"Smart” city” concept for settlements in the Arctic zone of the Russian Federation

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Abstract. The paper deals with issues related to the use of the concept of a "smart" city. It is concluded that the "smart" city concept is reviewed in the scientific literature and has practical achievements for large cities. The analysis of features of the Arctic zone of the Russian Federation in the context of innovative development is carried out. The analysis of the process of population distribution in the Arctic zone of the Russian Federation and its result - a network of settlements - is presented. The conclusion is made that the Arctic zone should be the place where, first of all, it is necessary to test the "smart" city concept, and the existing network of settlements and interrelation of various types of settlements in the Arctic zone should be used as the objects of using the technologies of the "smart" city concept and their applications. The technologies of the "smart" city concept, which can be used for different types of settlements in the Arctic zone, are determined. The methodological approach taken as the basis for this paper includes: a) an analytical review of literature, focused on the geographical, technological, and institutional characteristics and abilities to implement the concept of sustainable development of the AZRF on the basis of using information and communication technologies (ICT), robotics, and intelligent solutions in the projects of the "smart" city; b) conceptual construction of the real-world virtual cyberspace of the AZRF, or a complex of "socio-cyber-physical systems and intellectual space", which could serve not only for the purposes of monitoring of the mentioned area but in the future could also become a flexible and multi-faceted tool for managing sustainable development of the AZRF. Keywords: Arctic zone of the Russian Federation, development drivers, real-virtual cyberspace, sustainable development, unmanned aerial vehicles.

1. Introduction

Recently, there has been an increased interest in the use of advanced information and communication technologies (ICT), robotics, and intelligent solutions in "smart" city projects. It is assumed that these technologies will help to create intelligent automated services to improve the productivity of infrastructure and the level of comfort of the city residents. The main purpose of creating a "smart" city is to create an efficient urban infrastructure and ensure a reduction in prices for services of citizens. "Smart” cities are widely defined [1] as urban areas that combine information and communication technologies to improve urban operations in everything: from traffic flows to water conservation and crime prevention.

The European Platform for Intelligent Cities and the European Network of Living Labs defined "smart cities" as "the use of discrete new technological applications such as RFID and the Internet of
Things through a more holistic concept of an intelligent, integrated system which is closely related to the concept of life and user services" [2].

The level of development of a "smart" city can be assessed by several parameters, including "smart" environment, "smart" life, "smart" economy, smart people, "smart" mobility, "smart" management, and "smart" tourism.

A smart city is a concept of planned urban development to integrate information and communication technologies (ICT) and Internet applications in the field of technology in a safe way of managing the city's assets [3]. These assets include local government's information systems, schools, libraries, transportation systems, hospitals, utilities, waste management, law enforcement, and other public services.

Development and use of "smart" city services require the use of modern technologies, including wireless sensor network (WSN), Internet of Things (IoT), cloud computing, fog computing, and big data analytics.

Many technologies can make a significant contribution to the concept of a "smart" city. However, unmanned transport vehicles (UTVs), including unmanned aerial vehicles (UAVs), are some of the technologies which can become an important component in smart cities. For example, when UAVs are equipped with control sensors and cameras, and software for analyzing the data detected from urban infrastructure, we get applications for checking and monitoring smart cities infrastructure. The "smart" city concept is considered in the scientific literature and has practical achievements for some cities. But this is the territory and space of large metropolitan cities.

The purpose of the paper is to analyze the possibility of applying the "smart" city concept for a territory and space different from a metropolis - for cities and settlements of the Arctic zone of the Russian Federation. The Arctic zone of the Russian Federation is characterized by weak population density, difficult living conditions, wealth of natural resources, and severe climate. Such conditions dictate the necessity of consideration of the Arctic zone of the Russian Federation as a "smart" territory and "smart" space and a presentation of the possibilities of applying the basic parameters of the "smart" city concept for the Arctic zone of the Russian Federation.

2. Background
The reasons why cities are becoming smart are described in [4] and include explanations such as rapidly growing populations, limited free and open areas for development, limited resources, increased attention to energy efficiency and environmental sustainability, and economic growth. In [5], the importance of considering how cities are managed, financed, regulated, and planned in the concept of "smart" cities is emphasized. Within the framework of the structure of smart cities, we can highlight various factors which, according to the authors of [6], are the most important in the functioning of "smart" cities.

Since 2010, special programs to support development of "smart functionality" of cities are being developed in the European Union. In Europe, these cities include Barcelona and Madrid in Spain, Amsterdam in the Netherlands, Manchester and Milton Keynes in the UK. However, the "smart" part in each of them is implemented in its own way. In Barcelona, the emphasis is on automation of urban transport and automatic watering of parks, in Amsterdam, more attention is paid to opportunities for small business development and smart electric power industry. It is expected that the global market of "smart" urban services will reach $400 billion in 2020.

The "smart" city concept implies using six state-of-the-art technologies: artificial intelligence; big data collection, storage, and processing; blockchain; Internet of Things; virtual and augmented reality; cybersecurity. The following are the components of the intellectual city system: video surveillance and photofixation; intelligent transport systems (ITS); a unified emergency call system (for example, "System-112" in Russia); a unified dispatch service and situational centers; the Internet of Things (IoT); the fifth generation of mobile communications (5G).
In paper [7], the authors show how smart cities can optimize the use of resources and improve the work of health care services, transport, energy and water supply, as well as increase the level of comfort of residents, through the use of technology "unmanned aerial vehicle (UAV)". Ulrike Esther Franke of the University of Oxford [8] notes that UAVs can make an effective contribution to the development of various civic applications, in contrast to previous periods, when unmanned aerial vehicles were mainly designed for military purposes. Research on unmanned transport vehicles began in Japan in the late 1970s. It is generally considered [9] that the main elements of the strategy for development of unmanned transport vehicles (UTV) in a "smart" city are dedicated infrastructure for unmanned transport; high-speed trains; delivery of goods by drones; smart parking. Traffic management, monitoring of urban transport, autonomous transport for a "smart" city is described in [10]. Methods of identifying unmanned vehicles that pose a threat to the functioning of "smart city" systems are described in paper [11].

The analysis of scientific achievements in solving the problems of a "smart" city shows that cities are more often turning to specialized technologies to solve problems related to society, environment, technology, and many others. The emerging concept of "smart cities" encourages this perspective by facilitating the inclusion of sensors and big data through the Internet of Things (IoT). This data flow brings new opportunities in urban management as well as an opportunity to deal with economic problems in the long run.

For example, the Finnish city of Oulu is described as a perfect smart city - the third Silicon Valley. The digital economy of this city has its roots in Nokia Research Centre and Technology Park Oulu. Despite the demise of Nokia in the 2000s, Oulu is still considered to be one of the world's best cities for start-up companies - a well-deserved reputation, given that it has more than 600 ICT companies, some of which use open platforms, including the 5G test network, OuluHealth (an "innovative ecosystem" for testing health products developments), and the citywide open and free wireless network (panOULU).

Similar discussions also touched Northern Norway and the town of Bodø. The decision of the Norwegian Air Force to relocate and close the military airport in Bodø made the city reconsider its urban development plans and create a modern, smart city in the north of Norway.

3. Features of the Arctic zone of the Russian Federation in the context of digital innovative development

The peculiarities of the AZRF include the following: extreme natural and climatic conditions, including permanent ice cover or drifting ice in the Arctic seas; focal nature of industrial and economic development of the territories; low population density; remoteness from the main industrial centers; high resource intensity and dependence of economic activity and life support of the population on the supply of fuel, food, and basic necessities from other regions of Russia; low stability of ecosystems, which determine biological balance and the Earth's climate, and their dependence on even insignificant anthropogenic impact. In such conditions, resettlement of the population, i.e. the process of distribution and redistribution of the population over the territory of the Arctic zone of the Russian Federation and its result - the network of settlements which includes accommodation of the population, the interrelation of settlements and migration of the population - has the following characteristics.

a) Cities where the majority of the population lives and where life is organized around enterprises. Most cities in the Arctic are monocities. They are tied to some enterprises where a significant part of the population works. The rest of the population works at state enterprises, in the infrastructure formations that support the existence of the city (boiler stations, electric power industry, municipal services), educational, health care, and cultural institutions. Major cities beyond the Arctic Circle are Murmansk, Norilsk, Vorkuta, Apatity, Severomorsk, Salekhard, Monchegorsk, Kandalaksha, Kirovsk, Naryan-Mar.

b) Small towns and villages, not necessarily small, are home to 300 to several thousand people: Polyarny (17 thousand people), Zapolyarny (15.4 thousand people). Polyarnye Zori (14.9 thousand),
Nikel (12.1 thousand), Gadzhievo (11.8 thousand), Vorgashor (10.9 thousand), Kola (10.1 thousand), Zaozersk (9.9 thousand), Ostrovnoy (2 thousand), Verkhoyansk (1.2 thousand).

c) Nomadic settlements where indigenous peoples and those who come to work live in tundra. Indigenous residents spend a lot of time in tundra, they are in contact with residents of villages and towns, come to towns where some people have apartments, work within the social sector and are fully integrated into regular urban life.

d) Hydrometeorological stations, where people come to perform some work for a certain period, can accommodate up to fifteen people each. In the Soviet times, there were 40 stations on the coast and islands.

e) Rotational villages which resemble dormitories and where employees of large enterprises, such as oil producers, live. Most oil workers come to work for a month or two, and then leave for the same period. Hundreds of people live in rotational villages at large oil deposits.

There are few roads in the Arctic, in medicine they use medical aviation, children are sent to boarding schools, and goods are delivered in summer by water. It is because of the climate that there are very few roads in the Arctic zone. However, there is contact between separate settlements. For example, the Taymyr Peninsula is a place where there are no roads at all. However, people there move quite actively: using snowmobiles, various modifications of track vehicles, and maintain contact with people who live at a quite long distance. In Yakutia, telemedicine is actively developing, with the help of which one can consult a doctor at a distance.

The existing network of settlements and interrelation of settlements of various types dictates general requirements to innovative development of the Arctic zone of the Russian Federation. It is very obvious that in the severe Arctic conditions, machines are more preferable than people. Mechanisms can work without rest and at minus temperatures, and at significant pressure drops, and at overloads. Technological achievements of recent years open new prospects for the Arctic, when even crucial and demanding areas can do without human involvement.

Proceeding from the difficult living conditions of people in the Arctic, the importance of preserving the environment, and the capabilities of advanced production and digital information technologies, the Arctic zone should be the place where the concept of a "smart" city should be tested first and foremost. Usually, the "smart" city concept is considered in scientific publications for large metropolitan cities. As for the space of the Arctic zone of the Russian Federation, it is logical to interpret the concept of a "smart" city in an expansive way, adding a "smart" network of settlements to the concept of a "smart" city. In this interpretation, the "smart" city concept applies to all types of settlements in the Arctic zone of the Russian Federation - Cities, Small Towns and Villages, Nomadic Settlements, Hydrometeorological Stations, Rotational Villages. The "smart" city concept will provide a variety of discrete new technological applications for all types of settlements in the Arctic zone of the Russian Federation.

The added part - "smart" network of settlements includes the notion of "virtual agglomeration" for network interrelation of all types of settlements of the AZRF, i.e. there is no physical proximity, but information and ideological (transformation into a network of "smart" settlements of different types as a fulfillment of one of the goals of sustainable development) proximity exists. Within the limits of virtual agglomeration of "smart" settlements, i.e. cities, small towns and villages, nomadic settlements, hydrometeorological stations, rotational villages, it is possible to unite resources, to coordinate management, to develop and use a joint material-information logistics infrastructure, which is significantly based on information solutions which allow more effective development of territorial units in the direction of their transformation into "smart" settlements, which in the long run should provide a synergetic effect of sustainable development of the Arctic zone in the Russian Federation.

4. Opportunities of the "smart" city concept for the Arctic Zone of the Russian Federation

The analysis of the "smart" city concept to provide a variety of discrete new technological applications for using in different types of settlements in the Arctic zone of the Russian Federation demonstrates the possibility of such an action.
Development and operation of services of "smart" settlements in the Arctic zone of the Russian Federation require the use of the following technologies of the concept of a "smart" city: the Internet of Things (IoT), wireless sensor networks (WSN), cloud computing, fog computing, analysis of big data, technology of unmanned transport vehicles, including unmanned aerial vehicles.

The fundamental principle of a "smart city" is introduction of information technologies and IoT objects into the urban environment, removal of human from operations in various processes. The Internet of Things (IoT) is a network of physical devices, such as sensors, actuators, and vehicles, that allow these devices to communicate and exchange messages. The IoT allows integrating various physical devices within smart cities in the urban network. Smart city applications built on this type of network are called IoT Smart city applications. These applications use IoT components and other necessary systems to perform their operations.

Wireless sensor networks (WSN) are a group of distributed connected sensors used to monitor various physical situations such as motion, wind, water flow, temperature, sound, humidity, etc. WSNs are used in smart cities to monitor the status of various resources and situations in various areas, including pollution monitoring, traffic, occupancy of buildings, energy and water consumption, etc.

Cloud computing, as defined by the National Institute of Standards and Technology (NIST), is a paradigm that allows users to access jointly configured computing resources via standard protocols. One of the key features of cloud computing is that the computational capabilities can be scaled quickly and easily according to the needs. Cloud computing can provide a variety of computations, storage, and advanced services for smart city applications. Examples of these advanced services include data mining, machine learning, simulation, optimization, and autonomous decision making.

Fog computing is an architecture that uses one or more peripheral devices, such as modern network routers, computers, or other computing systems, devices available near IoT applications to provide localized services for these applications. These services can be storage, security, communication, control, configuration, monitoring, management, or mobility support services. Using fog computing will provide better support of the requirements of IoT applications for "smart cities", such as low latency, location awareness, mobility, streaming, and real-time responses [12,13]. Fog nodes are distributed in different locations within a smart city to effectively deliver their services.

Big data analytics is the process of checking, cleaning, transforming, and modeling exponentially growing data in order to implement useful information that improves various decision-making processes. Big data analytics can be used to facilitate intelligent (as well as autonomous) decision-making based on the data collected to improve "smart city" services.

Unmanned transport vehicles. The large expanse of the Arctic and small population makes the operation of unmanned robotic vehicles safer in case of emergency situations. In the area of ground unmanned transport vehicles, the issue of "remote" movement in the Arctic is not considered a problem. Compared to the urban environment, where autonomous cars are already being successfully tested, a trip through the tundra, where there are no road signs or oncoming cars, will be an easy walk. Apart from that, it is necessary to provide heating for the sensors. In addition, electronics "sees" much better than a person, regardless of whether it is nighttime or midnight, rain or blizzard - the program perceives precipitation as some kind of noise that can be filtered out.

Similarly, in the air: UAVs are flexible and fast mobile platforms which can be used for many applications in "smart" settlements of the AZRF. These include traffic and congestion monitoring, environmental monitoring, civil security, delivery of goods, and much more. UAV applications designed to meet the requirements and functionality of "smart" cities (settlements) in the Arctic zone of the Russian Federation, will be productively linking UAVs with "smart" cities (settlements).

The analysis of the research on the topical problems of the concept of "smart" settlement in the Arctic zone of the Russian Federation confirms that at the present time, a set of problems facing the concept of "smart" settlement, taking into account the technology of a "smart" city with appropriate applications, developed from a fundamental position, can be presented for the Arctic zone of the Russian Federation in the form of a digital real-world virtual cyberspace with built-in multifunctional unmanned aerial vehicles (UAVs) in the form of a self-organizing distributed computer network.
We imagine the digital real-world virtual cyberspace of the smart Arctic with built-in multifunctional unmanned aerial vehicles (UAVs) as a self-organizing distributed computer network. In cyberspace, UAVs, along with peripheral devices, are both UAV-functions (logistics) and elements (nodes) of this self-organizing distributed computer network. UAVs are able to quickly deploy a UAV fleet (of small size and different computing power, depending on computational tasks - the UAVs are the nodes of the network in the technology of fog computing) and provide stability and continuity of this self-organizing distributed computing network, including in the event of a breakage of communication.

The digital real-world virtual cyberspace of a "smart" settlement in the Arctic zone of the Russian Federation can be presented in three different dimensions: 1) Physical aspect of cyberspace; 2) Information aspect of cyberspace; 3) Social aspect of cyberspace. From the point of view of physical or material perception of cyberspace, it is availability of certain devices (computers, smartphones, means of virtual reality, etc.) through which the cyberspace is created and functions. Cyberspace is a virtual place created by a network of interconnected computers in which agents interact. The information aspect of cyberspace involves analyzing cyberspace as a set of countless information flows through which the digitized information flows at an incredible speed. And the social aspect of the cyberspace analysis is related to the study of all social interactions that occur in this intangible digital environment. This view of cyberspace implies consideration of four layers.

The first layer. Providing the material support of the real-world virtual cyberspace consists of a chain of electronic impulses - technological infrastructure of information systems, telecommunications systems (microelectronics, telecommunications, computer processing, broadcasting, and high-speed transport systems, etc.). The second layer consists of nodes, hubs, and communication centers. Hubs are places of communication. Hubs operate on the basis of an electronic network, but this network links specific locations with clearly defined social, cultural, physical, and functional characteristics. Nodes and communication centers are organized hierarchically according to their significance in the network, but the network hierarchy is flexible.

The third layer refers to spatial organization of ruling institutions [14,15,16].

The fourth layer of space contains electronic spaces, such as websites, messengers, etc. (these can be both unidirectional and interactive flows). It is this layer of flow space that is characterized today by the greatest development dynamics and has a crucial impact on decision-making processes, information production, and communication.

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