), Sofia, Bulgaria, pp 58-61, doi: 10.1109/TELECOM48729.2019.8994894

[8] https://crc.bg/files/_bg/resh_512-07_08_2014.pdf

[9] CURRY, Tristan; ABBAS, Robert. 5G Coverage, Prediction, and Trial Measurements. arXiv preprint arXiv:2003.09574, 2020

[10] Tikhvinskiy V, Bochecka G, Gryazev A and Aitmagambetov A 2018 Comparative Analysis of QoS Management and Technical Requirements in 3GPP Standards for Cellular IoT Technologies, Journal of Telecommunications and Information Technology, 2, pp. 41-47

[11] Balabanova I, Kostadinova S, Markova V and Georgiev G 2019 Analysis and categorization of traffic streams by artificial intelligence. International Conference on Biomedical Innovations and Applications (BIA), Varna, Bulgaria, pp 1-5, doi: 10.1109/BIA48344.2019.8967475

[12] Balabanova I, Kostadinova S, Georgiev G, 2019 Regression Analysis and Optimization of Teletraffic Models for Parameters Forecasting. Journal of Engineering Science and Technology Review Special Issue on Telecommunications, Informatics, Energy and Management 2019, Kavala, Greece, 2019, pp 9-13, ISSN: 1791-2377

[13] Ivanova E, Iliev T, Mihaylov G, Keseev V and Stoyanov I 2019 Significant simulation parameters for RESTART/LRE method in teletraffic systems of SDN, Lecture Notes in Networks and Systems, 68. Springer, Cham. pp. 265-273, https://doi.org/10.1007/978-3-030-12450-2_25

[14] Ivanova E, Iliev T, Mihaylov G, Tsvetanov F, Osetsova E and Radev D 2015 Computer modeling and simulation of teletraffic models for 5G networks, 38th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, pp. 432-435, doi: 10.1109/MIPRO.2015.7160310

[15] Angelov K, Manchev N, Kogias P and Sadinov S 2019 Design and Development of a Platform for Test Applications in LoRa/LoRaWAN, Journal of Engineering Science and Technology Review (JESTR), Kavala Institute of Technology, pp. 17-21

[16] Koumaras V, Foteas A, Foteas A, Kapari M, Sakkas C and Koumaras H 2018 5G Performance Testing of Mobile Chatbot Applications, IEEE 23rd International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD), Barcelona, pp. 1-6, doi: 10.1109/CAMAD.2018.8515004