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Software-defined wireless urban network

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Abstract. Software-defined wireless urban network (SD-WUN) is a new network subclass for implementation in the “Smart City” project. SD-WUN can be offered as a single technical solution, built based on the most relevant technologies in the world of computer networks and the Internet. The theoretical model of existing technological solutions interaction is one of the best ways to eliminate the problems of the “Smart City” project mentioned in the work and offers one of the possible ways of its development in the future. The analysis is based on assessments of the prospects for the development of existing methods for implementing computer network nodes and the Internet of things (IoT), and their comparison with each other. One of the most pressing problems of the “Smart City” project implementation is the best choice from the point of view of network technologies. An urgent problem in the field of network technologies is the problem of the transition of network addressing from the IPv4 address space to IPv6. It is obvious that the Smart City project is associated with the popular IoT technology (Internet of Things) due to the progression of the number of devices. Another key point is the need to implement a project based on a high-speed wireless network, excluding wired switching. It is obvious that the network should possess such properties as security, distribution of computing resources, high data transfer speed and ease of use and support of the network.

1. Introduction

The modern society development, is fully consistent with the concept of Industry 4.0 in terms of technical equipment. Requirements for Internet technologies and their components, computer systems and software components cause the improvement of theoretical and practical developments in accordance with this concept. The modern production processes development is moving towards full automation with the real time management of all processes, taking into account external conditions changing. Internet technologies and their components must ensure reliable communication between the production process components and personnel. And this makes it necessary to improve the development of components that could carry out a complex restructuring of their characteristics, self-tuning and self-learning in accordance with this concept [1].

The Internet of Things technology (IoT) use the Internet for information exchange not only between humans, but between all kinds of "things": machines, devices, sensors, etc. On the one hand, sensor-based things can exchange and process data without human intervention, and on the other hand, a person can actively participate in this process, for example, when it comes to "smart home" or "smart production".

A variety of IoT is the Industrial Internet of Things, (IIoT). It opens the direct path to the fully automated production facilities creation. The key equipment components are equipped with various sensors, actuators and controllers; the collected data is processed and sent to the appropriate enterprise



services, than allows the staff to make informed and balanced decisions quickly. But the maximum task is to achieve such enterprise automation level that make machines work without the participation of people possible in all areas. The personnel role is reduced to monitoring the machines operation and emergency situations responding [1-3].

Such problems are found in various human activity areas, including robotics, various mobile platforms and critical application systems [4-7].

The human environment and urban infrastructure development face similar challenges. Today, one of the most pressing tasks of the Smart City project is the best network technologies choice. In this regard, an urgent problem in the network technologies field is the problem of switching network addressing from the IPv4 address space to IPv6. It is obvious that the Smart City project is associated with the popular IoT technology, due to a sharp increase in the number of devices. In addition, an important point is the need to ensure the project implementation based on a high-speed wireless network without wired switching. It can be argued that the network for the project should have such properties as:

- safety and security,
- computing resources distribution,
- high data transfer rate,
- ease of use and network support.

2. Problem analysis

2.1. Technology development options

The “Smart City” project implementation primarily involves the creation of a long-range wireless network in accordance with the concept "Industry 4.0", based on the use of sensors, a large number of network addressed devices, with a set of network protocols and related technologies. An analysis of technology development options, their relevance and pace of development, allowed to distinguish the following:

- IPv6 addressing;
- the prospect of wireless networks through 5G;
- the use of sensor-based LoRaWAN networks (Long Range Wide-Area Network).

2.2. LoRa, as an implementation of IoT

One of the most relevant technological solutions for IoT is the LPWAN (Low-power Wide-Area Network) wireless technology, which is a wireless network with low energy costs (figure 1).

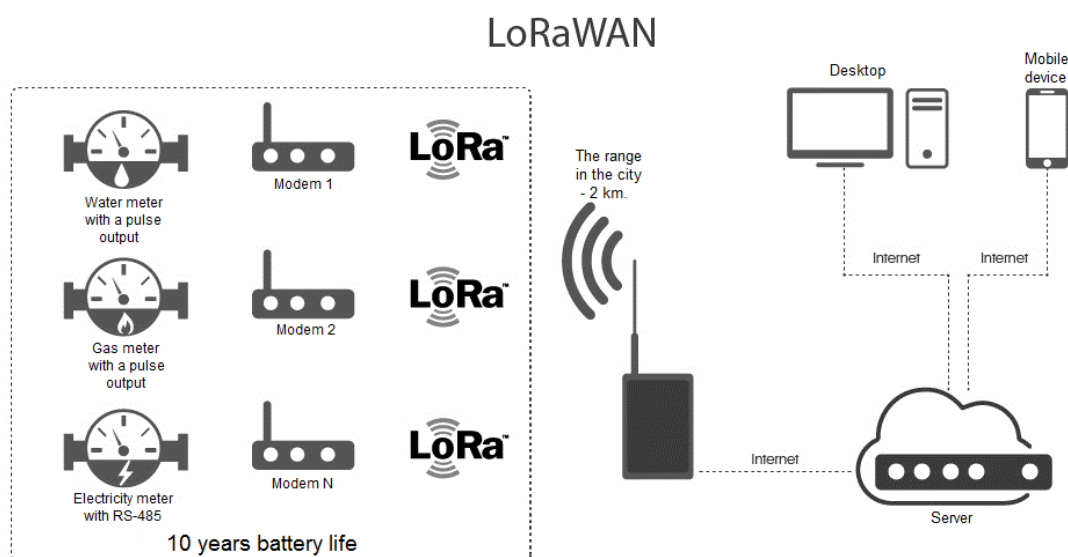


Figure 1. Principle LoRaWAN functioning.

Protocol LoRaWAN, which implements the network topology "star" is a specification LPWAN [8]. Radius network is about 1-2 km in such a case. A stable signal is expandable up to 4 km without significant obstruction signal, but with a possible loss of packets [9]. The low energy consumption of the sensors used in the network is another advantage of LoRaWAN.

2.3. IPv4 and IPv6 Addressing Dilemma

Modern statistics (figure 2) indicate that 20% of the global volume of Internet access devices are connected to the network using IPv6 [10, 11].

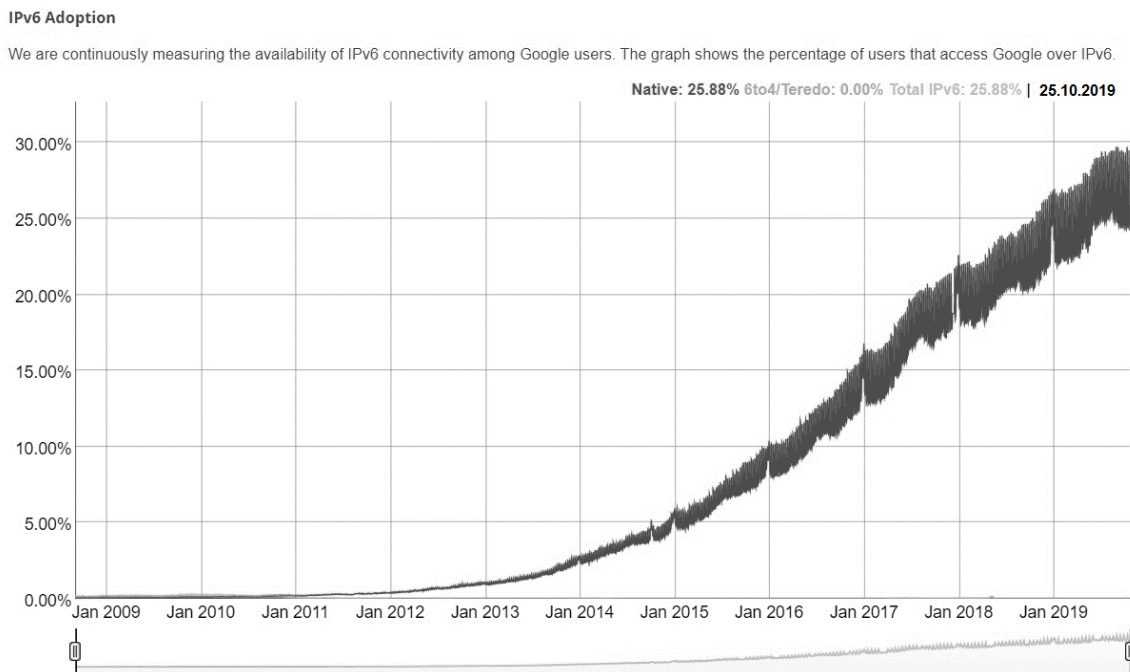


Figure 2. IPv6 usage statistics in the world.

In comparison with IPv4 addressing, IPv6 deprives the network of certain bottlenecks that need to be addressed: NAT (Network Address Translation), the need to use VLAN (Virtual Local Area Network), the complexity of managing network security rules. IPv6 addressing has many advantages over IPv4 addressing, however, the challenges of global transition hinder its rapid implementation. The main problem is that IPv4 requires maintaining backward compatibility in building networks, so the transition requires large financial investments.

Small network providers do not have the appropriate resources to conduct relevant experiments and cannot actively contribute to the global transition.

The generally accepted fact today is that the global transition is an irrevocable event. Currently, the United States, India, the countries of Central Europe and Asia are leading the world in implementing IPv6. Regardless of the pace and complexity of adapting a new type of addressing, a global transition in the near future will occur under the conditions of a constant increase in the number of IoT devices and equipment with Internet access. If the transition of existing networks is difficult to establish the reasons and consequences of using IPv4 destination network equipment, the city specified for the project "Smart City" should be built by using IPv6.

2.4. Technologies of wireless long range

With current trends in the world of network technology, high-speed wireless networks are a priority. This is due to the large amount of media traffic and QoS (Quality of Service) requirements. 5G is the single and perhaps the most rational solution for today. An approximate solution is WiMAX

(Worldwide Interoperability for Microwave Access), but the technology loses competition and is selective in cases of use, being in the 3rd generation category.

WiMAX wins the competition due to the range and frequencies at which it operates. But in the modern world, high speeds and support for the quality of service are required (table 1). However, IoT assumes low energy consumption, and the principles of functioning of 5G will favorably affect the implementation of the "Smart City" project [12].

As to 5G, active discussions are ongoing. The subject of discussion is electromagnetic safety. 5G operates at high frequencies, which may not be safe for human health until proven. In conditions of uncertain security, a vivid precedent was the case in April 2019 in the Swiss canton of Geneva, where the regional government imposed a moratorium on the use of 5G.

The vulnerability of 5G is that the declared figures of the transmission speed are guaranteed in the absence of any interference. Experiments have shown that bad weather conditions strongly affect communication quality. Additionally, it should be noted that in conditions of a city saturation with devices and high-rise buildings, the signal may be lost.

Table 1. WiMAX and 5G comparison.

Parameter	WiMAX	5G
Throughput	25-75 Mbit/s	1-35 Mbit/s
Radius	25-80 Km	Unlimited (depends on station density)
Frequency band	1.5-11 GHz	30-300 GHz
QoS	Non priority	Provided
Energy consumption	Middle	Low

2.5. Technologies of software-defined networks

Modern computer networks have many disadvantages. It's a constant need to optimize the information flow, complex security organization, a large number of protocols to be integrated in the set up. All it needs improvement and organizing simplification.

Software-defined networks (SDN) - is the principle of building networks, in which the entire network management mechanism is placed on a separate software base, and all traffic management is based on special protocols that operate on the concept of "data channel" and can perform various actions with it (allow, prohibit, redirect, rewrite fields in packages, etc.) [13]. In fact, the controller determines the network management rules based on real-time events, as well as the specialized applications operation (for example, emulation of STP or routing protocols, depending on the channels state in real time). The end result is transferred to the OpenFlow protocol switches in a flow-tables containing information about where, how and what traffic to pass. On the one hand, this approach gives great flexibility in network management, on the other - significantly simplifies network administration. This promotes virtualization in network management.

An important question - is building a network security system based on OpenFlow. The controller actually centralizes the intelligent functions of Firewall, IPsec and other common network security systems. The problem of security and its organization is the most energy-intensive and requires large resources.

3. Research results.

3.1. Objective

Search and formation of a unified technical solution and strategy for the implementation of network communication tools in the Smart City project, based on analysis and comparison of the complex of available technologies within the concept of "Industry 4.0".

3.2. The choice of technological solutions

Taking into account the specifics of the project and a result of a comparative analysis of the most promising solutions, a new subtype of networks is proposed as a common set of technological solutions for creating an urban wireless network of a wide range based on mobile communications (SD-WUN).

The proposed technical solution provides for the implementation of public Internet through 5G. It is planned to reserve communication channels with frequencies for the functioning of sensors based on LoRaWAN and the TCP protocol. Quality of Service (QoS) is provided according to the needs for media traffic based on the UDP protocol.

The implementation based on IPv6 involves the subsequent exclusion of IPv4 and NAT, and the structuring of network space without using VLANs, with a simplification of security policy, reduction to the use of AAA protocol and multi-level Firewall, with the transfer of security under the control of the network operating system.

The technical solution involves the construction of a SDN. This will give the network the flexibility to allocate resources through an open architecture in which various components can be combined. The technology involves dynamic cloud services, representing a computer network of physical objects. Such implementation is based on a network operating system.

A wide range of frequencies using 5G allows for a large range of different techniques and combinations of device types. With increasing amounts of the new wave device type, popularity acquires RFID technology. The network assumes the use of passive, semi-active, active RFID tags with a range of up to 300 meters. This makes it possible to localize objects in space, access control and contributes to the implementation of IoT functions.

3.3. Technical Solution

The proposed technical solution takes into account the fact that IPv6 addressing allows you to structure addresses by geographic location. Since the length of the network address is 128 bits, which gives an almost inexhaustible limit of address space and the possibility of networking [14]. The solution is to use IPv6 geography not only to identify the city, but also to determine the area or neighborhood. This improves the structure of the urban network, and makes it easier to solve problems that are not solved by routing protocols. The density of devices makes it possible. Smart City is to use to 2000000 devices per 1 square kilometer, which corresponds to the use of a large number of stations that will relay the wireless signal.

Each 5G signal propagation zone has its own radius, within which addresses of a certain range are used, which is reserved for geographical affiliation, an example of which can be a residential city block. This makes it possible to structure in the management of the SD-WUN network (figure 3). 5G provides a low energy requirement, and introduces the possibility of implementing many technical innovations, such as augmented reality and others that require high data rates of large amounts of data in a short period of time.

The urban network should focus on the SDN. This creates great advantages, making the network flexible and distributed. The network does not require large resources to manage it. This choice caused great richness of personal use devices, and IoT organizing means.

SDN will give it flexibility in the resources allocation through an open architecture, which can combine different components. The technology implements a computer network of physical objects, which provides dynamic cloud services. The implementation is based on a network operating system. A significant advantage of this networking - is managing the program module and artificial intelligence. This ensures that there is no data flows distribution problem, as the system monitors channels in real time, and shifts the responsibility to choose the shortest path. This creates real-time routing dynamics.

The Internet of Things in this project version can be embodied in the full range of industries and reproduction prospects. This is a smart transport, smart buildings, communication with industry, web crawling things with artificial intelligence.

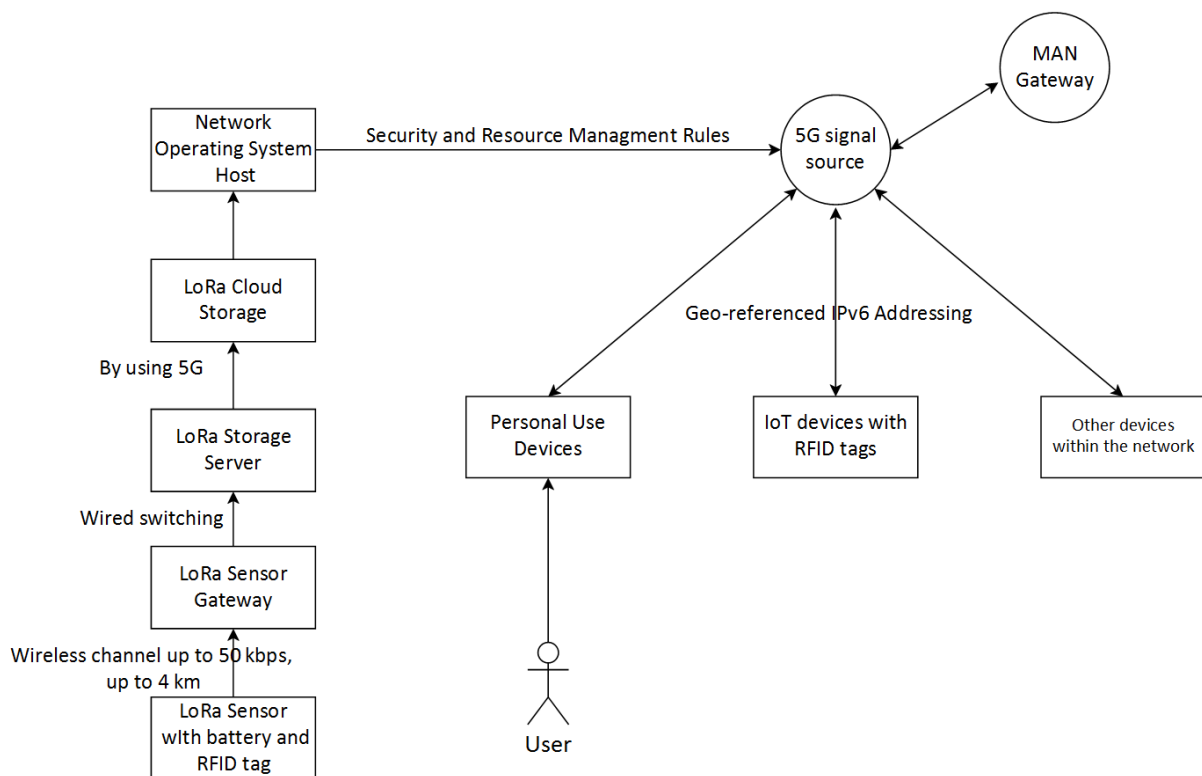


Figure 3. The principle of SD-WUN operation.

Radio frequency identification allows geographic identification of smart city objects. This technology can be used very variably and widely, especially given the project needs, such a solution will be in great demand.

The geographical distribution of network address space creates an opportunity to plan global network re-equipment processes. This simplifies the planning of certain network events, simplifies the network perception.

The quality of service is ensured, which makes it possible to work with a large amount of high-quality media traffic.

Such project implementation brings the city into a single autonomous mechanism that is distributed and self-serving. The city observes its events, optimizes processes, creates comfort and makes planning.

The proposed model increases the network technologies efficiency due to greater disclosure of project functions in more convenient ways.

During the simulation, two scenarios of operation of individual nodes of the system were considered. The first – is the operation of a smart home in a smart city, and household management. The second – is the operation of radio frequency identification, and its use for project purposes. Both models show positive results and confirmed the effectiveness of these technologies.

4. Conclusions

Based on the analysis of information sources for a variety of solutions that can be used in the field of network technologies and IoT, more promising ones with potential for further development are selected. The proposed network implementation option for the Smart City project is a city-specific software-defined wireless network (SDWN), as a subtype of 5G-based SDN networks, with leading LoRa technology, as the main IoT implementation technology, using RFID for identification of communication devices.

The main advantage of the proposed network model is the ability to solve all the relevant problems in this area with a single, universal technical solution.

The main problem in implementing the model is the cost of the project and a number of factors affecting the model. Significant influence factors are the narrow specialization and compatibility of the technologies used in the model.

Further research requires the creation and verification of a large project model with the reproduction of the full range of proposed technologies. Namely, the reproduction of the test model in a real test layout within the boundaries of a wireless local area network with software control, and the implementation of radio frequency identification using the Internet of Things. At present, only the theoretical substantiation of the SD-WUN network subclass has been performed.

It is also necessary to explore the possibility of implementing a technology stack, on a global scale, based on the idea of communication between cities with SD-WUN.

References

- [1] Grangel-González et al. 2017 The industry 4.0 standards landscape from a semantic integration perspective, *22nd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, Limassol, pp 1-8, doi: 10.1109/ETFA.2017.8247584
- [2] Santos B, Charrua-Santos F and Lima T 2018 Industry 4.0: An Overview, https://www.researchgate.net/publication/326352993_Industry_40_an_overview
- [3] Industry 4.0, available: <https://www.cognex.com/ru-ru/what-is/industry-4-0-machine-vision/development> (in Russian)
- [4] Semenov S, Voloshyn D and Ahmed A 2019 Mathematical model of the implementation process of flight task of unmanned aerial vehicle in the conditions of external impact, *International Journal of Advanced Trends in Computer Science and Engineering*, **8**(1), pp 7-13
- [5] Zhuravska I, Musyienko M and Tohoiev O 2019 Development the heat leak detection method for hidden thermal objects by means the information- measuring computer system. *CEUR Workshop Proceedings*, **2353**, pp 350-364
- [6] Musiyenko M, Denysov O, Zhuravska I and Burlachenko I 2016 Development of double median filter for optical navigation problems, *Proceedings of the 2016 IEEE 1st International Conference on Data Stream Mining and Processing*, DSMP 2016, **7583535**, pp 177-181
- [7] Ukhina H, Sytnikov V, Streltsov O, Stupen P and Yakovlev D 2019 Transfer Function Coefficients Influence on the Processing Path Bandpass Frequency-Dependent Components' Amplitude-Frequency Characteristics Properties at the NPP TP ACS, *Conference Proceedings of 2019 10th International Conference on Dependable Systems, Services and Technologies*, DESSERT 2019, Leeds; United Kingdom; pp 193-196 doi: 10.1109/DESSERT.2019.8770050
- [8] LoRaWAN™ *What is it?* A technical overview of LoRa® and LoRaWAN™ - *Technical Marketing Workgroup* 1.0. LoRa® Alliance. 2015
- [9] Ray B 2018 *What Is LoRaWAN?* [Technical Breakdown] [Online] – available at: <https://www.link-labs.com/blog/what-is-lorawan>
- [10] Common *Problems When Deploying IPv6*, 2012 [Online] – available at: https://docs.oracle.com/cd/E23824_01/html/821-1453/ipv6-troubleshoot-2.html
- [11] Google *IPv6 Statistic* [Online] – available at: <https://www.google.com/intl/en/ipv6/statistics.html#tab=per-country-ipv6-adoption>
- [12] Mihaylov G, Iliev T, Bikov T, Ivanova E, Stoyanov I and Keseev V 2018 Test cases and challenges for mobile network evolution from LTE to 5G, *41st International Convention on Information and Communication Technology Electronics and Microelectronics (MIPRO)*, pp 0449-0452, doi: 10.23919/MIPRO.2018.8400085
- [13] Loew S 2017 *Advantages of software defined networking (SDN)*, [Online] – available at: <https://www.fidelus.com/software-defined-networking-advantages/>
- [14] Loshin P 1999 *IPv6: theory, protocol, and practice*. Library of Congress Cataloging-in-Publication Data