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Problems and prospects for the telecommunications industry development in emerging a digital economy

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***Abstract* — As of today, the telecommunications industry in Russia and around the world stand at the threshold of introducing a new, fifth generation of mobile communications. Like previous generations, 5G will give impetus to the development of not telecommunications only, but also other sectors of the economy. The article is devoted to a quantitative analysis of the possible costs and benefits of telecommunication companies as a result of the formation of 5G network infrastructure, the perspective scenarios of the mobile technologies development in Russia are considered, the successful experience of implementing this technology in other countries is analyzed. The paper also describes quantitative estimates of the factors determining the advantage of network competition over other models. All of these estimates are predictive, but the scenarios underlying them are very plausible and are confirmed by international experience.**

Keywords — telecommunications, 5G, mobile communications, investments, digital information and communication services, data transmission.

I. INTRODUCTION

Today, the telecommunications industry in Russia and around the world stand at the threshold of introducing a new, fifth generation of mobile communications. Like previous generations, 5G will give impetus to the development of not telecommunications only, but also other sectors of the economy. The expected technological innovations of the fifth generation standard will lead to an increase in the bandwidth of mobile networks and data transfer rates, as well as the emergence of new scenarios for the use of mobile communications and the development of innovative digital services. This will contribute to economic development by increasing productivity, automation and the introduction of new technologies in various areas of the economy and human activities.

Fifth generation technologies will provide effective answers to the challenges they face, including providing the necessary increase in the mobile operator networks bandwidth and allowing them to be developed on the basis of existing infrastructure, without explosive growth in the number of cells and the volume of capital investments.

New technologies for building multi-standard networks, centralization of radio access networks, software verification and virtualization of network functions will further increase the efficiency of capital costs and reduce the total cost of network ownership.

In the scenario of independent development of networks, the total investment of the mobile industry (in 2020-2027), taking into account the tasks of introducing 5G, can amount to 18-22% of total income. This represents a definite but not very significant increase compared to the historical level of 18-20%. The average ratio of capital costs to revenues in case of networks active infrastructure sharing by mobile operators will be 16-20% [1].

4G networks will coexist with the fifth generation networks for a long time and will serve as the basis for the implementation of the latter as 5G ICT services develop. The long-term vision of 5G networks in the early stages of development is represented by the following features:

1) The main mobile consumption will be provided by multi-standard 5G/LTE macrocells using medium and low radio frequencies;
2) Ultrahigh throughput in some areas will be provided by small cells using high radio frequencies;
3) Broad coverage (highways, communications in buildings) with low bandwidth requirements can be provided for even low radio frequencies less than 1 GHz;
4) “Device to device” communications that are already in use today do not involve a telecommunications network.

In view of the above, as well as the observed trend of reducing the cost of telecommunication equipment and the development of infrastructure sharing practices (which will be discussed below), there is reason to believe that the fifth-generation technological innovations will not only provide the basis for the development of a whole range of digital information and communication services, but also create the basis for the effective development of 5G networks with comparable periods and budgets to previous generations,

without significant changes in the model of ownership of infrastructure mobile network.

II. RESULTS

IMT-2020 identifies three main blocks of scenarios for the prospective use of mobile technologies: enhanced mobile broadband (eMBB), massive machine-type communication (mMTC), ultra-reliable low-latency communications (uRLLC) [2].

1. Enhanced Mobile Broadband (eMBB)

In the coming years, the main driver for the mobile networks development will be the services of the eMBB segment, which are the evolution of traditional services of wireless broadband access and the distribution of multimedia content, but more demanding on the networks quality and bandwidth. These services include high-quality and high-speed access to the Internet and mobile applications, augmented and virtual reality services, broadcast of high-definition video content, provision of services in places of mass congestion of subscribers, etc.

TABLE I. EMBB USAGE SCENARIOS

Peak data rate	ELTE opportunity zone	5G opportunity zone
20 Gbps		VR gaming services with real-time communications (delay less than 7 ms)
1 Gbps	The use of VR in production, telepresence, etc. VR services (delay less than 7 ms) Mobile "last mile" - an alternative to the optical line to the apartment	
50 Mbps	Wireless communications in high speed train (delay 10 ms, speed 500 km/h) Ultra high quality video (delay 200 ms)	Zones with a high concentration of subscribers (stadiums, shopping centers, etc.)

Key requirements include high peak speeds, low signal delay and ultrahigh network bandwidth in a limited area. The fifth generation technologies effectively provide the implementation of such services, but most of the services can also be implemented on the basis of evolving networks of the fourth generation. Within the eMBB, we can perhaps single out only two main scenarios for which the introduction of 5G networks in certain territories is absolutely necessary:

- a number of specialized AR / VR services requiring not more than 2 ms signal delay and a speed of more than 4 Gbps;
- ensuring stable communication with the concentration of a large number of subscribers.
- By our estimates, the consumption of mobile traffic in Russia over the next 10 years will increase, depending on the market development scenario, from 12 to 21 times. The introduction of fifth-generation technologies will enable the effective growth of the necessary bandwidth of existing mobile networks and will create a significant reserve of capacity for further development.

2. Massive machine-type communication (mMTC)

In the field of wireless communications, more and more various connected devices are involved, from household appliances to industrial equipment. They collect information about the external environment, their own technical condition and are managed through a communication network. The development of massive machine-type communication and IoT will be one of the most relevant and common scenarios for the development of next-generation digital ICT services. The main requirements that such services make are high reliability of data transmission, low power consumption and support for a large number of devices in a limited area. Two usage scenarios can be distinguished for which the development of fifth-generation networks is critical because of the high requirements for the number of supported connections per 1 sq. km:

- Full-scale development of an intelligent city management system in areas with a very high population density and the need to transfer a large amount of media traffic to support a video surveillance system - smart city
- Scenarios of a high concentration of connected devices in the most technically developed cities: the simultaneous implementation of smart home services, wearable and medical devices, transportation control and other services in a limited area with a high population density and economic activity [3].

TABLE II. MMTC USAGE SCENARIOS

Actual data rate	ELTE opportunity zone	5G opportunity zone
1 Gbps	Existing MTS services of smart cities - up to 100 thousand devices per sq. km	Full-blown smart city: in large metropolitan areas
10 Mbps		Scenarios with ultra-fast concentration of IoT sensors in individual zones (production, infrastructure, mass segment)
1 Mbps 100 kbps	Connected devices in production: performance analysis, personnel monitoring, etc.	Remote traffic control - monitoring of goods and vehicles
10 kbps	Connected water and electricity meters	Smart home devices – connected household devices, etc.

3. Ultra-reliable low-latency communications (uRLLC)

A number of promising services will place increased demands on the quality and reliability of communication services – uRLLC. These typically include remote monitoring and management of production operations and vehicles. For their implementation, low delay of signal transmission, reliability and low probability of errors during data transmission are important.

TABLE III. URLLC USAGE SCENARIOS

Delay	ELTE opportunity zone	5G opportunity zone
10 - 1 ms	1. Smart Grid – management of production, transmission and consumption of energy efficiency 2. Existing transport support scenarios	1. Real-time (people search, fire fighting, etc.) 2. Tactile Internet (remote surgery, diagnostics, etc.) 3. Full automation of production facilities 4. Full-featured intelligent support for the transport system, including driving automation
100 - 10 ms	Drones (surveillance, drug delivery, etc.)	1. Remotely controlled equipment 2. Smart Grid - management of key energy facilities
Up to 100 ms.	Remote control of production equipment and facilities	

Some of these scenarios are already being implemented today — remote control of production operations and Smart Grid, some services using drones. Existing technologies and their evolution allows to support the most massive services. 5G technologies are needed to implement the most futuristic services, such as:

- remotely controlled production equipment;
- tactile Internet - remote medical diagnostics, surgical operations using robots, etc.
- fully functional automated transport system;
- drone control in scenarios most sensitive to data transmission delay [4].

A survey of 750 operators around the world by the GSMA international association of mobile operators allows to formulate an industry vision regarding priorities for infrastructure development and network deployment:

- Most operators (80% of respondents) expect the existing competitive model of development and ownership of 5G network infrastructure to be maintained.
- At the same time, 40% of all respondents note the priority of the model of networks joint development with other operators.
- About 11% of operators suggest that the deployment of 5G will require hybrid models of network development, where the construction or financing the construction of a certain part of the infrastructure (rural areas, roads, specific industry solutions, etc.) will be performed not only by operators, but also by other market participants.
- Only 3% of operators assume that 5G development will follow the model of a single network creation in certain regions of the country, and 3% assume that one or two single fifth-generation national networks will be created, operating according to the wholesale model.
- Most operators consider the gradual deployment of networks covering areas of high economic activity optimal, and 5G services in the early stages are supposed to focus mainly on wireless broadband access.

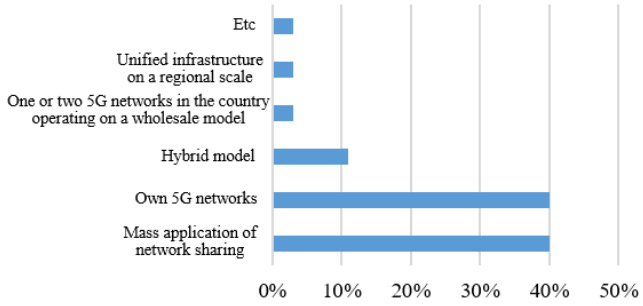

Fig. 1 View of mobile operators on infrastructure ownership models (% of respondents)

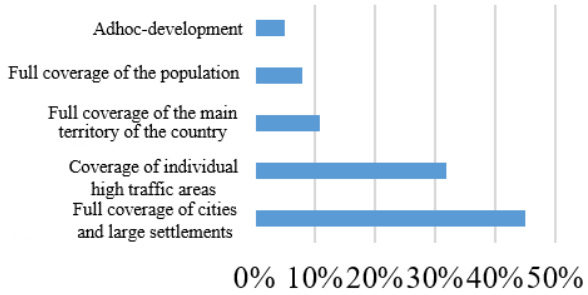

Fig. 2 View of mobile operators on coverage with 5G networks in the early phase of network development (% of respondents)

According to the analysis results, it is worth noting that industry regulators see 5G as a strategically important initiative to develop the infrastructure of the digital economy and therefore try to ensure the effective implementation of this standard.

All leading countries are working to create state policy to stimulate the deployment of next-generation networks, recognizing their strategic importance for acquiring national technological leadership on the world stage.

Most countries have already identified various target frequency ranges for the new communication standard and are undertaking practical steps to release them and use them for fifth generation networks [5].

For example, in the USA and Canada, industry regulators have not yet published 5G development roadmaps, but they have already outlined the main policy guidelines in this area - an emphasis on supporting competition. Both countries have technological neutrality; radio frequency distribution is performed through auctions with access by all operators. In the USA, there are restrictions on the volume of acquired 5G-spectrum by one operator. The American regulator is actively investing in mobile development: $350 million goes to wireless technology research, $85 million goes to test platforms of 5G systems.

In the European Union, strategic documents on the 5G development, common for the EU, have been developed; radio frequencies for new technology have been determined.

Countries additionally establish their own strategies. The acquisition of radio frequencies is performed competitively. In a number of countries (including the United Kingdom) there are restrictions on the amount of frequency resources acquired by a player. 5G developments and tests are actively funded: - In the UK, £16 million has been allocated to three universities for local 5G clusters creation, €80 million has been allocated in Germany for 5G research

Japan has already formed the main documents regulating the 5G policy. Korea is only forming a 5G strategy. Japan is one of the few countries with a non-competitive radio frequency distribution system. The regulator allocates frequencies based on an assessment of the telecom operators plans for their use. The principle of technological neutrality is not implemented in Japan.

Competitive frequency allocation is expected in South Korea. The South Korean regulator is planning to invest $490 million in 5G technology research by 2020.

Based on the analysis of international experience, three key models of network infrastructure development used in the world can be distinguished:

1. Independent development of networks by telecommunication operators when sharing (Network Sharing or sharing) passive infrastructure — sites for equipment, towers, fiber-optic communication lines.
2. Development of active network equipment based on intensive sharing.
3. Development of a unified national network used by all other operators on a contractual basis.

Intensive use of active infrastructure sharing can be considered as the priority and less risky scenario for the fifth-generation networks development. An important factor in efficiency, cost reduction and increasing the speed of network development will also be the activities of municipal authorities, providers of antenna mast structures and fixed-line telephony operators, which can stimulate such sharing by offering their services for the placement of equipment on a non-discriminatory basis, organizing communication channels for all players of mobile communications market at once [6].

Scenario 1 implies the largest total investment for the industry: on average during 2020-202 , each operator will have to invest 130-165 billion rubles in the radio access network and upgrade the transport network for 5G, the total costs of the industry will amount to 550-610 billion rubles, subject to the development of networks by four operators. Such indicators approximately correspond to or slightly exceed historically formed levels of capital investments for the deployment of previous generations of mobile communications and will amount to about 8% of the industry's forecasted revenue in 2020-2027.

Scenario 2 in a sharing variant similar to the current LTE co-development model in the Russian Federation, but with the joint use of about 70% of 5G base stations by a couple of operators, will require significantly lower costs – about 110 billion rubles on average (radio access and transport networks, excluding the home network). The total costs of the industry will amount to 400-445 billion rubles for the creation of 5G networks infrastructure by four mobile operators with an additional, very significant reduction in operating costs.

In the case of conservative traffic growth rates (x12 times by 2027) or when optimizing investments in coverage, the presented levels of capital investments will be lower by another 5-20%.

Despite the creation of a unified network Scenario 3 has a high level of capital investments and operating costs, since it will require a large-scale creation of infrastructure (communication lines, platforms for the placement of base station equipment, switching rooms and data centers), as well as the introduction of IT systems that ensure the operation of a single national network that existing players already have. Network development (5G radio access network and transport network, excluding home networks) will require at least 330-365 billion rubles and will increase the total operating costs of the industry by 109 billion rubles annually. The additional operational costs make Scenario 3 less efficient in terms of the network ownership cost compared to Scenario 2.

The implementation of Scenario 2 – the intensive use of the sharing model of active network equipment according to the competitive development model – will allow the industry to introduce fifth-generation networks with comparable or lower budgets for total capital investments compared to historical levels, i.e. 16-20% of the industry's revenue in 2020-2027, taking into account the most conservative forecast of the dynamics of the mobile market.

In the option of 5G networks independent development by mobile operators, the total level of capital expenditures can reach 18-22% of the industry's income with a historical level of 19%, which implies a certain, but insignificant growth, which can be partially offset by further expansion of sharing practices of passive network infrastructure within Scenario 1.

One can define seven key criteria for analyzing the scenarios listed in the previous section:

1. Cost effectiveness

As we saw from the previous section, the scenario of intensive network sharing (Scenario 2), which will ensure sustainable development of the industry, is the most effective in terms of cost and total cost of network ownership.

An important factor in the long-term development efficiency of the entire telecommunications industry is also the efficiency of using the limited radio frequency spectrum.

According to our estimates, each operator, through effective investment in new network technologies, by 2027 will be able to additionally release a total of up to 20-30 MHz of the 900 MHz and 2100 MHz radio frequency spectrum used by it (in addition to the already released radio frequency resource of 2G 1800 MHz networks) for further use for new generations of communication. Scenarios 1 and 2 imply the obvious presence of economic incentives for the efficient use of radio frequency resources in the form of potential to reduce capital and operating costs. Scenario 3 does not contain incentives to refarm the existing spectrum for fifth-generation technologies and limits the existing mobile operators in this, which will lead to less efficient use of resources in the long term [7].

2. Securing infrastructure development financing

The speed and efficiency of network deployment largely depends on the availability of very significant financial resources for the equipment acquisition and the network construction. Foreign experience shows that the delay in launching integrated national networks was largely due to the need to reach and formalize agreements between many different parties, including raising funds, or the lack of necessary financial resources from a single operator.

3. Network rollout and service penetration

The speed of new networks development and the new technologies introduction in the telecommunications industry is due to the high level of competition. As mentioned above, a number of operators are trying to ensure quick access to the market with a new service and thereby use the quality and coverage of the network as a source of differentiation. Others are focused on maintaining the optimal pace of network development and the minimum commercially justifiable lag in the level of infrastructure development compared to leaders in order to prevent the loss of customers. The competitive development of the network, as a rule, creates the basis for the high rate of new technologies introduction (5-6 years to reach 85-95% of the population's coverage of networks) and the high penetration of services of the next generations. Operators actively model and promote them on the market due to this.

The single network creation (Scenario 3) eliminates the differentiation capabilities of mobile operators by covering the network and marketing new technologies (all operators have the same degree).

Largely because of these reasons, telecommunication regulators and antitrust authorities of countries with a high level of ICT markets and the digital economy development do not allow reducing the level of infrastructure competition among industry players.

4. Competition and innovation development

The presence of competition in the modern mobile communications market determines not only the speed of network construction, but also such important factors for the consumer as:

- Ability to personalize the service: for example, provision of service settings, such as customer equipment, reuse of an existing telecommunications infrastructure, establishment of the required SLA level, contractual conditions, personalized for the customer's tasks as much as possible.
- The possibility of implementing differential pricing for different categories of consumers: customers demanding the quality and coverage of the network select operators – leaders in network development, usually with premium pricing, while consumers who are price-sensitive and less demanding on network coverage and the availability of innovative technologies choose discounter operators.
- Incentives for the introduction of new network services or ICT services: operators are interested in introducing new services, which often require upgrading network equipment in order to achieve competitive advantages in the market.
- Incentives to increase efficiency: in conditions of intense competition, operators are interested in a constant improvement in the efficiency of network operation and development: optimization of procurement, processes, automation, implementation of technological innovations and network optimization. As a rule, increased efficiency contributes to lower prices for communication services.

The introduction of a single network increases the risks and difficulties in implementing the above factors due to the lack of necessary market incentives. On the contrary, competitive scenarios stimulate the growth of efficiency and customer focus, the operators flexibility in developing the network for the customer's tasks, which in practice is confirmed by the history of telecommunications industry evolution [8].

5. The presence of incentives to improve the services quality

The quality of communication services, along with the cost and coverage of the network, is one of the main consumer properties. The competitive development of infrastructure and the operators flexibility in making infrastructure decisions, the availability of their own radio frequency resources stimulate and provide effective leverage for continuous network optimization and modernization to achieve the target parameters of service quality.

6. Technology risk management

With the high level of ICT technologies penetration, consumers are increasingly dependent on ensuring the necessary quality and uninterrupted operation of communication networks of mobile operators. In such a situation, the current model of several network infrastructures presence provides additional stability and the possibility of physical duplication of mobile communication channels (for example, several SIM cards in ATMs, payment terminals, alarm devices, multi-operator SIM ERA-GLONASS, etc.) [9] .

7. Political risk management

Network technologies and infrastructure are increasingly seen as an important factor in national security and a factor in the country's development. In these conditions, it is important to take into account the risks of introducing foreign trade or political restrictions for players in the telecom market. The possible imposition of sanctions or restrictions on the supply of equipment, IT platforms in the event of the 5G network development under Scenario 3 may increase the risks for the continuity of operation of the fifth-generation unified national network. Competitive scenarios (1 and 2) can reduce such risks — restrictions for one player are smoothed out by the presence of other telecommunication networks.

III. DISCUSSION OF RESULTS

The simulation results show: even in very high projected rates of traffic growth, reaching high target levels of 5G network coverage and maintaining existing competitive models for infrastructure development, the industry does not expect a

significant increase in capital investments compared to the already established level.

Assessment of the level of investment in the 5G infrastructure construction in 2020-2027 (a radio access network and additional transport network capacities) using the model of independent development of networks by mobile operators will average about 8% of the industry's revenue annually.

The practice of joint development of infrastructure will provide an additional reduction in the cost of 5G networks ownership and the volume of capital investments (up to 30% in the case of joint development and operation of networks by two operators). An estimate of the required capital costs in 2020-2027 for the construction of a radio access network and modernization of the last miles of a transport network for one operator averages about 110 billion rubles, the industry's total costs reached 400-445 billion rubles with an additional reduction in operating costs.

Expanding the infrastructure sharing and development by operators within a competitive model will be the industry's new paradigm for the fifth-generation networks development. Other scenarios – independent construction of 5G infrastructure or the creation of a unified fifth-generation national network – will either require more financial resources and time (option for independent development), or will be associated with risks of lowering the level of competition in the industry and, as a result, a possible negative impact on the consumer over the main parameters — price, quality, innovativeness and personalization of services, the possibility of physical reservation of infrastructure (option of a unified national network).

Even without taking into account investments in the infrastructure of the home and backbone networks, the costs of creating a unified national 5G network (the third simulated scenario) will amount to not less than 330-365 billion rubles. The total annual operating costs of the industry will increase by 10-19 billion rubles [10].

IV. CONCLUSIONS

5G provides new opportunities for creating digital ICT services and, of course, will form the basis for the digital economy development. At the same time, operators developing mobile networks of new generations in the next decade, will inevitably face challenges such as continued traffic growth (we estimate 12–21 times growth in the next 10 years), the need to use new high radio frequency ranges and improve performance communication services in the face of severe competition and low growth rates of industry revenues.

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