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5G TRANSIT CONNECTIONS

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Abstract: In this article expected characteristics, architecture and roadmap development of a fifth-generation cellular network are considered. Moreover, it justifies the need for 5G optimization of the whole network and a transit hub in particular. A possibility to use open optical transmission systems as a transit connection from a base station to an Internet service provider is shown in it.

Keywords: Standard, characteristics, architecture, 5G, OOTS (open optical transmission systems).

I. INTRODUCTION

A number of devices connected to the World Wide Web and the subscribers' requirements for mobile Internet access speed is increasing steadily every year. Existing networks no longer meet these requirements and therefore the next stage in the evolution of fourth-generation networks (LTE, 4G), a fifth-generation network (5G) is being developed.

It is expected that in a 5G network, unlike LTE, many devices will be connected that can establish billions of connections, which will allow to create new services in such areas as:

• Tactile internet – contact transfer not a distance;
• IT and telecom sector;
• Automobile field — unmanned driving;
• Entertainment industry;
• Education;
• Agriculture and many others.

Bell Labs considers that a wide variety of devices will work on 5G networks.[3] Smartphones and tablets will continue to be in demand, but in addition to them, a number of different devices including surveillance cameras, weather sensors, smart electric network sensors, smart homes, cars and others will appear in the network. Fifth-generation networks will also improve the usage quality of already existing services where large volumes of traffic are involved.

A number of devices interacting with the Internet and among them will constantly increase. Therefore, more advanced networks are needed to ensure this interaction in the most efficient way. As representatives of the Communication & Storage Infrastructure Group at Intel believe that new generation networks will have to open up new opportunities in many spheres from raising the efficiency of production processes, safety on the roads and in the city as a whole and improves Communal Services to have a much cleaner environment.

Objective setting: 5G requires use of new frequency resources, network architecture and infrastructure, business models and subscriber devices. However, the lack of a frequency resource that is important to ensure an acceptable service quality related to mobile data transmission in continuing exponential traffic growth condition and the coming era of the Internet of things (IoT) is one of the main constraint in 5G implementation.

II. Problem formulation

5G will require the availability of new frequency resources, network architecture and infrastructure, business models and subscriber devices. However, the lack of a frequency resource necessary to ensure an acceptable quality of services related to mobile data transmission in the context of the continuing exponential growth of traffic and the coming era of the Internet of Things (IoT) is one of the main limiting factors in the implementation of 5G.

In 2014, CNews expressed views by a number of experts who consider that 5G networks will be “device-oriented”, not “cell-oriented”, i.e. "cellular communication» concept will not be applicable [1].As it is known, in cellular communications the operator’s network consists of cells — base stations (BS) that provide communication within a specific range. The device located in this range generates outgoing and downlink communication channels, controlling both the self-connection and transmitted traffic volume, while the BS controls the entire cell containing a number of subscriber devices. Unlike existing cellular telecommunication, in 5G networks devices will exchange multiple streams of information with various types nodes simultaneously. whose task at a particular point in time will be to maintenance this very device [2].

Modern radio access networks consist of large (macro) cells, which ensure continuity of subscriber coverage / mobility and small (micro) cells, which are installed in places with the highest subscriber density (hot spots) and provide essential extra capacity there. Macro cells sizes are mainly determined by the frequency range used (for low frequencies - more, for high frequencies - less) and quantity of micro cells (installation density) is proportional to the required capacity. It is possible to forecast a considerable rise of required micro cells’ number in 5G implementation, taking into account capacity growth by magnitude orders from generation to generation of mobile communication, [1].

According to Ericsson's forecast, in the future the number of active Internet subscriber devices worldwide will be from 50 to 500 billion - 10–100 times more than today [1]. Therefore, standards developers’ important task is to provide a reliable wireless connection to each of them. Moreover, each device must have its own interaction policy with network that considers the amount of transmitted data, the value of the allowable delay and other parameters. Furthermore, if now one base station serves several hundreds of connected devices simultaneously, in the coming years, due to the proliferation of machine-to-machine communications (M2M), the number of devices will increase repeatedly. And in some cases, the base station will have to handle up to 10 thousand devices simultaneously. This requires both the development of new nodes that will be able to manage networks and the modernization of the supporting infrastructure (primarily transit networks).

Thus, 5G is not a solution that will come to replace 4G in the form in which 4G replaced 3G, and 3G superseded 2G. 5G will be a heterogeneous network that will use various technologies to serve the traffic and different types users.

The 3GPP consortium (5G standard developer) presented the new NSA 5G NR standard of the final version of Release 15 at the quarterly plenary meeting in Lisbon, Portugal, [4]. Standard 5G NR (5th generation, a new radio - New Radio) is approved by all global community members in 3GPP telecommunication companies. Earlier, telecommunications industry representatives approved the accelerated standardization of 5G. For this purpose, it was decided to divide the process into two phases. The priority was the announcement of a non-autonomous version of Release 15 NSA (Non-standalone) [8] and presented a roadmap of its development (Fig. 1).

Autonomous and non-autonomous (SA and NSA) releases are based on the same physical layer characteristics, so the NSA equipment is expected to be fully compatible with the SA technology after its subsequent standardization.

The 5G NR standard involves use of new frequency ranges that provide an increase in the speed of data exchange with a decrease in latency. This very mode was developed as a foundation for the first development years and 5G networks implementation.

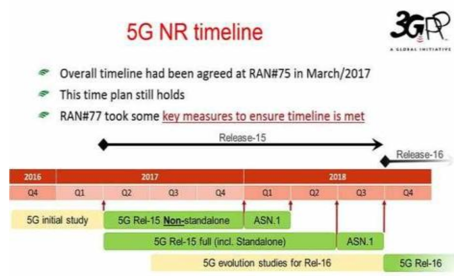

Fig.1 Roadmap for 5G NR development

The final specifications of 5G describe support of several frequency spectra for new generation mobile networks. The low frequency spectrum includes frequencies in the range of 600-700 MHz. The mid-frequency spectrum includes frequencies in the 3.5 GHz range. The high frequency spectrum is located in the 50 GHz band.

Officially, data exchange rates for user devices are regulated at up to 20 Gbit / s for reception and 10 Gbit / s for transmission, while the 5G network must hold a load of at least 500 thousand subscriber connections per square kilometer.

A comparison chart of the IMT-Advanced (4G) and IMT-2020 (5G) technologies, developed by the International Telecommunication Union (ITU), a specialized United Nations agency for information and communication technologies, is shown in Figure 2 [6].

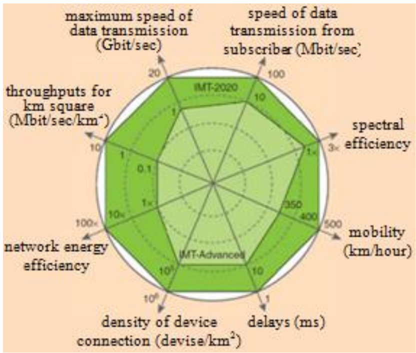

Fig.2. IMT-Advanced (4G) and IMT-2020 (5G) technology comparison diagram

It is clear from the diagram that a significant increase in the users' data transfer rate as well as a significant increase in capacity and radio coverage are planned (almost an order of magnitude for some characteristics).

III. Problem solution

Creating 5G networks will need not only the implementation of new hardware and software that meets demand of 5G networks, but also it needs to develop an infrastructure for microcellular networks, since data will be transmitted, including at short distances, at frequencies up to 100 GHz. Since 5G will pump gigabit traffic in near future, there will also be an urgent need to optimize the performance of the entire network as a whole. It is considered that the optimization will relate directly to the transit hub connecting the cellular communication BS to the Internet service provider (Front haul Aggregation in Figure 3, the source of the 3GPP consortium) [6].

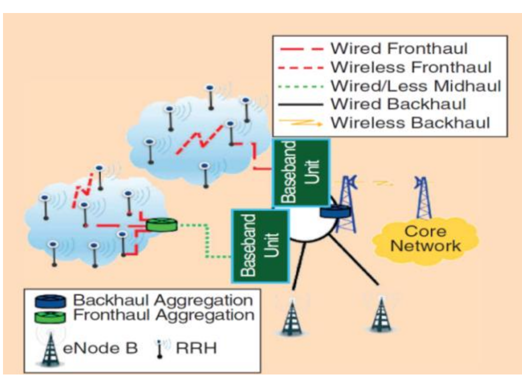

Fig.3. Organization of a transit connection connecting a cellular BS communication with an Internet service provider

It is clear from Fig. 3 that, in accordance with the working paper 5G, the transit connection from the subscriber can be realized either over a wired channel using a dedicated line (copper or fiber optic) or using high-speed wireless bridges (point-to-point or point- multipoint). Deploying a wired transit route in some places can be a rather expensive and complicated technical solution. Therefore, in 5G networks there are "multihop wireless" wireless stations capable of serving large areas of coverage. In addition, their use will allow to scale up network segments in the future quickly. In near future, besides wireless technology in the 5G radio band, to use equipment for environmental protection and environmental protection (open optical transmission systems) is planned. At the same time, it is believed that the main niche in 5G networks will be occupied by the E-band (E-Band). Figure 4 shows the characteristics of the E-band in comparison (in data transfer speed and distance) with other communication technologies [6].

However, German specialists obtained a maximum connection speed of no more than 6 Gbit / s in experimental E-band wireless networks. ("To tell the truth, German specialists' scientific work has not been reviewed and has not been published in the public domain yet, so we have to take every word on trust") [8]. Therefore, one of the options is to use OOTS, which allows receiving data transmission speeds of up to 10 Gbit / s, with sufficient confidence at distances of up to 5-6 km at the first stage of 5G implementation for transit communication connecting BS with an Internet service provider.

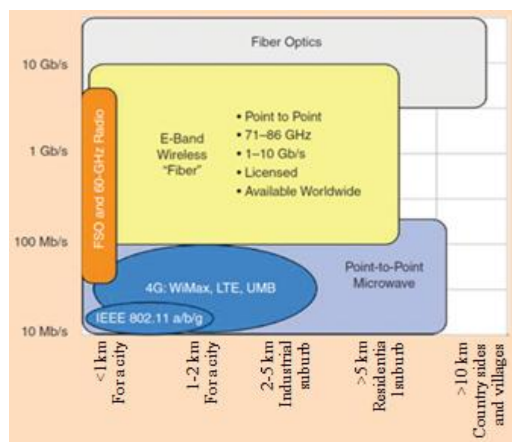

Fig.4 E-band characteristics

The principle of OOTS constructing is known to be similar to fiber optic communication lines (FOCL), except in used transmission medium. The technology is based on data transmission by modulated radiation in the infrared part of the spectrum through the atmosphere. To connect OOTS to consumers, each manufacturer uses its own interface. However, they all follow general connection, which is that the atmospheric communication line is an emulation of a cable segment (two twisted pairs or two cores of an optical cable). Thus, for all devices involved, for instance, in the cable network of connected objects OOTS is not "visible", i.e. no equipment restrictions are imposed; no additional communication protocols or changes and additions to them are made [9].

The advantages of using OOTS based on infrared semiconductor LEDs and laser diodes, as compared to other wireless solutions are as follows:

- Air time is utilized due to the radio band limitation but use of infrared optical range extends wireless data transmission capabilities.
- a narrow beam transmission in the absence of lateral radiation provides high noise immunity and optical communication privacy;
- High energy efficiency and low cost of specific bits of transmitted information;
- Compatibility with other transmission devices of digital data.

It should also be noted that in recent years, OOTS have been increasingly introduced into telecommunications networks and this is due to the following circumstances [9]:

a. created stable laser radiation sources with the
b. operating time of failure to several hundred
c. thousand hours;
d. simple and easy installation and connection,
e. therefore commissioning reduced to a month;
f. possibility to organize communication between
g. moving objects;
h. cost of OOTS organizing has become
i. commensurable, and in some cases cheaper than
j. fiber optic cables;
k. subscriber locations can be changed;
l. high communication confidentiality;
m. no need for permission to use;
n. the possibility to provide high rates of data transfer
o. (up to 10 Gbit / s).

Unfortunately, in some cases it is impossible to use OOTS. One of the most significant issues is considered to be limited range communication connected with the energy reduction of optical waves during the propagation in the atmosphere by molecular and aerosol absorption and scattering is. [9].

Total reduction value made by the action of all these factors, as well as its statistical characteristics is important in calculating OOTS. It is known [9] that energy losses consist of two components, a constant component and a variable, that are determined by changes in atmospheric transparency depending on changes in meteorological conditions.

As a rule, for a particular region the magnitude of the constant component is known, and therefore in designing OOTS the main problem is identification the wave energy attenuation that is caused by changes in the transparency of atmosphere due to aerosols presence. Establishing statistical characteristics of optical radiation attenuation that depends on changes in the atmosphere, which in turn determines the reliability of OOTS function is a matter of considerable interest. To this end, experimental measurements of laser radiation attenuation in the atmosphere have been carried out in various regions of the world to determine possible occurrence of appropriate attenuation at specific highways [9-11].

Atmosphere transparency quantity constantly measured in meteorological stations network at airports in order to identify the minimum visibility range on the runway. Measurements are made at a wavelength of λ = 0.55 μm (corresponds to the highest sensitivity of the eye and adopted to measure MVR at all airports in the world). The measurement period is variable and automatic: with constant weather conditions - after 15 minutes, with a dramatic change, the measurement interval decreases up to 1 min, which solves the problem of the reliability of the measured results. According to the obtained atmospheric transparency data, the meteorological visibility range Sm is determined using the Koshmider's ratio:

$$S_m = -\ln\varepsilon_r/\alpha_A = 3,9/\alpha_A(1/km) = [16,9/\ \alpha_A(db/km)],\ km \quad (1)$$

where ε_r = 0.02 is the threshold of the contrast eye sensitivity at λ = 0.55 μm;
α_A – a wave attenuation indicator of visible range.

In the case of waves in visible and near-infrared ranges, attenuation due to aerosol scattering is recalculated using this formula:

$$\alpha_A(\lambda_i) = (3,9/S_m) \bullet (0,55/\lambda_i)^m = 0,55\alpha_A \bullet (0,55/\lambda_i)^m, \quad (2)$$

where λ_i - the wave lying in the “transparency window” of the atmosphere;
m - a parameter dependent on S_m (in S_m<6 km, m = 0.585 • S_m 1/3;
for average visibility conditions, m = 1.3;
for very good ones - m = 1.5).

Thus, fairly it is possible to forecast OOTS readiness with zoning of extended territories using MVR as a criterion.

Statistical data about MVR that have been collected by the authors in accordance with the recommendations of the International Civil Aviation Organization (ICAO) with the meteorological stations in the airports of the Republic of Uzbekistan were processed and presented as integral distribution functions (IDF) MVR-F (sm) [10]. Subsequently (IDF) MVR-F (sm) of some regions were processed in the MATLAB in order to present in an analytical form, for instance for Tashkent and Bukhara regions [12]. Such a representation (IDF) MVR - F (sm), allows to obtain a significant gain in laborious and reduce account time in designing OOTS.

The processing results of MVR statistical data by regions of the Republic of Uzbekistan show that, with the required availability of AK, the length of the interval is about 2-3 km. [10-12]. If it is considered that transit connection distance of a BS in 5G with an Internet service provider in an urban setting is within the same range, then the length provided by the OOTS can be considered quite satisfactory. In addition, it should be taken into account that in order to increase the channel availability ratio and increase communication reliability, OOTS manufacturers use various methods [9].

IV. Conclusion

Not “cell-oriented” but “device-oriented” networks of the fifth generation (5G) are being developed in order to meet the growing demands of subscribers to mobile Internet access speed. Creating such networks will require not only new hardware and software implementation that meets new generation networks’ requirements, but developing an infrastructure for microcell networks is also needed.

It is expected that 5G in the future will pump Gigabit traffic, so there will be an urgent need to optimize the operation of the entire network as a whole and directly the transit node that connects the cellular communication BS to the Internet service provider. It is expedient to use OOTS at the first stage of 5G implementation for transit communication. Statistical data on MVR collected for the regions of the Republic of Uzbekistan shows that, with the required availability of AC (atmosphere channel), the length of the distances meets the requirements for transit communication in 5G at a transmission rate of up to 10 Gbit/s.

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