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OPTICAL INTERNET OF THINGS
ОПТИЧЕСКИЙ ИНТЕРНЕТ ВЕЩЕЙ
ЗАТТАРДЫҢ ОПТИКАЛЫҚ ИНТЕРНЕТІ

Abstract. The article reveals the existing problems for the widespread adoption of the Internet of Things technol- ogy, presents promising areas based on optical wireless communications for implementing intelligent life support systems.
Keywords: Internet of Things, optical wireless communication, data transmission, Visible Light Communications, optical camera.

Аннотация. В статье раскрыты существующие проблемы для широкого внедрения технологии Интернета вещей, приведены перспективные направления на основе оптической беспроводной связи для реализации интеллектуальных систем жизнеобеспечения.
Ключевые слова: Интернет вещей, оптическая беспроводная связь, передача данных, Visible Light Communications, оптическая камера.

Аңдатпа. Мақалада интернет заттардың технологиясын кеңінен енгізу проблемалары қарастырылған, өмірді зияткерлік жүйелерді енгізу үшін оптикалық сымсыз байланыс негізінде перспек- тивалық бағыттар берілген.
Түйін сөздер: заттар интернеті, оптикалық сымсыз байланыс, деректерді беру, Visible Light Communications, оптикалық камера.

Introduction. The beginning of the rapid growth of the Internet of Things is considered to be the year 2011, when international analytical companies recorded an excess of the number of connected physical objects over the number of connected people. But back in 2001, a report by the U.S. National Research Council predicted: "The number of physical devices with embedded computers connected to networks will grow rapidly... This will radically change human interaction with the world around us.

The Internet of Things (loT, lnternet of Things) is a network of physical objects equipped with embedded technologies for interacting with each other or the external environment," as defined by Gartner, a leading research and consulting company specializing in information technology markets. As the IoT paradigm opens up opportunities for innovation that foster interaction between objects and people, it enables the creation of smart cities, infrastructures and services to improve quality of life and efficient use of resources.

Scientific news. Most international analytical agencies give high estimates to the growth of the number of co-branded devices in the world. In 2016, at the lnternet of Things World conference (Santa Clara, USA), the SigFox company provided projected data from various companies (Fig. 1). The graph shows that the values differ by an order of magnitude, for example: analysts from Gartner stated that the number of connected devices in 2020 will reach 21 billion units, and specialists from lntel for the same year are given the value of 200 billion units.

In May 2019, experts from Strategy Analytics published data on the connection of 22 billion units in 2018. This forecast, as well as real data on the growth rate of the Internet of Things market, dictates that industrial companies, platform and application developers invest in the development and promotion of this segment.

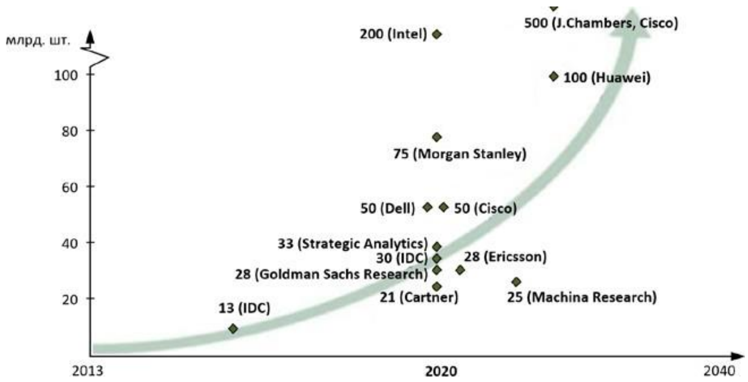

Figure 1. Forecast of IoT implementation in the world by the number of connected devices, billion units.

In the IoT, every object or object is virtually connected and the Internet becomes the infrastructure to support the connections of these interconnected objects. As more and more devices evolve to use the wireless network, there is a significant increase in traffic and the need for spectrum expansion. The key requirements of IoT systems are: low device cost, low deployment cost, high energy efficiency, high security and privacy, and support for a huge number of devices. The widespread adoption of devices in smart environments presents a major challenge for communications service providers to provide cost-effective, high-quality wireless connectivity.

The optimal radio frequency for use in the 1-2 GHz band is already overloaded. Therefore, spectrum shortages, called spectrum crises, must be addressed with appropriate countermeasures in wireless communications systems.

To meet the growing demand of the wireless network, either increasing bandwidth or increasing spectral efficiency must be used. However, increasing spectral efficiency is slow and cannot meet the rapidly increasing demand. Using new spectrum becomes a unique solution.

In parallel with the development of technology in the field of radio frequency, there is potential for the use of optical wireless communication (Optical Wireless Communication, OWC) as a new generation communication system. OWC technologies have a number of unique advantages, such as wide spectrum, high data transmission speed, low latency, high security, low cost and low power consumption [4-6].

Three basic bands of ultraviolet, infrared and visible light can be used in optical wireless communication. Within the last two bands communication is possible through visible light (Visible Light Communications, VLC), wireless optics (Free Space Optics, FSO) and through an optical camera (Optical Camera Communications, OCC), which could potentially be considered for the implementation of IoT technology. Fig. 2 shows schemes of data transmission via optical wireless communication. Each of these technologies has individual distinct features and some limitations.

VLC technology uses LED lights and photo detectors to provide simultaneous data transmission and indoor lighting. Visible wavelength range ~370-780 nm provides a bandwidth of ~400 THz, which is 10,000 times the radio frequency bandwidth [9]. In addition, VLC technology includes intrinsic security at the physical level, resistance to radio frequency electromagnetic interference and free licensing. LEDs have a number of advantages over existing lighting infrastructure: lower power consumption, longer lifetime, high energy efficiency, convenient maintenance, low heat generation characteristics and high switching speed.

Figure 2. Diagrams of data transmission over optical wireless communication.

VLC is capable of high data rates in the range of tens of meters, but does not account for multiuser access. In contrast to VLC bi-directional data transfer Li-Fi (Light Fidelity) is a network technology based on LED re-sensors, which includes multi-user access, bi-directional communication. Li-Fi is similar to Wi-Fi technology: it realizes high-speed wireless connection together with lighting, using LEDs as transmitters and photodetectors as receivers; visible light is used for the forward path and infrared port or visible light is used as the communication medium for the backward transfer. Receivers in most user devices, such as smartphones, are not equipped with high-power LEDs; thus, uplink communication in VLC and Li-Fi is not good enough at the moment.

The peculiarity. FSO technology transmits data in the infrared part of the spectrum. The transceiver module includes a high-power laser diode for signal transmission and a highly sensitive photodiode for reception (Fig. 2). The wavelength in the existing systems depends on the used laser diode and varies in the range of 700-950 nm or 1550 nm. The FSO equipment operates in the ~400 THz range and requires no licensing or frequency allocation procedure. FSO solutions in the wireless backhaul market currently support speeds of up to 30 Gbps, which is considered the highest ever recorded.

FSO channels are immune to any type of electromagnetic interference from RF devices and communication lines. Due to this you can achieve a high density of coverage without problems with interference from simultaneous operation of multiple systems. It has high confidentiality. The signal can only be intercepted by placing scanners-receivers directly in the narrow beam from the transmitters. Deployment and dismantling of the system is easy to perform in a few hours to establish connections between blocks of FSO transceivers. It can operate both indoors and outdoors at high data transmission rates of up to several kilometers, while visible light communication can reach short distances of a few meters. The advantages of FSO technology make it attractive for a variety of military and civilian applications compared with traditional communications networks.

The importance of work. The main problems for widespread implementation are related to the dependence of FSO on weather conditions and the need to ensure direct line of sight between the transmitter and receiver.

All receivers of FSO, VLC and Li-Fi technologies consist of photodetectors, which are rarely used in modern receivers, and the cost of commercialization to change the receiver structure is high.

In the last few years, smart devices with built-in additional high-resolution metal-oxide-semiconductor cameras have appeared.

Most next-generation smartphones have built-in CMOS cameras that provide photo and video capabilities and can be used for data transfer and localization.

The VLC smartphone or video camera within wireless optical communications is considered a candidate for the IEEE802.15.7rl standard and is referred to as the OCC. OCC is an extension of VLC with the advantage of no additional hardware at low data rates and indoor positioning.

Unlike conventional VLC systems, which use a photodetector as the receiver, OCC uses a CMOS camera as the receiver, embedded in today's standard smartphones, digital cameras, car rear cameras, surveillance cameras. That is, OCC captures two-dimensional data in the form of image sequences, which allows more information to be transmitted compared to photodetector-based VLC. OCC technology is making significant progress in key applications in the fourth industrial revolution.

In terms of infrastructure, the described technologies have differences in the type of transmitter, receiver and communication facilities. Table 1 compares the performance of the OWC technologies.

Table 1. Comparative performance of OWC technologies

Indicators	**VLC**	**Li-Fi**	**FSO**	**OCC**
Communication topology	Unidirectional or bidirectional	Bidirectional	Unidirectional or bidirectional	Unidirectional
Communication range	20 m	10 m	over 10,000 km	60 m
Cell phone support	not necessarily	by all means	not available	not necessarily
Interference level	low	low	low	not available
Data rate	10 Gbps using LEDs	10 Gbps using LEDs	40 Gbps	55 Mbps
Security	High	High	High	High

Figure 3. Shows the features and benefits of optical wireless communication in IoT technology.

Figure 3. Benefits of the Optical Internet of Things

The result of the work. At present, radio-frequency systems cannot meet the high demands of future communications networks. Optical wireless communication technologies are the best complementary solution. VLC and OCC-based offerings can pave the way for deploying optical IoT networks to realize intelligent and cost-effective environments.

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