ANALYSIS AND REVIEW OF THE POSSIBILITIES OF APPLICATION OF SATELLITE COMMUNICATIONS IN 5G NETWORKS

R.R.Ibraimov,

D.A.Davronbekov

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Abstract: *The main technical requirements for 5G networks are given, the integration of satellite systems with the terrestrial infrastructure of 5G mobile operators is discussed. The statements of experts from the world's leading companies involved in the development of 5G networks are given and a summary is provided on this issue.*

Key words - 5G (5th Generation - fifth generation), Gbps, digital processing.

Introduction. 5G (5th Generation - fifth generation) is the official name of the mobile communication standard following the fourth generation. It is a further development of technologies designed to expand the possibilities of Internet access using radio access networks.

It is assumed that 5G networks will be a collection of new and existing radio interfaces that will create a single wireless infrastructure that provides the widest range of services. The use of new and existing services will serve as an incentive for a significant increase in traffic in mobile networks.

The main technical requirements for 5G networks are:

– the maximum achievable data transfer rate under ideal conditions for one subscriber terminal should be 20 Gbps (to the subscriber) and 100 Mbps - 1 Gbps (from the subscriber);
– achievable data transfer rate available throughout the coverage area to the subscriber/device 100 Mbps - 1 Gbps;
– the average data throughput per unit of spectrum resource and per cell should increase by 2-5 times compared to LTE-Advanced;
– energy efficiency will increase by 100 times compared to LTE- Advanced;
– the time delay in the radio interface should be up to 0.5 ms (for URLLC) and up to 4 ms (for mMTC);
– the maximum mobility (in km/h) of the subscriber, achieved with a given quality of service (QoS) and continuity of control transfer, can be up to 500 km/h;
– the total speed of traffic served per unit of geographical area must be ≥ 10 Mbps/ sq.m;
– the total number of connected or available subscriber terminals per area unit (per sq. km) must be ≥1 million / sq.km.

Realization of such parameters will allow 5G to provide a universal connection of everything to everything, combining wideband, energy -consuming protocols with narrowband, energy-saving ones. This will open up new directions inaccessible to 4G: machine-to-machine communication on the ground and in the air, industry 4.0, the Internet of things.

Problem statement. In recent years there has been a resurgence of interest in satellite communications and the concept of using low orbit (LEO) satellite constellations such as OneWeb and SpaceX has been widely discussed. [1, 15] when organizing broadband access, as an addition to well-known satellite systems, such as, for example, Iridium. In turn, the integration of such satellite systems with the terrestrial infrastructure of 5 G mobile operators will make it possible to cover hard-to-reach territories with modern networks and provide communication networks with universal connectivity of “everything, anytime, anywhere” (anything, anytime, anywhere connectivity).

Already in the 1990s, a number of satellite communications projects (Iridium and Globalstar), but they were of limited use and so the rapid growth of terrestrial networks seemed more cost-effective.

Interest in space communications has revived, somewhere since 2014, this has contributed a lot to the progress of technologies and requirements for ensuring universal connectivity. Advances in microelectronics have made it possible to use technologies such as multi-directional (multipoint) antennas, built-in digital processing (onboard digital processing) of the radio signal, as well as improved modulation and signal coding schemes [2]. The duration of development and the cost of equipment for satellite communications continued to decrease significantly.

The introduction of 5G standards provides a unique opportunity to redefine the concept of satellite communications. 3GPP seizes this opportunity and is conducting a series of studies on the development of 5G solutions for satellite communications. Academia is also working closely in this area. It should be noted that similar work is being carried out on the use of satellites in 4th generation cellular communication systems 4G (LTE) [3].

Until recently, satellite systems were mainly intended for redundant communication channels of terrestrial systems. However, it is known that terrestrial systems, for economic reasons, are unable to cover absolutely the entire territory of the Earth. Communication satellites can cover large areas, so they are attractive for use in remote oil fields, geophysical exploration, offshore oil platforms, ships, communications and broadband access in aircraft, etc. M2M machine-to-machine communications and telemetry can also be included in the scenario for using satellite communications. It is also indispensable in natural disasters, when terrestrial communication networks are disrupted.

Satellite communications are also indispensable for improving the quality of services with unreliable terrestrial communications. Therefore, the integration of satellite channels with terrestrial cellular networks will improve the reliability of the latter, especially when the subscriber moves between areas of the "island" coverage of terrestrial mobile networks.

Solution. ***The concept of using the 5G satellite segment.*** Continuous coverage of sparsely populated and uninhabited regions with terrestrial 5G networks, provided that the millimeter wave is used, is not economically feasible. Therefore, there is a need to study the possibility of using the satellite segment of the network for these purposes, since it is possible to require from 5G communication networks the universal connectivity of “everything, always and everywhere” only if the continuity and globality of their provision is ensured [4, 9-14].

When creating 3G networks (IMT-2000), for the global provision of services, the presence of a satellite segment was provided. However, in the future, when developing 4G networks, the global

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coverage of these networks was not even considered, suggesting the possibility of introducing converged solutions for satellite and terrestrial mobile communications.

The concept of using the 5G satellite segment is proposed, which will be based on the following prerequisites [5]:

– mobile and fixed communication networks will be integrated with the satellite segment, with the core being the integration of the 5G satellite and terrestrial segment;
– space communications systems will be the basis for the continuous and reliable provision of 5G services in all regions of the globe at all times and at an affordable cost;
– the satellite segment should provide globality, allowing you to increase the capabilities of 5G services and solve the problems of the growth of multimedia traffic, M2M and mission-critical telecommunications tasks in order to optimize the cost for subscribers;
– provide for the possibility for the space segment to become part of a hybrid network configuration, including a combination of broadcast and broadband infrastructures and managed in such a way that they can organize uninterrupted and immediate convergence of 5G services for all subscribers.

The requirements for the satellite segment integrated with 5G networks are determined by the set of services provided and they are united by three main business models [6]:

– enhanced mobile broadband (Enhanced mobile broadband - eMBB);
– mass connection of machine-type devices (Massive Machine - Type Communications - mMTC);
– ultra-reliable low-latency communication (uRLLC - ultra - Reliable Low Latency communications).

The existing characteristics of space communication networks, as well as future development trends in satellite technologies, determine the ability of satellite networks to use the following scenarios.

From the eMBB scenario. Here, satellite networks must support data rates of up to several Gbps to meet the demands of advanced mobile broadband services. Modern satellite technologies are capable of broadcasting thousands of channels with content requiring bit rates corresponding to HD and UHD. Such transmission rates will allow, in the future, to support the services of the next generations of mobile networks. Many 2G/3G mobile transport networks in the world are already using satellite channels, and modern space vehicles (SV) of the current and next generations (HTS) located in geostationary and non-geostationary orbits will be able to support the transport infrastructure of 4G/LTE and 5G mobile networks in the future.

From the mMTC scenario. SCADA control technology and other global applications designed to track cargo and objects with Internet of Things (IoT) devices use satellite communication channels. Satellite systems can be scaled to support IoT devices and services in a forward control channel or as backlinks to IoT and M2M devices from remote locations, from ships and other vehicles.

From the uRLLC scenario. As you know, satellite systems are highly reliable and can provide the necessary signal delay in the network. Such networks are mainly used by international broadcasting systems, mobile operators, government communications and commercial customers who are critical to ultra-reliable communications. Delay of signals during use Geostationary space vehicles have a rather high signal delay, however, many applications of 5G networks are not critical to them. For those for whom a large delay is not acceptable, modern and future medium- and low-orbit satellite networks can be used.

The four main scenarios considered for the integration of the satellite segment for 5G networks (IMT-2020) may include [7]:

- trunking and head-end Feed;
- backhauling and Tower Feed;
- communications on the move;
- hybrid multiplay.

The high capacity and global coverage provided by satellite networks will expand the capabilities of the terrestrial segment of 5G networks under these scenarios.

Projects of leading manufacturers. Companies - Boeing [5] and Samsung [8] have already made a preliminary presentation of their projects for the deployment of the satellite segment in 5G networks.

Boeing has requested permission from the US Federal Communications Commission to launch into non-geostationary satellite orbit (NGSO), fixed satellite service (FSS) networks, a spacecraft capable of operating in Earth orbit (LEO) in the 37.5-42.5 GHz band (space -Earth) and in the frequency bands 47.2–50.2 and 50.4–52.4 GHz (Earth-to-space), to solve the problems of the 5G satellite segment.

Boeing 's NGSO system is positioned as a 5G satellite segment [4]. It is also intended to provide various advanced communication and 5G Internet services to a wide range of earth stations and V-band subscriber terminals. Subscriber terminals in this range are equipped with modern antenna arrays that allow you to generate and receive broadband signals with different bandwidths. For higher throughput, terminals with multi-channel and multi -polarization modes are used.

A set of 2956 NGSS FSS spacecraft, to provide high-speed access with low latency for subscriber terminals connected through access gateways to the 5G network and to the associated terrestrial fiber-optic communication line [16-19], will represent the Boeing NGSO system. The system gateways are expected to be located outside densely populated regions where consumer demand for 5G services is low. The satellites of the system will have to form beams covering cells with cell diameters ranging from 8 to 11 km on the Earth's surface in the area of the total coverage area of spacecraft.

Obviously, NGSO system gateways will use the same V-band as the earth terminals. Gateways will provide selection of signals both in frequency and polarization. By providing gateways with more than one antenna, there will be simultaneous access to multiple NGSO satellites visible from the gateway.

At the first stage, the Boeing NGSO system will include 1396 LEO satellites, at an altitude of 1200 km. The satellites will be in 45-degree inclined 35 circular orbital planes, which will be complemented by six additional 55-degree inclined circular orbital planes. In antenna beam-forming, the payload of the NGSO system will use advanced space-time processing and on-board digital processing to form thousands of narrow-band beams for the satellite segment of the 5G communication network on the surface of the Earth.

In the uplink or downlink, satellite links will have up to five 1 GHz bandwidth links, with a total bandwidth of up to 5 GHz, depending on the amount of instantaneous capacity required by the cell being served by the beam. Channels in the uplink can be connected to any channel in the downlink according to the interconnection algorithm used.

It is possible to use a satellite network for FSS channels and their spectrum sharing with a terrestrial 5G network in the range of 37.5-40.0 GHz in the following cases:

– if the 37.5-40.0 GHz band is used only for downlink reception of the FSS satellite network;
– spectrum sharing is possible only at high viewing angles of spacecraft;
– ensuring high transmission rates is possible in the case of using methods of spatial selection (beamforming) both by antennas of satellite network terminals and by 5G network equipment.

ITU limits on *power flux-density* levels, while meeting the requirements of a minimum signal level reduction from the 5G network to 0.2-0.6 dBW, will protect the terrestrial segments of the 5G network from the influence of interference from the downlink of the FSS satellite network

Boeing 's calculations show, with spectrum sharing, as the power of the base station increases, the number of satellite terminals subject to interference will increase. Therefore, the level of attenuation of interference from 5G networks between satellite receivers of FSS earth stations and transmitters of mobile and base stations of the terrestrial segment must be more than 50 dB.

Boeing 's research, through statistical modeling and interference estimation, has shown that the effective isotropically radiated power (EIRP) of base stations in a 5G network should be limited to 62-65 dBm in a 100 MHz band. In this case, the sharing of FSS and 5G systems is facilitated without limiting the transmission rate in 5G networks.

Thus, the need to cover hard-to-reach territories with modern 5G networks, to ensure universal connectivity from communication networks “everything, always and everywhere”, and also given the role of these networks in the infrastructure of the future digital economy, the use of the satellite segment becomes relevant.

Statement by experts from companies involved in 5G networks. The Russian industry, for example, is skeptical of us and considers the joint use of satellite and mobile infrastructure for 5G looks more like a reserve for the distant future, which is unlikely to be applied in practice. Therefore, we present the opinions of experts from the world's leading companies involved in the implementation of 5G networks.

In February 2020, an agreement was signed in Frankfurt between the NGMN alliance (-combining mobile operators, vendors and research institutes) and the EMEA satellite communications operators association (ESOA). NGMN CEO *Peter Meissner* said after signing the agreement: “We are proud to have demonstrated the potential of integrating terrestrial networks and NTN networks (networks using air or space vehicle for data transmission) to provide Internet and mobile communications in remote areas. By 2025, we expect the full deployment of NTN networks to solve the problems of mobile network operators and enterprises of vertical sectors of the economy in terms of reachability, availability and fault tolerance. This will have a significant impact on the expansion of 5G connectivity."

Dmitry Konarev, a leading expert on Huawei wireless technologies in Russia, drew attention to the fact that when working on the further development of the fifth generation standard, 3GPP laid the possibility of integrating the standard with satellite communication systems in Rel.17. He further noted, "The development of this release is in full swing, the end of the formation of specifications is expected by mid-2022. Accordingly, we can speak with full confidence about the evolutionary path of integrating the 5G standard with satellite communication systems." He also noted that Huawei is actively involved in the work on the specifications of the 5G standard and is involved in the work to create an integrated solution.

Commenting on the agreement signed between the NGMN alliance and EMEA, Sergey Pekhterev, head of the AltegroSky group of companies, said that "This document is some general intentions and capabilities of satellite technologies to provide communication with base stations operating in the 5G standard, and the specific implementation depends on local conditions and their features. As an example, he stated that "for many countries, services based on low-orbit constellations such as OneWeb and StarLink, which have not yet gained access to the Russian market, will be promising." He also noted that "most of the Russian mobile operators have their own satellite communications networks and the corresponding infrastructure. Therefore, most likely, the degree of involvement of Russian satellite operators in providing channels for 5G will not be as wide as it could ideally be."

In confirmation of the words of Sergei Pekhterev, the press service of PJSC MegaFon reminds that satellite communications have long been used to connect base stations of existing standards in hard-to-reach places. At the same time, they note: "The question of the prospects for using satellite communications for organizing 5G network coverage will depend on the specific end service and delay requirements, as well as the availability and cost of the satellite resource."

Daria Kolesnikova, a spokeswoman for Tele2 (T2 Mobile LLC), expressing the company's opinion, states that "there are doubts that satellite operators can provide sufficient channel capacity for the development of 5G networks. Moreover, the company believes that the lease of channels is quite expensive for mobile operators, so a separate issue is the commercial payback of such cases.

As the representatives of the operator PJSC VimpelCom (Beeline) note, "At the moment, they see no prerequisites for changing the existing model of interaction with satellite operators when organizing coverage of remote territories. When implementing 5G, especially in industrial enterprises with their specific cases of smart production, it is important to bring the nodes on which user traffic is processed as close as possible to the base stations. The implementation of this approach, including based on MEC solutions (Mobile edge Computing), fits perfectly into our network architecture development strategy, but will be extremely difficult for any 5G satellite operator."

In "Beeline" does not see big pluses from the possibility of integration with satellite operators. The press service says: "In the early stages of 5G development, attempts to "join forces" in practice may lead to additional restrictions on the use of frequencies for mobile operators when introducing

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5G networks throughout the country. The company is for a clear separation of frequency bands for satellite and terrestrial 5G segments."

The leading research center on the basis of the Skolkovo Institute of Science and Technology, represented by the head V.Shub, believes that the need to combine the efforts of mobile and satellite operators may be associated with a shortage of radio frequency resources. He explains his idea as follows: "We are witnessing a process when each next generation of cellular communication squeezes operators higher and higher on the scale of the frequency spectrum. For GSM, the bands 800, 900, 1800 and 1900 MHz are used, for 3G / WCDMA - 2100 MHz, for LTE - up to 2500-2600 MHz. For networks of the fifth generation, the root range will already be 3400-3800 MHz, which is bad for indoor coverage, especially in the case of strong metallization of windows in office buildings. Therefore, it turns out that cellular operators have to install more and more base stations, worsening the business case."

To get out of this situation, V.Shub proposes refarming of the low- frequency resource used for 2G, 3G, 4G. For example, the USA (600 MHz, 700 MHz, 850 MHz) and Europe (700 MHz and 800 MHz) see the prospect of launching 5G networks in the range below 1 GHz. "At the same time, it should be borne in mind that 5G requires the allocation of wide free carriers, which cannot always be allocated in these low-frequency ranges. In our opinion, Russia should follow this example of the USA and the European Union - give the 600-800 MHz range - "digital dividends" - to 5G, and leave the frequency band between 500 MHz and 600 MHz for broadcasters to solve social problems.

The key idea, according to the head of the leading research center, is that in the process of changing generations of cellular communication, mobile and satellite operators found themselves on the same "frequency field" in high ranges. "Obviously, the proposed Rel.17 3GPP is an attempt to harmonize their interests. It is possible that in the end some new techniques will be found. But our old calculations showed that you can provide indoor coverage from satellites only if they operate in the range of about 700 MHz. However, this may require a lot of work, since, according to our preliminary studies, it would be necessary to launch low -orbiting satellites or satellites on a high ellipse with sufficiently high energy performance of the transceivers on board. Yes, it is theoretically and technically possible, but in the end everything will be put in its place by the business cases of mobile operators."

A.Ganitsev, Ericsson Development Director for Eastern Europe and Central Asia, also supports the idea of combining the efforts of mobile and satellite operators to obtain the possibility of sharing a common frequency resource. He believes that the most popular 3.5GHz band will also be available for 5G NR with this approach. "The 5G application contains several significant areas - these are FWA fixed wireless access, eMBB mobile broadband access and URLLC ultra-low latency solution," lists Alexey Ganitsev. Currently, he continues: "Fixed wireless access has become widespread, for example, in Latin America, specifically for the tasks of providing high-speed connections in remote areas. Implementation of Critical Internet of Things applications (Critical IoT) is possible based on the creation of private 5G networks in remote areas with the organization of satellite communication channels. However, the disadvantages of such solutions are the cost of the satellite transport network and low bandwidth."

The idea of integrating space systems with the terrestrial infrastructure of mobile operators, taking into account the 3GPP decision to include NTNs technology in Rel.17, Tigran Pogosyan, *the* *senior vice president* of *ZTI-Svyaztekhnologii* LLC (ZTE in Russia), allows only in the future, since in practical implementation at the moment it is practically unrealizable. He believes that "Satellite bands tend to be narrowband, which is not enough for 5G. It is also necessary to take into account their congestion with current consumers - television, military and special services, etc.

A ComNews source in the telecommunications market believes that "Theoretically, the emergence of commercial satellite constellations in low and medium orbits will significantly speed up the speed of data transmission over the satellite. Such transmissions will definitely be faster than those that operators use today to connect base stations in remote areas. However, there is no certainty that the level of satellite signal delay (latency) even when using MEO constellations will be sufficient to meet the requirements of 5G networks. As for low-orbit satellites, there are questions about the timing of their launch."

The proposal to include satellite access in the 3GPP Rel.17 specification, according to the ComNews interlocutor, looks more like a reserve for the distant future and is unlikely to be applied in practice. In conclusion, the source believes that "The initiative describes the ability of 5G user devices to automatically switch between 5G and the satellite network, as is the case today between LTE and 2G. This is a very specific use case, and given the power consumption of satellite modems, such solutions are more likely to have a fixed, than mobile performance."

Conclusion. Summarizing the above statements of experts from leading world companies developing and implementing 5G networks (on the example of Russian ones), we can assume that today some experts (Russian) doubt the prospects for a symbiosis of satellite communications and 5G networks. However, most experts believe, including the authors, that ".... with full confidence we can talk about the evolutionary path of integrating the 5G standard with satellite communication systems."

References

1. http://licensing.fcc.gov

2. del Portillo Barrios, Inigo & Cameron, Bruce & Crawley, Edward. (2019). A technical comparison of three low earth orbit satellite constellation systems to provide global broadband. Acta Astronautica. 159. 10.1016/j.actaastro.2019.03.040.

3. Bastia, Francesco & Bersani , Cecilia & Candreva , Enzo & Cioni , Stefano & Corazza , Giovanni & Neri , Massimo & Palestini , Claudio & Papaleo , Marco & Rosati , Stefano & Vanelli-Coralli , Alessandro. (2009). LTE Adaptation for Mobile Broadband Satellite Networks. EURASIP Journal on Wireless Communications and Networking. 1-13. 10.1155/2009/989062.

4. V.O.Tikhvinsky, M.V.Sagittarius. Prospects for creating a 5G satellite segment. Magazine «First mile» № 1, 2018

5. Jonas Eneberg. Satellite Role in 5G. Inmarsat, 2017.

6. Mah Daniel CH Role of Satellite in 5G. SAS, Satellite Connectivity Workshop, Nadi, Fuji, 24 April 2017.

7. Evans Barry, Onireti Oluwakayode, Spathopoulos Theodoros, Imran Muhammad Ali. The role of satellites in 5G. 23rd European Signal processing conference (EUSIPCO), 2015.

8 Farooq Khan Mobile Internet from the Heavens. Samsung Electronics. Richardson, Texas, 2015.

9. Davronbekov D., Khakimov Z., Isroilov J. Features Identifiers Implemented in the Context of Generations of Mobile Cellular Development / International Journal of Advanced Trends in Computer Science and Engineering, Volume 9, No.5, September – October, 2020. - P.8753-8757

10. Davronbekov D.A., Matyokubov U.K. The Role of Network Components in Improving the Reliability and Survivability of Mobile Communication Networks / Acta of Turin Polytechnic University in Tashkent. 2020, Vol.10: Iss.3, Article 2. - pp.7-14.

11. Давронбеков Д., Исроилов Ж., Хакимов З. Архитектура организации регистрации IMEI-кодов в базе данных информационной системы идентификации мобильных устройств / International scientific journal "Science and World", №10 (86), 2020.-P.39-43

12. Davronbekov D.A., Khakimov Z.T., Isroilov J.D. Implementation of the Algorithm for Checking and Registering Mobile Devices in the Information System Using the IMEI Code / International Journal of Advanced Research in Science, Engineering and Technology. Vol. 7, Issue 10, October 2020. - p.15054-15059

13. Davronbekov D.A., Matyokubov U.K. The Effect of the Number of Backup Communication Lines in the BTS-BSC System on Reliability / Scientific Collection «InterConf», 40: Proceedings of the 2nd International Scientific and Practical Conference "Scientific Community: Interdisciplinary Research", January, 26-28, 2021, Hamburg, Germany: Busse Verlag GmbH, 2021. – p.679-684

14. Davronbekov D.A., Matyokubov U.K., Abdullayeva M.I. Evaluation of Reliability Indicators of Mobile Communication System Bases / Bulletin of TUIT: Management and Communication Technologies: Vol. 3 , 2020, Article 1.- p.1-9.

15. Давронбеков Д.А., Ибрагимова П.А., Давронбеков Н.Д. Применение систем спутниковой навигации в различных областях жизнедеятельности / Scientific Collection «InterConf», 2(35). Proceedings of the 1st International Scientific and Practical Conference «Experimental and Theoretical Research in Modern Science», November 16-18, 2020, Kishinev, Moldova: Giperion Editura, 2020. – C.622-626

16. Davronbekov D.A., Khakimov Z.T. Research of FOCL Parameters in the Range of Positive Temperatures / Bulletin of TUIT: Management and Communication Technologies: 2021, Vol. 4 , Article 3.- p.1-9

17. Давронбеков Д.А., Хакимов З.Т., Исроилов Ж.Д. Нейро-нечеткое моделирование экспериментальных данных по оптимизации спектральных характеристик ВОЛС / Acta of Turin Polytechnic University in Tashkent. -2021, Vol.11. – C.55-70.

18. Давронбеков Д.А., Жумамуратов И.К. Особенности применения ВОЛС в системах мобильной связи / Scientific Collection «InterConf», №2(35). Proceedings of the 1st International

Scientific and Practical Conference «Experimental and Theoretical Research in Modern Science», November 16-18, 2020, Kishinev, Moldova: Giperion Editura, 2020. – C.627-632

19. Давронбеков Д.А., Хакимов З.Т., Исроилов Ж.Д. Определение границы технологического запаса оптического волокна с прямолинейными элементами / Scientific Collection «InterConf», 2(38): Proceedings of the 1st International Scientific and Practical Conference «Science, Education, Innovation: Topical Issues and Modern Aspects», December 16-18, 2020, Tallinn, Estonia: Uhingu Teadus juhatus, 2020. - C.1163-1169