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IoT innovations: today and tomorrow

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IoT innovations: today and tomorrow

Executive Summary

Internet of Things is now trending in the top of IT sphere development. In 2007 quantity of connected things exceeded quantity of people. Now this market is already 4 times bigger than in 2007 and projected to be up to 7 times bigger in 2020. Smart devices have to be controlled, have to be organized, have to be monitored[1]. This paper discusses various IoT trends from technology and innovative perspective, and gives an idea to challenges and opportunities in developing new IoT innovative applications in this emerging discipline. Russian IoT market is ready for considerable up-growth due to state companies' demand. Skolkovo Foundation has launched the comprehensive program to support technology entrepreneurs in IoT sphere and collected more than seventy innovative projects all over the country.

IoT main trends and challenges

Based on IDC report, the installed base for the Internet of Things will grow to approximately 212 billion devices by 2020, a number that includes 30 billion connected devices. IDC sees this growth driven largely by intelligent systems that will be installed and collecting data - across both consumer and enterprise applications[2].

There are several reasons for considerable jump for huge IoT development in IT sphere. Kevin Ashton in 1999 tried to stress the term Internet of Things in the context of supply chain management[3]. Nowadays, there are several definitions of IoT , however, all experts are covering wide range of applications like healthcare, utilities, transport, etc[4]. We are living in the time of changes, in the post-PC period, where all digital smart devices are transforming our ecosystem and environment by making it more interactive as well as informative. Mark Weiser, the forefather of Ubiquitous Computing, defined a smart environment[5] as "the physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network."

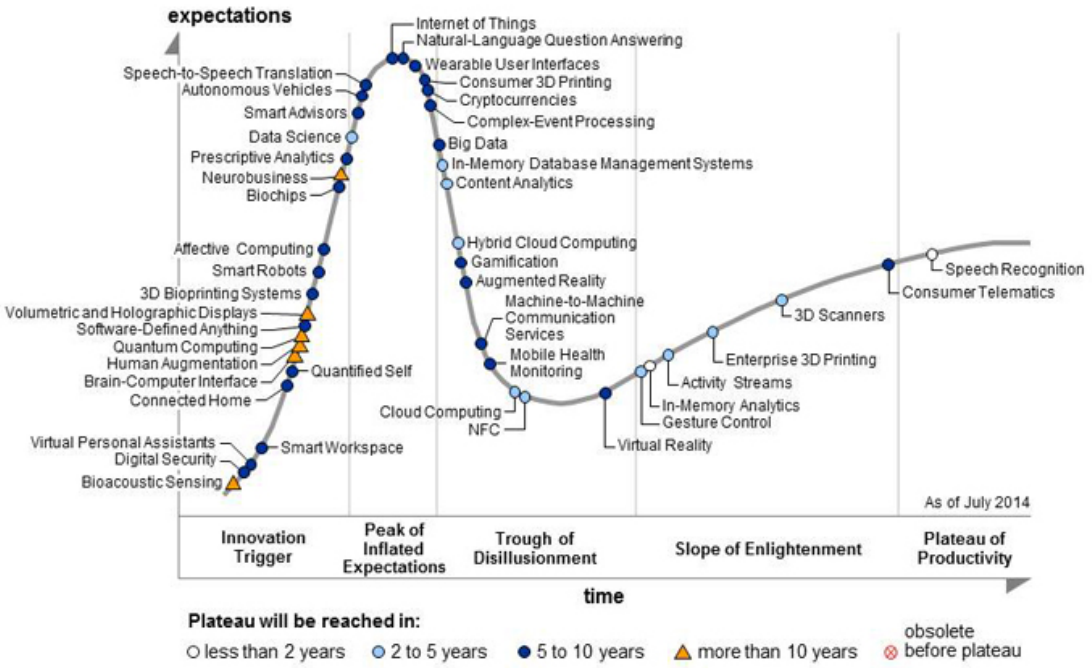

Figure 1: Gartner 2014 Hype Cycle of Emerging Technologies (Source: Gartner Inc.)

1.Raymond James & Associates, " The Internet of Things - A Study in Hype, Reality, Disruption, and Growth", online at http://sitic.org/wp-content/uploads/The-Internet-of-Things-A-Studyin-Hype-Reality-Disruption-and-Growth.pdf, January 2014.

2.IDC, "Worldwide Internet of Things 2013–2020 Forecast: Billions of Things, Trillions of Dollars," Doc #: 243661, October 2013.

3.K. Ashton, That —Internet of Thingsǁ Thing, RFiD Journal. (2009)

4. H. Sundmaeker, P. Guillemin, P. Friess, S. Woelfflé, Vision and challenges for realising the Internet of Things, Cluster of European Research Projects on the Internet of Things - CERP IoT, 2010

5.M. Weiser, R. Gold, The origins of ubiquitous computing research at PARC in the late 1980s, IBM Systems Journal. (1999).

6.Gartner's Hype Cycle Special Report for 2014, Gartner Inc. http://www.gartner.com/technology/research/hype-cycles/ (2014).

Internet of Things has been identified as one of the emerging technologies in IT as noted in Gartner's IT Hype Cycle (see Figure 1). A Hype Cycle[6] is a way to represent the emergence, adoption, maturity, and impact on applications of specific technologies. It has been forecasted that IoT will take more than 10 years for market adoption.

Nowadays we could stress four important reasons for such considerable IoT jump:
- Microelectronics challenges
- New channels for Telecom
- Huge Cloud facilities
- Dramatic demand for human data

Microelectronic and platform challenges

Up-to-date technologies in microelectronics provide a unique basis for development new projects in IoT. Modern platforms focus on small, powerful, adaptable hardware solutions with supportive online environment and have been designed specifically for the technological IoT startups and innovators. We could absolutely stress on abundance of IoT platforms available today[7]. Some solutions can be developed and run on applications and end-user devices, i.e. general purpose computers like PCs or smartphones. Others products offer functionality on "things" to build and run embedded applications. Furthermore, the instruments can centralize and process execution. IoT technology innovators can use a wide spectrum of M2M use cases, however, M2M middleware solutions and enterprise applications take over the central coordination and processing role. The business logic of the application can be supported by the platform in different ways. There are several engines for operating IoT data: rule engines, process engines, runtime engines (for Java) and event engines. Rule and process engines are focused on business logic implementation and they are not so powerful in programming environment. Java oriented engines are quite effective for programming but they are not easy for realisation. Modern platforms provide "easy implementation" approach (e.g. Xively, Thingworx). Experts point out special platforms with M2M focus like Axeda. These platforms possess strong functionality that is to connect with enterprise applications (CRM, ERP etc.). Up-to-date frameworks, furthermore, should provide rapid connectivity to web services and especially social services (Twitter, Facebook, Vk.com etc.).

New challenges for Telecom

Nowadays Telecom sphere is one of the drivers of IoT industry. Experts admit the wide spectrum opportunities for new telecom services, focused on intelligent and data –driven customer services.

There are three main data touch-points at home: Internet, television and telephone. Telecom providers considerably cover all these spheres. There is a millions of consumers` demand for an intellectual unified smart services to manage smart devices.

"The enormous number of devices, coupled with the sheer volume, velocity and structure of IoT data, creates challenges, particularly in the areas of security, data, storage management, servers and the data center network, as real-time business processes are at stake," said Joe Skorupa, vice president and distinguished

7. MUNJIN, DEJAN ; MORIN, JEAN-HENRY: Toward Internet of Things Application Markets. In: 2012 IEEE International Conference on Green Computing and Communications, Ieee (2012), pp. 156–162 — ISBN 978-1-4673-5146-1

analyst at Gartner. "Data center managers will need to deploy more forward-looking capacity management in these areas to be able to proactively meet the business priorities associated with IoT[8]."

IoT telecom services should be oriented to the next level of data operating; these services allow more intelligent use of collected data. Telecom operators collect and maintain big, unstructured data and IoT driven signals within common user interface. These schemes provide discovering additional revenue-growth platform and deliver a new sphere of customer services.

Another aspect of telecom challenges is considerable wireless technologies growth from the network perspective for IoT applications. The most famous are Wi-Fi, Bluetooth technologies (Bluetooth Classic, Bluetooth Low Energy, and CSRmesh), IEEE 802.15.4 technologies (ZigBee and 6LoWPAN), other wireless technologies (WirelessHART, Z-WAVE, and Sigfox). However, none of them yet provides appropriate quality and efficiency among the key IoT requirements. Specialists define the following important group of requirements:
1)ultra-low-power consumption for battery-powered or battery-less devices or sensors
2)low-to-moderate data rates
3)reasonable and scalable range
4)low complexity and cost for small form factors
5)large number of reliably connected devices on collocated networks.

Various companies try to combine technologies efforts to resolve this market demand by means by creating network Alliances. Among them, the ZigBee Alliance[9]. Available: https://www.zigbee.org/.] is probably the most well-known pioneer, followed by Bluetooth Special Interest Group (SIG)[10] and the Z-Wave Alliance["Homepage Z-Wave Alliance[11]." .

Luc Julia, the VP of Innovation at the Samsung Innovation Center, commented the issue when presenting the Samsung Architecture Multimodal Interaction (SAMI) during Connected Conference in Paris in June this year[12]. He summarized the current state of the IoT as essentially 'broken' by stating: "Downstairs is hell, Upstairs is Paradise." With hell, he referred to the incompatible communication standards when connecting the communication 'pipes' between devices, and with paradise, he meant the relative ease of fixing incompatible data formats in the cloud. Finally, Liat Ben-Zur of the AllSeen Alliance recently stated that "Unexpected capabilities pop up when devices speak the same language[13]".

Solutions and approaches in Sensor and network area
- Power and energy storage technologies
- Smart grids and new protocols approaches
- Addressing scalability and standards interoperability
- Control loops and other critical latencies problems
- Real-time Models and design methods describing reliable interworking of heterogeneous systems
- Security functions

8. Gartner, March 2014
9. "Homepage ZigBee Alliance." [Online]. Available: https://www.zigbee.org/.
10. "Homepage Bluetooth Technology Special Interest Group." [Online]. Available: https://www.bluetooth.org/en-us.
11. "Homepage Z-Wave Alliance." [Online]. Available: http://www.z-wavealliance.org/.
12. R. Vanier, "Luc Julia introduces SAMI, the architecture that lets you play with existing and future data.," Rude Baguette, 18-Jul-2014.
13. "The language of the internet of things," The Economist, 06-Sep-2014.

· Technologies for data anonymity addressing privacy concerns
· Real-time data over networks
· IoT protocols convergence

It means that there is a wide spectrum of opportunities for young engineers and talented innovators to develop different IoT applications or new network approaches.

Cloud challenges

Unprecedented amount of data, this is the emerging edge in IoT sphere. Experts and analysts stress that storage of the data become critical issues. The internet consumes up to 5% of the total energy generated today and with these types of demands, it is sure to go up even further. Hence, data centers that run on harvested energy and are centralized will ensure energy efficiency as well as reliability[14].

Data engineers and IoT innovators should develop applications to store data in special structures for smart managing and actuation. They need to develop artificial intelligence algorithms which could be centralized or distributed and absolutely data driven oriented. Artificial Intelligence algorithms are the foundation for developing appropriate automated decision making applications. Experts use temporal machine learning methods based on evolutionary algorithms, genetic algorithms, neural networks, semantic nets and other artificial intelligence methods. These applications should provide interoperability, integration and adaptive communications.

Modern cloud methodologies named as “Applications as a Service”, “Platforms as a Service” and “Infrastructure and Networks as a Service” considerably changed IT paradigm. They reduced cost of ownership and monitoring of virtualized resources, lowering the market entry to new Web engineers developed new services.

With the virtualization of objects being the next natural step in this trend, the convergence of cloud computing and Internet of Things will enable unprecedented opportunities in the IoT services arena. As part of this convergence, IoT applications (such as sensor-based services) will be delivered on-demand through a cloud environment[15].

This extends beyond the need to virtualize sensor data stores in a scalable fashion. It asks for virtualization of Internet-connected objects and their ability to become orchestrated into on-demand services (such as Sensing-as-a-Service)[16].

And growing amount of data and connected devices should be secured and adequate protected.
In contrast to today’s networks, where assets under protection are typically inside firewalls and protected with access control devices, many things in the IoT arena will operate in unprotected or highly vulnerable environments (i.e. vehicles, sensors, and medical devices used in homes and embedded on patients).

14. Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic,Marimuthu Palaniswami: Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions, pp.9
15. M. M. Hassan, B. Song, and E. Huh, “A framework of sensor-cloud integration opportunities and challenges”, in Proceedings of the 3rd International Conference on Ubiquitous Information Management and Communication, ICUIMC 2009, Suwon, Korea, January 15–16, pp. 618–626, 2009
16. Ovidiu Vermesan Peter Friess: Internet of Things – From Research and Innovation to Market Deployment, pp.71

Protecting such things poses additional challenges beyond enterprise networks[17].

Many Internet of Things applications require mobility support and geodistribution in addition to location awareness and low latency, while the data need to be processed in "real-time" in micro clouds or fog. Micro cloud or Fog computing enables new applications and services applies a different data management and analytics and extends the Cloud Computing paradigm to the edge of the network. Similar to Cloud, Micro Cloud/Fog provides data, compute, storage, and application services to end-users. The Micro Cloud or the fog needs to have the following features in order to efficiently implement the required IoT applications:

· Low latency and location awareness;
· Wide-spread geographical distribution;
· Mobility;
· Very large number of nodes,
· Predominant role of wireless access,
· Strong presence of streaming and real time applications,
· Heterogeneity[18]

Experts focus on main technology aspects for developing new IoT approaches:

· Big data and unreliable data
· Sensor clouds, SeaaS, virtual sensor approaches
· "real-time" micro clouds, fog technologies
· Semantic approaches for data operating
· Standardization of interfaces from sensors and local systems
· Reuse technologies over smooth progression between low-level "sensor devices" and higher level "cloud" services

IoT applications require mobility support, geo-distribution and low latency in real-time process. It requires new types of clouds: Micro Clouds, Fog, Sensor clouds.

Dramatic demand for human data

Experts stress a considerable change of our computation used a wide range of open source hardware i.e. sensors and actuators managed in more and more connected objects embodied with intelligence.

For example, people can interact with clothes to exchange health parameters, with home devices as furniture for personalized information services etc.

The fact is that, we could discover a massive rise in amount of ubiquitous devices, these devices facilitate our lives and will be everywhere, from home automation to public spaces, and used by everyone. The common facet of all these devices is that they all collect data that is produced by or about people[19]. Nowadays, experts define special discipline to analyze these issues as Human-Data Interaction (HDI).

17. Cisco, "Securely Integrating the Cyber and Physical Worlds", online at https://techradar.cisco.com/trends/Securing-the-Internet-of-Things
18. Ovidiu Vermesan Peter Friess: Internet of Things – From Research and Innovation to Market Deployment, pp.72
19. Afra Mashhadi, Fahim Kawsar and Utku Gunay Acer: Human Data Interaction in IoT: The Ownership Aspect, pp. 1

The impact of this data processing is pervasive and wide-ranging – it informs credit ratings, the online advertising industry, and retailing, and it is used in a wide range of other predictions and inferences; from sexual orientation, to voting preference, and even (some claim) likelihood of a divorce[20]. These data are at the heart of most Internet business models, particularly those based on advertising and market intelligence. In fact, the act of data collection has been shown to alter individuals' behaviour[21], reinforcing the need for understanding the interaction between individuals and the information gathered about them.

Innovations cover the main spheres of our daily activities. The future landscape is the intellectual network of interconnected identifiable objects and their virtual copies-clones in an Internet. It allows building a new ecosystem for economic growth.

• Smart City: Smart Parking, Traffic Congestion, Waste Management, Intelligent Transportation Systems, Safe City, Smart tourism, Smart Environment Monitoring etc.
• Smart Home: Perimeter Access Control, Intelligent Thermostat-Alarm –Climate controls, Art and Goods Preservation, Indoor navigation, etc.
• Smart Industry: Smart Grids, Power Supply Controllers, Toxic Gas-Radiation and other Levels controllers, Smart production line, Telework, Maintenance and repair
• Smart Health: Physical Activity Monitoring, Sportsmen and Fitness Care, Patients Surveillance etc.

Russian market challenges

Russian IoT community is in the beginning of impetuous upgrowth due to state companies demand. According to the forecast of J'son & Partners Consulting Russian market IoT in 2015 will grow to $ 527 million, and in the future we could expect $ 980 million by 2020[22]. The main drivers will be the technology of RFID, sensor networks, NFC and navigation systems. Russian experts forecast quite carefully current situation and development of the Russian IoT market compared with global trends in Europe and USA. However, in recent years the national market began to rise through a number of "pioneer" projects in RFID spheres, navigation systems of GPRS / GLONASS, construction of smart parking, NFC pilot projects in the Moscow metro and payment terminals, M2M-run services on the basis of special SIM-cards and devices such as GPS-trackers for different target groups of consumers, several projects for smart home industry. Furthermore, there a lot of Wearables projects in Health sphere.

The main drivers for Russian market are big state companies in oil-and-gas industry to analyze and monitor comprehensive data structures, Russian big cities (Moscow, Saint-Petersburg, Kazan etc) to monitor "smart cities", "smart home" and "smart grids" facilities and telecom providers to monetize new telecom services.

On Sept. 28, 2010, then-President Dmitry Medvedev signed a law "On the Skolkovo Innovation Center," giving rise to the project's managing entity, the not-for-profit Skolkovo Foundation. Charged with providing the catalyst for the diversification of the Russian economy, the Skolkovo Foundation's overarching goal is to create a sustainable ecosystem of entrepreneurship and innovation, engendering a startup culture and

20. Hamed Haddadi, Richard Mortier, Derek McAuley, Jon Crowcroft: Human-data interaction, 2013, pp.3
21. R. H. Thaler and C. R. Sunstein. Nudge: Improving Decisions about Health, Wealth, and Happiness. 2008
22. J'son & Partners Consulting: Internet of Things and M2M communication. Overview of the situation in Russia and the world, 2013

encouraging venture capitalism. The Skolkovo Foundation identified five key areas of potential growth: energy efficiency, strategic computer technologies, biomedicine, nuclear technologies and space technologies. The goal of Skolkovo Foundation is to create an environment in Russia where new projects proposed by Skolkovo participants may be developed and commercialized.

Skolkovo Foundation launched comprehensive program in Russia to support and develop IoT innovations in 2014. Skolkovo cover more than fifty innovative IoT projects from different cities in Russia implemented in the main business spheres (see Figure 2). Skolkovo IoT projects are oriented on emerging IoT technologies such as new identification technologies and solutions, technologies for data processing and actuating. IoT projects are implemented in several business vertical areas: Retail, Smart City, Smart Home, Healthcare, Smart industry, Smart transport and Automotive.

Our projects are competitive in Russian and world markets. For example, iRidium company developed software package for controlling automation systems, A/V equipment from mobile devices based on iOS, Android, OS X, Windows 7/8; controlling different equipment from one app on tablets and smartphones; integrating different equipment in one solution, controlled from one interface. Integration of different automation and A/V equipment in one solution controlled from mobile devices allows to create automation projects for different groups of customers within different budges. Powerful visualization creates beautiful intuitive interfaces with wide graphic and sound capabilities. iRidium projects are used to control smart homes, home cinemas, multi-room systems, etc. all over the world. Commercial projects: House of Rock (USA), Rabobank Land van Cuijk-Maasduinen (the Netherlands), CRQ Auditorium (Brazil), HIFI club (South Korea), management center of Son San Juan airport (Spain). iRidium has been implemented in industry as well – monitoring system for reservoir park in Endress+Hauser. About 1,000 iRidium-based projects in home and commercial automation are made every year.

Several companies are focused on M2M sphere communications. The main goal of innovative project "GO+" is to develop an analytical unit on the basis of mathematical apparatus and methodology of non-obviously structured dynamical systems with structure that changes in the operation which gives the ability to quickly build and integrate M2M solutions with highly customized applications for M2M service-providers. This unit enables you to manage IoT-devices' business logic and to assess the efficiency of business processes implemented on the platform. Smart Office is a joint project by GO+ and Intel (Russia). The project's goal is to intelligently manage the office climate. Solution can work in two modes: automatic and manual. Automatic mode allows for all user actions and can make decisions on the basis of these data. If one of the staff on a daily basis using additional lighting and the other likes to work in daylight, the system remembers their preferences. Now there is no need for the employee to use the manual mode, the system will automatically adjust required level of illumination for them. Quite a lot of the ideas can be implemented on the basis of the developed project. Custom scripts for managing devices can configure your system administrator. Change them simply using the conditions if/else as well as to connect new devices. Potential customers in the global market are the company's service providers and device manufacturers. Such as AT&T, Virgin mobile, Google mobile, liberium, Texas Instruments, Gemalto, Qualcomm, PTC, SAP.

Some projects are connected with agriculture sector. Lesnoy Dozor is a hardware software system for real time monitoring and detection of forest fires. With its help remote recognition of wood fires is possible as well as high-accuracy positioning of flame base. Hardware part of the system consists of a set of intellectual sensors which are installed on any accessible high-rise towers. The action range of sensors is 5-35 km depending on the height of tower and type of sensor. For installations of sensors any high-rise structures good enough for placing of equipment are used. Such as television relay towers, cell towers and fire lookout towers. If the sensor detects a fire, the information is transmitted to the servers of Lesnoy Dozor system via

various communication channels: optical, radio, wire, GSM, etc. The system is used in 33 regions of Russia, though it could be applied in any part of the world.

Industry	Implementation	Technologies	SK Companies
Manufacturing	IoT process management	Smart machines, robots, Big data, real time controlling, security, cloud technologies	AdapLab, IntroVision, Lintec,RealLab, Radiosensor nets, Mobixchip, QModule, BeIT Company
Retail	IoT production management	RFID and analog technologies, sensors, security, Big data, Cloud technologies, robots,, Smart machines, video analytics	KB Sever, Information and net technologies, SteamLabs
Smart Home	Perimeter Access Control, Intelligent Thermostat-Alarm –Climate controls, Indoor navigation	Sensors, security, Big data, Cloud technologies, robots, plug-and-play machines, video analytics	Iridium, Sodis Lab, Ratelsys, ViEye, IndoorGo, Vocord, WIoT
HealthCare	Physical Activity Monitoring, Sportsmen and Fitness Care, Patients Surveillance etc	Telemodicine, Big data, real time controlling, security, Cloud technologies, sensors	Angioscan, Fruct MD, Liandri, MedM, Medarhiv
Wearable	Wearable, Everyday things	Sensors, security, Cloud and hardware technologies, sensors	Elandis, Exoatlet, Oriense
Automotive	IoT for automotive	Cloud technologies, speech recognition	RealSpeaker, Speereo
Smart City	IoT for City	Sensors, navigation technologies, security, cloud technologies, Big data , video analytics	Logos AT, Avtodoria, GO +, RTLS, GeoStar Navigition, SPIRIT Navigation, Kvinta, STC, VisionLabs, Macroscop, Lesnoy Dozor

Figure 2. Skolkovo main IoT projects

Project WIoT - Wireless Internet of Things devoted to super low power & long range radio-network for IoT. Advantages of WIoT expressed by the Energy Harvesting technology that is used to make some nodes of the WIoT radionetwork battery-free. The unique technology makes WIoT actual & high demanded at Smart City & Smart Building automation networks, that can cover large area (more than 1000 000 sq.m) and needs no maintenance (battery replacement) for 10th years. The implementation of the project is targeted to region governments to utilize IoT for various applications at building, hotels, waste treatment, and agricultural farms.

Skolkvo launched the first open competition “IoT challenge” in Russia for talented technology innovators in 2014. We collect more than seventy innovative projects from different cities. These numbers confirm considerable interest in innovative development of IoT community in Russia.

Conclusion

We are living in the time of changes, and new IoT technologies come to our life day-by-day. More and more sensors and actuators, embedded devices, communication services associated with usual things are being adopted in healthcare, home/city, manufacturing. IoT approaches also affect development of new business models based on real-time data acquired by million smart things. It allows new talented IoT technology entrepreneurs and engineers to create innovative sensors, nanomaterials, cloud applications, telecom platforms and protocols, data driven algorithms and unique IoT projects. Russian projects are quite competitive in the world and they can find a niche to apply mathematical and engineering approaches effectively in cooperation with a variety of partners.