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CURRENT APPLICATIONS AND CHALLENGES OF THE INTERNET OF THINGS

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Abstract. The concept of the Internet of Things is capable of making a giant leap in the economy, including research in the field of computer science, network technologies, microelectronics and sensor technology. Combined with the technological developments of nanotechnology and robotics, IoT can play a central role in the industrial revolution by creating economic relations between machines and connecting the economy of people and machines, solving a number of problems that humanity is facing. All devices controlled via the Internet are elements of the Internet of things. The IoT has allowed various possibilities for all countries to improve life quality and the technological ideas for efficiency, productivity, security, and profit. An integrated security system is a giant step towards the improved economy. The concept of IoT plays a decisive role in the further development of the infocommunication industry. This is confirmed both by the position of the International Telecommunication Union (ITU) and the European Union on this issue, and by the inclusion of the Internet of Things in the list of breakthrough technologies in the United States, China and other countries. Thus, this article will go over the current state of the IoT as well as describe which devices and industries stand to benefit from the advantages it brings. Additionally, statistical data on the actual trends and investments into IoT across the world are also provided.

Keywords: internet of things, integration, smart devices, smart cities, remote communication, globalization, information exchange.

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Introduction

The Internet of Things is the next era in the development of infocommunication networks, a qualitatively new technology for the interaction of individual specialized computing devices or control devices, both among themselves on a local scale within individual buildings and structures, and globally at the level of cities and even the whole world (Kalinin, 2019). Factors that have contributed to the rise of the Internet of Things, especially in business and industrial settings, include cost-effective cloud storage and better analytics programs that enable organizations to manage and extract insights from vast arrays of data (Dubravac & Ratti, 2015). The potential of the Internet of Things market is huge, where "things" interacting with each other act as active participants in the business (Hakan, 2023). Objects connected to the global Internet contribute both to improving the quality of life of the population and influence the processes taking place in the surrounding world. Such interconnection of devices in a single network brings colossal opportunities, opening up new and broader prospects in the field of management, analytics, and security (Ystgaard et al., 2023).

In the policy of the European Commission, RAND Europe has indicated an upper estimate of the economic potential of the Internet of Things between 1.4 trillion USD per year (1.09 trillion EUR) to 14.4 trillion USD (11.2 trillion EUR) in all sectors of the global market. In addition, the sale of devices and services with connection will have a twofold increase from 761 billion in 2020 to 1.4 trillion USD in 2023 (Jaxel, 2022). while the cumulative investment from connecting billions of connected devices will reach at least 2 trillion EUR in current prices. Furthemore, according to CIW team report (CIW team, 2023) China's investment into IoT will reach 681 billion by 2026.

This phenomenon is explained by the ever-increasing need for the broadening of channels for data transmission as well as the processing of data arrays which only keep getting larger. Another reason is the need to establish a synergy between the different types of economy (digital and classical). In this regard, such digitalization is conducive to a more accurate prediction of changes taking place on the market. It also helps various companies in the decision-making process, providing them with analyzed and processed information on different elements of entrepreneurial practices. Thus, the "Internet of Things" concept can be considered a manifestation of such digital transformation (Shcherbinina & Stefanova, 2016). For ordinary consumers of such technologies, life becomes more comfortable. In the national economy, this is a way to save resources and optimize production (Koltynyuk & Wolfson, 2012; Sadeghi-Niaraki, 2023).

As a result, the Internet of things will allow to acquire even more opportunities to open up new, vast prospects for humanity, as well as provide an opportunity to increase production potential and reduce costs. The analysis of the last few years has shown that innovative developments in the field of IT have a positive impact on the life of society as a whole (Berman et al., 2022).

1. Emergence of the IoT

The concept of the Internet of things is the autonomy of all the Internet of things devices, where sensors do not run on batteries, but on the energy of the environment. Information technology is an integral part of the Internet of Things. Sensors, processors and software are part of every product in every industry and are complemented by analytics. This combination allows highlighting unique information, for example, about the hidden needs of customers and, accordingly, change the way one interacts with them. Various kinds of innovations arising from the Internet of Things can manifest themselves at all stages of the business process. Depending on the stage or process in which they are planned to be introduced, different effects are possible: in some cases, costs will be reduced and inventory will be optimized, while in others it will be possible to attract additional customers or increase the average bill (Bubnova & Kryukova, 2014).

The emergence and development of the Internet of Things concept (both in practical and theoretical terms) is mainly attributed to the following major factors: (Tyurin, 2016).

- internet bandwidth expansion (which enables an unlimited amount of required data exchange in various formats);

- a rapid increase in the number of devices which have connection to the internet (creates an environment where users and devices can actively interact and results in the appearance of respective needs);
- Internet's accessibility in various modes and via diverse communication channels (allows devices and users to gain access to the network from multiple locations with established quality standards);
- occurrence of needs associated with the devices' interaction within the global information network (encourages interest in the issues of intensive communication of devices and users on the Internet by multiple public and commercial organizations);
- infrastructure development of the Internet of things, which includes: identification and security certificates, secure data chains, network storage of data, standards and regulations for interaction (brings elements of stability and irreversibility into the network development);
- a rise in the number of connections and business projects within the Internet (creates infrastructure as well as financial and economic blueprints which facilitate the evolution of the network);
- a great variety of businesses, projects and innovative ideas within the network communication of devices and users (brings about active development of various network communications formats, both in theory and practice);
- understanding of the evident benefits of networking (attracts investments, resources, entrepreneurs and information);
- an abundance of devices with Internet access (facilitates the development of protocols and technologies for communication between devices and users, as well as the realization of a broad-spectrum of tasks using the network).

In the context of the Internet of Things, wireless sensor networks have such important qualities and specific constraints (Nazarov et al., 2021). Also, the hardware of wireless nodes and network interaction protocols between them are optimized for power consumption to ensure a long service life of the system with autonomous power supplies (DeMedeiros et al., 2023; Kalinin, 2019).

The successful implementation of the Internet of Things project involves the integration of various telecommunication technologies under the control of common alternative standards. For rational and effective interaction, companies are building various solutions for developing new infrastructure of various levels of complexity of architecture and technical platforms.

The Internet of Things is a popular technology for the development of computer networks, including technical devices equipped with technologies for interacting both with each other and with the external environment without human intervention. For IoT items, one of the key challenges is fast and reliable pairing to securely transfer data between each other. One such technology that solves this problem is NFC (Near Field Communication), which is based on the principles of RFID (Radio-Frequency Identification) and communication technologies, maximizing the positive effect of their use (Nikiforov, 2015).

After 2003, interest in IoT moved to a new level in terms of quality thanks to the occurrence of the Internet Protocol Version 6 (IPv6), which allows assigning addresses to 340 undecillion (1039) objects. This is more than the amount needed to assign an Internet Protocol address (IP address) to every atom on the surface of the Earth. Other factors contributing to the rapid development of the Internet of Things have been the spread of cloud computing and wireless networks, as well as the development of machine-to-machine (M2M) technologies (Borodin, 2014).

2. IoT technologies

Radio frequency identification (RFID) and wireless sensors networks (WSNs) have made a significant contribution to the development of the Internet of Things. In addition, many other technologies and devices nowadays, such as barcodes, smartphones, social networks and cloud computing are also used to form a wide network of support for IoT (Uckelmann et al., 2011).

According to the Conference report (SRI Consulting Business Intelligence, 2008) by the year 2025, intelligent networks are becoming a reality, connecting billions of objects and devices (things), and commuting with each other. Each object of the real world is connected by wireless networks with the digital world, in which it is respectively identified.

The Internet of things containing software (software) and a huge number of sensor devices (sensors) cannot fully provide a unified system of protection against information and technical terrorism. Security issues for IoT devices are especially relevant in preparation for the emergence of the IoT ecosystem, when billions of objects will be connected to the Internet and interconnected (Dubravac & Ratti, 2015). While it is important to strive to improve the efficiency of manufacturing processes, safety issues should always be one of the top priorities. Integrating operational technologies with the Internet might render the industry more efficient, but if proper security strategies are not put in place, then any benefits of the Industrial Internet of Things will be irrelevant (Guzuyeva, 2018). As Rob van Kranenburg points out (Van Kranenburg, 2014): "The Internet of Things is a continuous stream of data that starts from our BAN (Body Area Network) body, LAN (Local Area Network) home and work environment, WAN (Wide Area Network) urban infrastructure and dissolves into the global information system VWAN (Very Wide Area Network).

The underlying technology for the Internet of Things is RFID technology, which allows microchips to wirelessly transmit identification information to readers. With RFID readers, people can identify, track and control any objects automatically connected using RFID tags (Jia et al., 2012). For the effective operation of the digital economy, it is necessary to create high-quality platforms that interact with each other. As noted in Chernyak (2013), IoT is no longer limited to communication with things tagged with RFID, but is viewed in the context of agglomerating such modern concepts as all-penetrating computer systems and intelligent environment (Ubiquitous Computing, Pervasive Computing, Ambient Intelligence). The result of the convergence is that the conditions are being created for an appearance of a new phenomenon – the Internet of the future, which comprises of, in addition to the current Internet of People (IoP), also the Internet of Services (IoS), the Internet of things (Internet of Things, IoT), Internet of media content (Internet of Media, IoM).

Tracking and identification technologies used in the IoT include smart sensors, barcodes and RFID systems. Such elements as RFID tag and RFID reader constitute a simple RFID system. Due to the system's ability to recognize and track physical objects and devices it is being used with increasing frequency in industrial sectors such as supply chain management, logistics, health monitoring service (Jia et al., 2012; Lim et al., 2013). There is a certain number of inhomogeneous networks, for instance: wireless mesh networks, WSNs, WLANs and so on. These networks facilitate the information exchange for the things in the IoT. The communication or interaction of different devices is made easier by the network gateway. Such gateway is also capable of utilizing a so-called "knowledge network" which executes optimization algorithms locally and thereby can be implemented to manage a variety of intricate nuances occurring in communication network (Zhu et al., 2010). In order to provide high-quality services to end users, the Internet of Things must develop technical standards, and specifications that define the exchange of information and its processing, as well as relationships between things. Success in the use of IoT depends on standardization of security at various levels (Bandyopadhyay & Sen, 2011).

Because "things" can move around or need to interact with the environment in real time, an adaptive architecture is needed. Also, the decentralized and heterogeneous nature of the Internet of Things requires its architecture to provide a variety of efficient event capabilities. Thus, SOA (Service Oriented Architecture) is a good method to achieve interoperability of dissimilar devices in many different ways (Atzori et al., 2010; Miorandi et al., 2012; Xu, 2011). Development of generally accepted standards and communication protocols for IoT technologies will ensure the coordinated operation of electronics from different companies, help developers and consumers use IoT applications and services on a large scale, and accelerate their development and distribution. At the sensing/probing level, smart wireless systems with sensors or tags can now automatically recognize and share information with various devices. Some industries have already deployed intelligent service schemes, with Universally Unique Identifiers (UUIDs) assigned to each required service or device. A device with a UUID can be easily discovered and identified, which is why UUIDs are critical to the successful deployment of services on a huge network like the Internet of Things (Wu et al., 2013; Ilie-Zudor et al., 2011).

The network layer is capable of information collection from existing IT infrastructures (e.g. transportation systems, healthcare systems business systems, power grids, information and communication systems, etc.). In a service-oriented "Internet of Things", the services provided by "things" are usually deployed in a heterogeneous network, and all related "things" are brought into Internet services (Atzori et al., 2010; Han et al., 2013).

The service layer handles all service-oriented concerns, including storage and information exchange, search engines, data management and communications (Atzori et al., 2010; Miorandi et al., 2012; Guinard et al., 2010).

Interface layer. Recently, the integration architecture SOCRADES (SIA, from the European research project SOCRADES) has been proposed for efficient interaction between applications and services (Romero et al., 2010). The Internet of Things, expanding the communication infrastructure, forms dynamic networks, opens up new opportunities where information is exchanged without the participation of people through certain platforms according to a given algorithm).

Currently, there is no generally accepted single platform that conceals the heterogeneity of dedicated network/communication technologies and ensures the transparency of named services for different applications (Miorandi et al., 2012). The testing and integration of IoT systems with numerous protocols, numerous platforms and a great number of APIs is a contemporary challenge. The fast-paced development of APIs may impose unexpected costs on developers, which is expected to be detrimental to the ability of project teams to incorporate novel features (Sand Hill, 2014). Privacy protection in the IoT environment are more significant than in the traditional ICT environment, as the amount of cyberattack instances against IoT "things" is likely to be much greater (Salim et al., 2022; Roman et al., 2011; Li, 2013).

3. IoT solutions in industries

The consequence of generating a huge resource of information data is the spread of the Internet of things which now covers the industrial (Nazarov et al., 2022; Khurshid et al., 2023), and consumer sectors (Lamya et al., 2023; Tzavaras et al., 2023). These sectors are:

Shipping. At the international exhibition CES 2015, the Swedish company Ericsson presented an improved IoT solution for nautical shipping. The cloud platform will connect ships at sea to maintenance service providers, shore operations, customer support centers, port operators, fleet/transport partners and authorities (Dubravac & Ratti, 2015). Recent study (Ichimura et al., 2022) shows that similar solutions are already put to use in maritime industry.

Aerospace. On Earth, aerospace companies are using IoT technologies for improvement of maintenance and safety measures. For example, in maintenance of aircraft engine, General Electric uses on-board sensors on jet engines to collect real-time engine performance data. The volume of data obtained allows GE to improve engine efficiency, reduce fuel costs, as well as travel time (Dubravac & Ratti, 2015).

Banking services. In its 2014 Bank of Things report, "Accenture" emphasized: "Bank of Things" will anticipate customer needs and responding to their constantly changing circumstances with prompt solutions helping them in the achievement their goals. It will remain a reliable advisor, coordinator and value aggregator for the clients (Jagadeesha et al., 2023). Furthermore, everything will be done with a practically individual understanding of the preferences and needs of every single client." (Dubravac & Ratti, 2015). Indeed, the aforementioned is being implemented in many banking models across the world as indicated by recent study (Arjun et al., 2021). Faster connectivity and wider bandwidth available nowadays facilitate the integration of smart solutions and access to wide range of internal data. The study reports that digitalization and spread of IoT solutions has a positive effect on interaction between banks and the customer as well as on the well-being of the employees.

The cardinal positive changes for IT market leaders to achieve commercial advantages are the development, implementation and management of applications for the Internet of things;

- integration of all information;
- high ability to relay messages from one segment to another;
- use of new generation Internet devices.

Functionality of IoT solutions:

Smart devices can collect data, track activities, and customize experiences for users' needs and desires. They can be worn on different parts of the body (head, eyes, wrists, waist, hands, fingers, legs) or these devices are built into various items of clothing (Wagan et al., 2022).

Smart House. Given the high potential of the market, a growing number of smart home solutions are making an appearance – the management of smart energy and resources is mainly focused on the system interaction as well as human activities (Perera et al., 2015; Yudidharma et al., 2023).

Smart city. The IoT paradigm application to the urban context represents a particular interest as it goes along with the trend of information implementation by many national governments and communication solutions in the public affairs management (Ali et al., 2023; Nazarov et al., 2021, 2023; Zanella et al., 2014).

Smart environment in the city includes intelligent management of mobility, utilities, buildings (Rajguru et al., 2015). Services supported by the IoT paradigm in a smart city environment can monitor health care buildings, waste management, air quality, noise levels, traffic congestion, parking, water quality, environmental conditions, and more. For example, Air Quality Egg device (Air Quality Egg, 2013) which is a system of sensors that helps to control air quality.

Smart enterprise. The most promising are manufacturing, supply chain optimization, energy, healthcare, transport and logistics. For example, the Irish company Wattics (Wattics, 2011) has developed innovative panels that allows energy consumption management via the Internet. The invention of Cantaloupe Systems (USA) provides vending machine owners with a possibility of remote tracking of the stocks in the machines. The American company – "Engaugeinc" is the inventor of smart sensors which allow remote monitoring of security products.

Processing a huge amount of information coming from various devices carries the risk of introducing malware, the threat of massive hacker attacks, and data leakage. To ensure the security of all structural components of the IoT architecture platform: (objects and things, network layer (communications), IoT platform (computing core, algorithms), application and data), unprecedented preventive measures will be required.

The huge number of players involved in the IoT will inevitably clash with each other in an effort to protect their systemic advantages. Currently, open systems advocates are trying to set new standards. We see the creation of several standards that evolve based on different requirements dictated by the class of devices, power, capabilities and needs. This will allow platform vendors and third-party developers to influence future standards (Sand Hill, 2014). Thus, there is a need to create a single standard that plays a significant role in several fields in the Internet of things: security, protection of personal information, architecture and communications. The requirement for mass adoption of the IoT is sound customer-centric communications and the appeal to the potential customer. IoT providers should be prepared to communicate the key advantages of their services and be as detailed, compelling and specific as possible (Sand Hill, 2014).

In its 2011 report, Cisco pointed out that in 2003 there were roughly 500 million devices with Internet connection, almost all of them were personal computers. The number of connected devices has increased to 12.5 billion, despite the fact that the world population has grown to only 6.8 billion (Dubravac & Ratti, 2015). According to more recent sources the world population has grown to 8 billion (Singh, 2022) while the number connected devices to 15 billion (Duarte, 2023). Specific issues in the field of standardization of the Internet of Things include problems of compatibility, radio access level, semantic interoperability, as well as security and confidentiality (Wang et al., 2013; Li et al., 2013; Xing et al., 2013). For analysts, it is of interest to assess the ability of various countries to benefit from the use of the Internet of things (Borodin, 2014). The strongest economies in the world, the United States and China, will benefit the most. In 2023 the Chinese will receive 5.3 billion USD from IoT, the Americans – 5.27 billion. The third will be Germany – 1.6 billion followed by India to which the "Internet of Things" will bring 1.1 billion. France – 500 million, then Russia with 350 million, and Brazil, which will be able to earn 200 million (Statista.com, 2022).

Conclusions

As was discussed in this article, IoT networks are likely to see rapid development in the nearest future. Many countries and organizations are interested in developing standards for the IoT, as this can bring huge economic benefits in the future. Today, the International Telecommunication Union, the International Electrotechnical Commission, the International Organization for Standardization, the Institute of Electrical and Electronics Engineers, the European Committee for Electrotechnical Standardization, the China Electronic Standards Institute and the American National Standards Institute are developing various standards for the Internet of Things (Zhan et al., 2021; Zeadally et al., 2021).

The March 2015 conference on improving the competitiveness of IoT technologies resulted in the creation of an alliance of European industrial companies with the support of the EU, including leading market players such as Phillips, Bosch, Orange, Alcatel, Nokia, Siemens, Telefonica and Volvo. The association was created to stimulate innovation in the field of the Internet of things. As Anne Lauvergeon, the new IoT Alliance board member and the CEO of Sigfox (French networking startup) said, "Creating an ecosystem for IoT innovation is fundamental to international competition." (Dubravac & Ratti, 2015).

According to research by RAND Europe, China is investing heavily in the development of the Internet of Things. In 2012, 625 million euros (775 million US dollars) was allocated for investments in the Internet of Things, and the Ministry of Information and Technology of China set up a fund of 775 million US dollars to support the development of the Internet of Things over the next five years. This investment will build ten IoT industrial parks at more than 100 major enterprises across the country by 2015. Additionally, CIW team report (CIW team, 2023) shows that China's IoT market investment might reach 681 billion by 2026. Research company IDC gives an estimate that in 2020, the Asia Pacific IoT market (except Japan), is about to expand from $250 billion (in 2013) to $583 billion. At the same time, the number of objects with the Internet connection in the Asia-Pacific market will expand from 2.59 billion (2013) (Dubravac & Ratti, 2015) to 30 billion (2030) (Withers, 2023).

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