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Impact of Digital Transformations on the Design Framework of a Modern City

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***Abstract* — The article presents the use of sensors and networks, which allows you to predict energy consumption, radio frequency congestion, information transfer rate and power consumption required for data processing, thus predicted the minimum economic benefits based on energy savings. Based on the analysis, the options for integrating IoT intellectual services into urban structures and the option of seeing the scalability of IoT systems depending on the growth rate of Smart cities are presented.**

Keywords* — *SIoT, IoT, engeneering, DigitalPublicWay systems, Smart City Design, M2M

I. Introduction

The ultimate use of the essence of things and phenomena, the most economical expenditure of space and time have become fundamental provisions for the deployment of the Internet of things (IoT) and its latest manifestation of the entire Internet (IoA, IoE, M2M). Creations of technology and computer science, whether we like it or not, become the starting point for the growth and development of new forms, methods of management and organization, urban and personal space. The question of the style in which urban structures will be executed becomes one of the most problematic for modern society. IoT has allowed devices around the world to integrate information flows, and this feature is often not used due to delays in processing and analyzing data related to system architecture.

Studies of new urbanism and "smart" urban growth [1] show that consumer factors and public policies have that shape and enforce technical and engineering standards for urban structures [2]. Those are important factors in designing engineering infrastructures [2]. Their assumptions are supported by studies [3], new urban principles for the development of the urban environment [4] and focus on the main indicators: housing problems [5], convenient highways for resource and energy distribution [6], wide streets and housing density problems [7], green or eco-cities [8], etc. At the same time, the functions of the "natural" habitat zone [9], regardless whether these principles conform to the history of the city development [10], the order parameters of the local culture [11], standards, or ideas about due [12], should satisfy paradigm of "smart" urban growth. The city "follows" the landscape [13], and they are easy to move [14], contain a wide range of housing, while being in compliance with all the currently known environmental criteria [15]. The theory of a smart city assumes that cities will not grow in the area but will preserve landscape configurations by maintaining the land using tradition and population density depending on the region, city, country [9, 16]. Convenience in movement is provided not only by developed transport infrastructure, but also in using the same areas of the city for different functional purposes, and all together, they meet the land use rules, health standards, technology and communication rules [1].

Traditionally, during the process of planning networks, including the Internet of Things, IT architects take into account a number of factors: what type of devices or sensors will be connected, how many devices there will be implemented, the expected volume of traffic, the types of traffic based on which connection options are planned to be used, and the approximate network budget, including capital costs and operating expenses. However, the decision about the using of fixed or mobile devices / sensors, security requirements, the possibility of analyzing data in real time or access to power sources are taken depending on the expert opinion of the smart city's designer. Modern technologies allow considering the natural and climatic features of the territory with the help of Digital Public Way systems — open platforms for exchanging data on the state of urban infrastructure, and the designer «records» their presence in the work of all infrastructures. Here it becomes important to determine the best project solution in the territory — information technology — Internet of things.

II. Data and Methods

For the study, secondary data (online) taken from open sources, texts, diagrams, reports of service providers, and advertising materials of equipment manufacturers were used. The research method is analysis and comparison of data, forecasting.

III. Results

Nowadays, Russian cities are comparable in energy consumption with the world average level; this can be taken from the report [17]. Moscow is the third in energy consumption of megacities in the world. In exact numbers, the power consumption of Moscow is 51954.3 million kWh [19]. That is a quarter of the total energy consumption of the Central Federal District and is comparable to the total consumption of the Southern Federal District which exceeds the total consumption of the entire Far Eastern District.

To build the model, we took the data of [20] as a basis, but with some limitations. The territory project is not being built for the metropolis but for the district, with a population limitation of 100 thousand in habitants. Unlike the source [20], our territory has no one-story buildings but is completely built up with multi-store buildings. The number of floors in modern realities has long been above 5, but we consider that similar capacities are transferred from two buildings to one in the case of resettlement and the actual value does not change. We consider the required number of houses and apartments per 100 thousand inhabitants — 334 houses, 80-100 apartments in a house, the average number of people in a family is 3. Taking into account service enterprises and the average production scale, we will conditionally consider the computing power equivalent to another 50 houses. In fact, the figure may differ up and down (the average is taken based on data [21] and divided into 1,100 cities of the Russian Federation participating in the 2010 census [22, 134-138]).

In addition, to get the power reserve and redundancy of systems, as well as systems of auxiliary operations, we need a value capable of processing information from 500 units of buildings. At the same time, we are offering a variant of the development of social infrastructure — business, education, medicine, sports, etc. The number of smart urban infrastructure is calculated according to the principle is approximately 5 per apartment and. 100 sensors from general home premises at least (5 light sensors per staircase are another 25 sensors, 2 switches, 1 line of the video surveillance system per staircase is 5 streams from one building). Also, global pressure sensors in systems and the states of engineering systems are 1 for each ladder, a total sum of 25 and more sensors with different minimum values [23]. In fact one building will contain approximately 230 measuring and control devices, of which 10 are control transmitting. It is they who will interest us first.

For 500 buildings there are 5,000 devices that transmit huge flows of collected information in a different form. It is minimum quality. To implement the collection and consolidation of information, it will be necessary to build a data network of the municipal scale — the metropolitan area network (MAN) — which can later transmit data to the centralized network of the country. The report 3GPP TR 38.913 defines the maximum requirements for key indicators (KPI) of the 5G / IMT-2020 network, the peak data transfer rate: downlink (DL) 20 Gbit / s; uplink transmission channel (UL) 10 Gb / s; per subscriber 1 Gbit / s; density of connected subscriber devices: 1 million per 1 km^2. Abonent terminal battery life is 10 years for IoT devices (M2M); continuous service during handover. Given the increase in data transfer rates and traffic density in mobile communication networks, the issue of effective regulation of the use of RFS comes out on top.

Within the municipal network, it is possible to use a hybrid network topology, depending on the network segment, a hierarchical (from districts to the city) star (from buildings to the district center, which serves as a hub). Inside the buildings, hybrid star and hierarchical networks are possible. So far, nothing complicated would seem until diving to the levels of transport protocols and types of data transmission used by the devices. So we have a group of devices that operate at different frequencies, for example, 433.92MHZ switches, modulation method: ASK, operating frequency: 433 MHz ± 2 MHz, RF Receiver 1527 EV1527 — for pairing. Or there is a second frequency: 868 MHz and several variants of modules for it. There are families of modules capable of operating in other frequencies: 2.4 GHz (less often 315 MHz, 450 MHz, 490 MHz, 915 MHz, etc.). But, not all frequencies are open for transmission at the level of the law and there are restrictions everywhere.

Since the frequencies 433 have long been open in our country, there are already enough devices in this range that can create noise and interference in the transmission. The broadcast is not very “free” and here we will most quickly encounter the problem that each manufacturer has its own protocol and systems device recognition “friend or foe”. In the forehead, we are faced with the fact that in addition to identifying the device, we will come to the point that it will be necessary to check the data for validity. Did anyone intervene in the transfer and did not replace one of the packages. Most of the packets use UDP protocols, protection in which is not in the first place, as well as the sequence of transmission and verification of the completeness of the transmitted data. Therefore, despite the transmission distance from 50 to 200 m as stated by the manufacturer (without taking into account interference from the blocked ceiling of the environment where devices are used), it will be necessary to artificially limit the area from which the signal is taken in order to minimize the number of possible false data.

Regardless of whether the subscriber connects through the cloud or directly in modern realities, the backbone is also organized through data transmission via a wired network, as the most common and capable of providing greater throughput, despite the topology of the area and buildings. To operate this network, you need several devices of the Cisco 6500 and 8500 family level, plus the 2950 family of devices for internal switching to reduce the total cost of the system based on the unification of infrastructure. Next node stations will be required to transfer information from municipal pools, even if we consider that the organization of the low-power wide-area network (LPWAN) will be organized without the participation of cellular networks of operators. Then the restrictions on the LoRaWAN (Long Range) modules themselves are currently considered to be among the most “long-range” (for example, AcSiP CW1276SL-915 — LoRa™), subject to technological limitations. It will still be within 15 km in the metropolis (based on signal attenuation when passing through obstacles) at least because it is impossible to use antenna powerful amplifiers and high power transmitters to the detriment of autonomy of the sensors themselves. Moreover the technology itself looks promising subject to a theoretical range of 100 km.

When using other technologies for example 6LoWPAN (IPv6 over Low-Power Wireless Personal Area Networks), we get a shorter range of 5–10 km in times of city conditions, but at the same time we get a signal almost ready for use and transmitted to the server without additional receiving and translating devices.

At the same time we must understand that in this way we will be able to transmit only signals from sensors and sensors due to limitations in network bandwidth and technology features. The autonomy and performance of sensors in several decades are achieved by immersing them in sleep and ultrafast transfer of the data itself. This in turn has its weak side in the form of a delay in accessing the module for information.

Regardless of the technology chosen we will need a receiver of signals from sensors, for example, the Cisco 910 Industrial Router (https://www.loriot.io/lora-gateways.html) will allow us to create a fairly wide coverage network, moreover communicating with our network in Date — the center and the highway in the same language. Again, we do not produce a zoo of unverified solutions and other protocols.

Or we select any other solution that is able to transmit data from the sensors to the wired network.

Next we have a video surveillance system that should function even when the light goes out in the house. It means that the most important thing is to look at TS-836 NVR mobile systems as an example, plus cameras capable of shooting in the absence of light — TS-317 — and that's all for every staircase. Plus you need a router that will collect data from DVRs and IOT network gateways. And anyway they will be needed for any technology. For example this is the standard LoRaWan map (in fact it can be transferred to any LPWan technology) (Fig. 1).

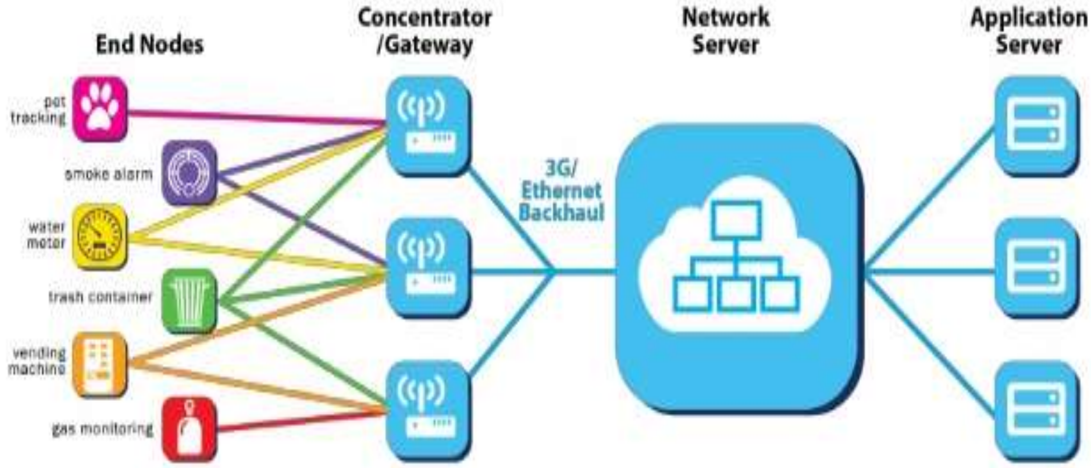

Fig. 1. Standard LoRaWan card

No matter how much we want there will be no miracles with one entry point in the situation center where you can collect all the data from all parts of the city simultaneously and without wires. And there will be additional nodes. It is possible to use the power of mobile operators, but in this case we get a direct dependence on relay towers and will have to pay rent or make financial concessions for using these facilities. As a side effect we can get a network "drawdown" on holidays, when the towers are not always able to survive the data stream. Again it is possible to use satellite channels but the retransmission of signals from sensors in this case will become extremely expensive and inefficient.

We calculate the economic feasibility of introducing automatic energy control systems using building energy management systems (BMS) [24]. This class of the system is responsible for the continuous energy-saving building management thereby achieving energy and cost savings. BMS are computer control systems including both software and hardware for controlling and monitoring the mechanical and electrical equipment of a building including ventilation, lighting, power supply systems, fire systems and security systems. It is enough to use introductory data that, on a city-wide scale, as energy consumption control can provide benefits in the following. Energy consumption control in commercial buildings can give an approximate amount of consumption savings of 29 %. For schools this figure rises to 49 %, freestanding stores and other service buildings - to 41 % [25]. The total from 500 buildings taken in the initial calculation under this category falls to 166 buildings. This is about 33 % of the total.

For a city of 100 thousand, there will be a need for 10 servers for computing clusters: 2 - for external resources, 4 - for internal processing of all signals, 2 - for connection to peak loads. We do not provide a separate server configuration as it is advisable to use cloud computing with dynamic load distribution and this is a subject for other calculations. We consider the availability of data storage and backup device. Ideally the whole system with switches will fit in two headquarters (considering the full redundancy system) 42U (Unit) and will not require a large room for accommodation, plus one cabinet with equipment for serving different networks and connections to trunk and backup networks. In total, 13 devices in the same cabinet, we believe that the average consumption of all is the same as that of the server (although the switches are often much more energy efficient) and amounts to 5265 kWh per year.

13*5265*2 = 136890 kWh per year

Within the area of 100 thousand people the amount of energy consumption of a single house for the maintenance of common property is approximately 3542.71 kWh per month (based on [26], in fact, the devices are twice as large), and 42512.88 kWh per year. Let us compare the consumption of one house with a high school or a stand-alone store. We get savings of 40 %. The otal for the year is about 17000 kWh. In total, in order to «feed» the energy center for data processing from the whole city, we will need to equip 8 houses with smart systems (out of 334) (136890/17000), which is less than 1 % of the total number of buildings.

And it will work. And this is just energy. At the same time, taking into account the particularities of cloud architecture, it will be possible to do projects in stages, gradually increasing the pool of equipment. For the organization of a new city and the addition of old ones it will not be necessary to increase the capacity of existing power plants which will allow saving resources spent on their production and maintenance of all networks that supply them to consumers. To top it off, it is possible to use the same benefit for the maintenance costs of data centers for calculating and processing data from all Smart IoT infrastructure (Fig. 2). Change over the period + 2.02% is just trends that mean leveling up the generation rate. So the economy tech can provide more energy for using during the same period. And it is just 10 % saving.

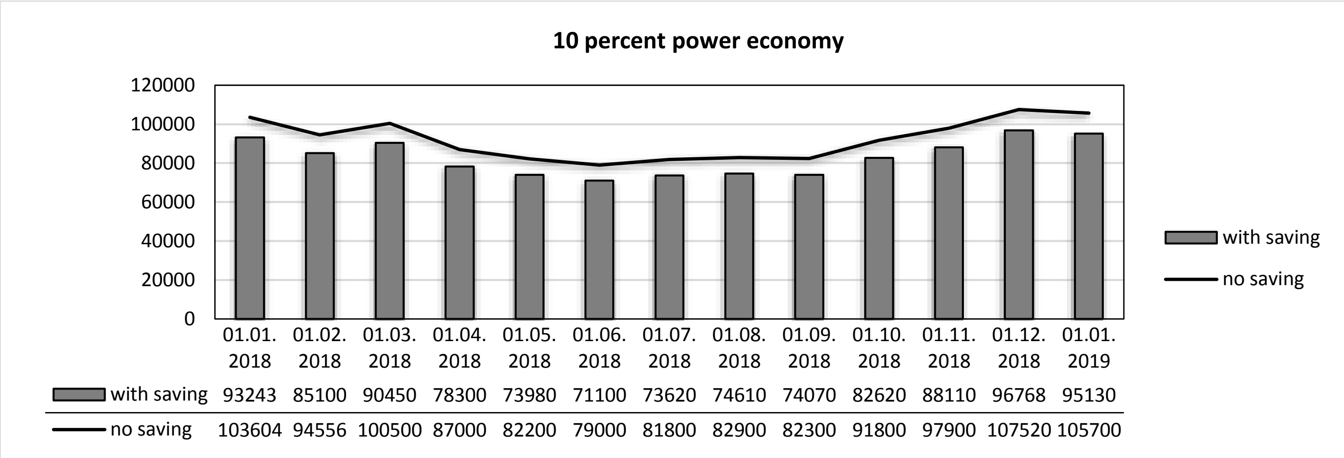

Fig. 2. Total Power Generation (https://minenergo.gov.ru/activity/statistic). All data are provided per 2018-year period in mln kWh: total for the period - 1196779.1 / total for the period (considering savings) 1077101.19 (10 %) / total economy - 119677.91)

The presented option considers only the energy during the building use phase, while the building materials themselves can also absorb energy. A large role in energy consumption is played by the lifestyle, habits, and needs of the residents of the home and the region, which also becomes a significant factor for designing a smart city. Another factor is the climate model of the city which significantly affects the design of buildings and urban spaces. These factors must be considered by designers, creating the infrastructure framework of the territory. If such factors are considered, then new requirements for building automation systems arise that will make the building's energy consumption more transparent. In this case the designers will be able to choose both the material and the shape of the building more appropriate to its new designation. Examples of smart city projects with energy-efficient structures are well known [2], and an analysis of their development shows that the main reason for the failure of development [27] in recent years has been a global change in requirements for the entire spectrum of urban services set by businesses and the public. And only an active response of designers and an increase in the level of comfort and energy efficiency in the projects will be the basis for their actual implementation.

IV. Conclusion

Gradual improvements in energy, heat consumption and the development of M2M systems, the Internet of things will allow you to use existing resources more efficiently and minimize losses. Nevertheless when designing any aspect of such systems, it is necessary to take into account different scenarios in their structure and transfer the scenario from a residential area to an industrial one is considered unacceptable. There will be the same mistakes as in the transfer of the megalopolis design model to the model of small cities. That will ultimately affect their development and question their existence in the future. We believe that it is possible to create a separate network based on the M2M nodes of different cities for intelligent distribution of excess capacity now based on existing resources which will further monitor the growth rate of the infrastructure of not only individual cities, but also regions and the country as a whole.

The urban environment, by definition, includes several layers of infrastructure. Designing a smart city is based on the concept of “sustainable” state of the system. When designing the urban environment, the main question is what basic factor will be applied by the designer when selecting categories of objects, resources and forecasting their consumption (in this case, consumption is understood as the ability to extract benefits from surrounding objects, their ability to generate, save, use, exchange information, etc.). Modern projects of spatial projects of cities as a rule include engineering infrastructures, communication network systems, systems of all types of communication, both electronic and physical communication of people, as well as all aspects of their biosphere compatibility. When designing a smart city the model of the city itself prevails over the model of individual structures and is transferred from the scale of the city to the scale of individual objects. The entropy of information in this case becomes the main problem in the organization of this practice. The basis for the design should be a condition for the active interaction of the system and the design of parameters in the study of algorithms and fine-grained sensor networks with urban power systems. Thus, we can conclude that the existing projects of smart cities will be able to develop and satisfy future residents only if they are focused on the transition from the current unified prospects to new intellectual and comprehensive projects, new technologies and material.

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