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THE FUTURE POTENTIAL OF INTERNET OF THINGS

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Abstract

Purpose: *To define the Internet of things and to analyze it as a background for the internet of services.*

Design/methodology/approach: *The article discusses potential possibilities and problematic issues concerning the Internet of things (IoT) and Internet of services (IoS). The debates concerning IoT and its possible application fields have continued for more than ten years. The technological background is there and the fields of application are broad. However, there is still a lack of understanding about the possible benefits that technology could give to various bodies if applied correctly. This article is based on comparison and analysis of scientific articles, research papers and case studies related to the potential for IoT and its implementation in IoS.*

Theoretical findings: *IoT is a logical evolutionary step for the internet. Despite the technological background, the concept of objects which are aware of their surroundings, allow to manipulate them by defining different rule patterns and ensuring interaction possibilities with other objects or human beings. The necessity for web-based services is increasing along with the technological gadgets which support them. Applying things, which are connected in a network, could revolutionize many industry and service sectors and create new service provision and administration methods based on information technology. However, there are*

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many problematic issues and research challenges related to the IoT. Few of the most significant are related to standardization of technology, legal regulation and ethical aspects concerning the IoT technology.

Research limitations/implications: *The IoT is a popular trend promoted by the business sector and governmental bodies. There are few comprehensive studies and projects which talk about the benefits that business and society could gain from the IoT. There is a lot less information about the possible risk and problematic aspects, and a lack of agreements between the developers of technologies. In the scientific community arguments are also varied depending on the technologies used and regulation models adopted. For that reason it is possible to review the topics only focusing on narrow, but most comprehensively analyzed spectrum of problematic issues.*

Practical implications: *Theoretical framework for future research in the field was developed.*

Keywords: *internet of things, internet of services, future internet.*

Research type: *conceptual paper.*

1. Introduction

The internet has become one of the most significant technologies with a tremendous impact on social and business environments. It completely changed the understanding of gathering informational resources, doing exchange of data or the ways of communication. As a technology it had several turn points and evolved, becoming more flexible, available and usable. The devices, which support internet based technologies, are becoming smaller, "smarter" and more aware of their surroundings. Internet has changed a lot since 1990, when World Wide Web was introduced. For several years it is claimed, that the technology reached another evolutionary step—the internet based network of things. The IoT links the objects of the real world with the virtual worlds, thus enabling anytime, anyplace connectivity for anything and not only for anyone. It refers to a world where physical objects and beings, as well as virtual data and environments, all interact with each other in the same space and time (Santucci, 2010). The idea of connecting things on the network is not new. The discussion concerning IoT is ongoing for more than a decade and may be dated back to Mark Weiser's idea of ubiquitous computing (Weiser, 1993). The term "internet of things" was introduced by MIT Auto-ID Center, which later evolved into organization named EPCglobal. According to a vision, IoT had to be a based on RFID technology, which is now widely used for tracking objects, people, or animals. RFID allow tagging different objects with electronic product code (EPC) which serves as unique ID. Using unique addressing schemes, objects bearing RFID tags are able to interact with each other and cooperate with other object or detect alterations in their surroundings. The vision for a future internet is not limited by IoT. Internet of Services, 3D Internet, Internet of Content, are

only few names of the emerging technologies, which should be considered as a linked parts of the future internet (Haller, Karnouskos, Schroth, 2009). IoS is considered to be one of the most significant parts of the future internet. Over the last decade, the service sector has become the biggest and fastest-growing business sector in the world and employs most people worldwide (Information Society Technologies Advisory Group, 2008). In order to continue the growth, services must become more available and widespread. Service management through IT may is a key factor in achieving this goal. The vision for next-generation services provided via the Internet is known as the IoS. It will go beyond the client-server model of service delivery to support rich mechanisms of global service supply, where third parties have the capability to aggregate services, act as intermediaries for service delivery and provide innovative new channels for consuming services. This reflects the future requirements of the mainstream enterprise service communities and the globalization of these enterprise services (ISTAG Working Group, 2008). IoS and IoT are closely connected with each other and can extend the possible application fields for technology and give economic boost to the service industry. While there are many optimistic predictions towards implementing IoT and IoS, technical, social, legal and ethical questions are considered a challenging issue. Technological standardization is not applied to all developing sectors for IoT and the technology itself has few ways of actualization. Moreover, privacy and data protection concerns are to be heard from public and governmental bodies. In this conceptual paper authors are analyzing the conception and realization for IoT, IoS and problematic aspects related to the implementation of the technologies.

2. Internet of things—an expanded vision for the future of the internet

The IoT, also known as the Internet of Objects or the Web of Objects, refers to the networked interconnection of everyday objects and it is described as a self-configuring wireless network of distributed sensors, the purpose of which would be to interconnect all things. The trend to a unified, seamless, pervasive Internet-of-Things using IP technology down to the field level is clearly identified. Proprietary solutions have reached their limits in the exploitation and do not allow for new innovative services. Relying on sophisticated architectures in which intelligent devices are seamlessly integrated into the IoS, creates a whole new and innovative market for new services for sensing and reacting to the physical world (medical, agricultural, environmental, energy-related, etc.) and the Web-based service industry will leverage the Future Internet in providing a new service experience to the users. Everything gets connected based on three different drivers: people, business, society. These three elements are the impulsive force for the technological development of the world. From a people's perspective, end-users are continuously looking for new things. Their hectic lifestyles are impacted by digital technologies. Networking, personalization and mobility will support transformation of user patterns. New applications will enable the lifestyle of the future. Safety,

convenience, applications related to personal health—these are the drivers for these new consumer applications. From a business perspective, enterprises are continuously looking for solutions that improve productivity and efficiency and ICT will be critical for sustainable competitiveness. New applications will support industrial and business processes, and help businesses manage their assets. From society's perspective, the role of new technologies, connected intelligent devices and new information highways is coming very strong in the notion of the development of the sustainable society. Sustainability will be on the top of political and business agendas.

The face of the Internet is continually changing, as new services and applications emerge and become globally significant at an increasing pace. (ISTAG Working Group, 2008). Recent developments include field closely related to internet and its broader spectrum of application (figure 1).

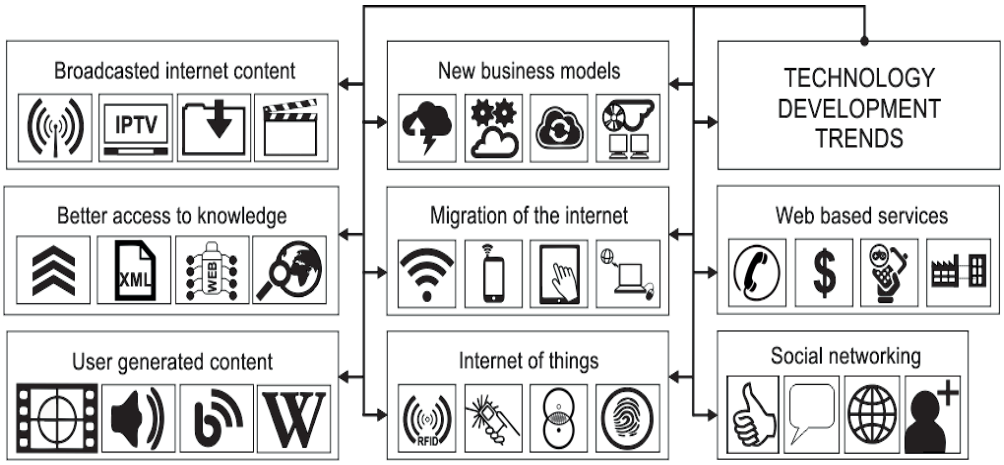

Figure 1. Technology development trends

However, the process is just beginning and, following the prognoses, which predict 50 to 100 billion devices to be connected by 2020, the true research work starts now. The European Commission decided to implement its IoT policy for supporting an economic revival and providing better life to its citizens, and it has just selected from the last call for proposals several new IoT research projects as part of the 7th Framework Programme on European Research (CERP IoT, 2010).

The IoT is made up of a loose collection of disparate, purpose-built network of networks. The nodes of the network are expected to become active participants in various processes including business, informational and social fields. They are enabled to interact and communicate among themselves and with the environment by exchanging data and information gathered about the environment, while reacting to the "triggers" of physical world with the ability to influence ongoing processes with their actions. Possibly all potential areas of application for IoT will be strongly connected with business sector,

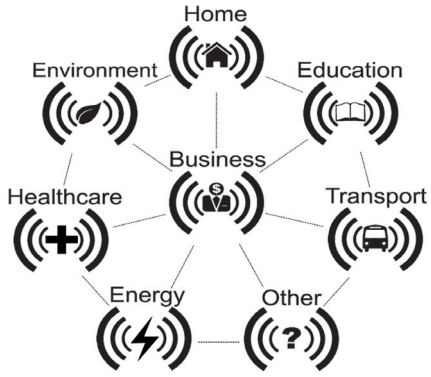

Figure 2. Relations of business and IoT. Made based on Cisco IBSG, April 2011.

which will develop technologies and connect separate networks through its platforms (figure 2). But business subjects are only one link in the chain. Two other important subjects are state and consumers. State provides necessary funds for infrastructure, contracts partnership with the industry and consumer will need to get used to smart technologies and be able to use them. According to IoT Strategic Research Roadmap (2009), the network merging trend will appear in the near future. This type of network of networks will be laid out as public/private infrastructures and dynamically extended and improved by edge points created by the "things" connecting to one another. IoT will extend communication between people and their environment. Terminals will gain bigger significant as an information storage space due to a lowering cost and availability, making nodes of the network serve as an information collection and transmission tool used for further analysis. Terminals will be able to create a local communication network and may serve as a link between communication networks thus extending overall infrastructure capacity.

The IoT is partly inspired by the success of RFID technology. RFID tag is a smart device equipped with an electronic chip and a smart antenna. RFID reader interacts with the tag and sends a signal to someone for further elaboration. RFID-enabled system will interpret the data and take some actions. RFID tag is a physical object, applied to a real world item in order to identify and track it electronically. Radio Science and related Technology, represented by a tag, makes the physical object an energy consumer, because RFID technology uses energy alimented active tags, or some energy is applied to the passive tags in order to ask them to activate the sending of data (Simono, Zich, Mazzitelli, 2008).

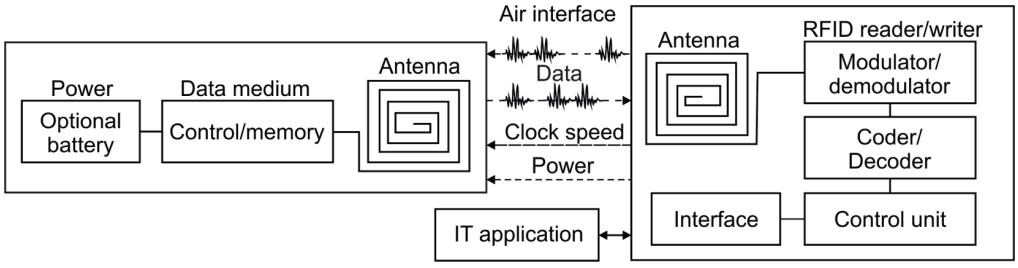

Figure 3. The working principle of RFID

RFID still stands at the forefront of the technologies driving the vision. This a consequence of the RFID maturity, low cost, and strong support from the business

community. However, they state that a wide portfolio of device, network, and service technologies will eventually build up the IoT. Near Field Communications (NFC) and Wireless Sensor and Actuator Networks (WSAN) together with RFID are recognized as the components which will link physical and virtual worlds (Atzori, Iera, Morabito, 2010).

Architecturally, the IoT can be divided into the sensing, communication, management, and application layers. These categories may vary depending on approach from different authors ant technological framework used. However, large-scale service deployment needs to be framed within a set of standards. The IoT involves many manufacturers, spans multiple industries, and differs widely in application scenarios and user requirements. Standardization has been sluggish, impacting large-scale commercial deployment of related services. Fortunately, companies are beginning to prioritize standardization (Zhihao, Yongfeng 2010). The EU is trying to move towards in order to apply IoT standards that cover multiple layers including technology, operation, and services. Standardization could reduce the costs of the technology and ensure availability to consumers which are the one of the key elements in the subject.

IoT is possible because of miniaturization of the hardware, software, which enable the entire parts work together, network infrastructure and data. Miniaturization involves technological processes which have allowed electronic devices, including sensors, to be built smaller. Together with nanotechnology, miniaturization has made it possible to minimize the size of elements such as microprocessors, without affecting the speeds at which they operate (Feller, Yoon, 2011). While the miniaturization of objects is not limitless, there are various opinions how problems, relating size and calculation speed can be solved. One of the possible solutions is to use "DNA computers" (which use organic molecules to store the basic information and resolve mathematical problems through chemical reactions) and "quantum computers" (which use elements of quantum mechanics to code and process information). The components used in quantum computers will be smaller, and at the same time it will be possible to make vast calculations in a much shorter time (Feller, Yoon, 2011). The other way is to divide calculations between separate elements which combined together could work faster and smoother. Software is none of the less important to IoT. The IoT systems exhibit very interesting properties and can have a wide range of applications. Yet, they are complex to develop, build, and maintain in spite of the purported spontaneity of the interactions between the objects. A crucial reason for these difficulties is the lack of a common software fabric underlying the IoT, i.e., the lack of a model of how the software in these different objects can be combined to build larger, composite systems (Rellermeyer, Duller, Gilmer, et al., 2008). The IoT generates massive amount of data which need to be handled, but if software systems will not be able to "communicate" among themselves, the possibility of creating a wide network of objects will be complicated. The applications for data processing according to certain standards will create a real business value enabling new types of services.

3. Internet-of-things as a background for Internet-of-services

Recently, the vision of the IoS (Schroth, Janner, 2007) emerged and can be seen as a new business model that can radically change the way we discover and invoke services. The IoS describes an infrastructure that uses the Internet as a medium for offering and selling services (Cardos, Voigt, Winkler, 2009). Some analysts estimate that the added value services using the IoT could reach as much as $200 billion/year, 15 billion devices by 2015, and could deliver the next wave of growth of the Internet, with new business models, application and services in most sectors of the economy. Such demand could also spur innovation and growth in the value chain of components, devices, wireless connectivity, middleware, decision support tools, etc.

While many of the smart space technologies, such as sensors and actuators are already known, their impact in social interaction is not addressed. What happens when things become social? Thinking of this, it becomes quickly clear that there is a huge potential for applications that can emerge when the smart space architecture is in place. The interplay between things and people allows data gathering, control, business opportunities with crowd based big data, or new opportunities on user identification. IoT creates new adoption ways for the internet technologies thus enabling IoS. The IoS is a new service-oriented approach toward the internet. IoT could boost this sector by expanding the physical boundaries for the internet. Service sector is one of the fastest growing in the world and using internet as a tool for service provision may affect this increase even more. In the last few years, Service Delivery Platforms (SDP) have emerged in the telecommunications sector to manage delivery of communications, media and entertainment services from communications service providers to mobiles, PDAs and IPTV. With substantial growth in a short time since inception and with massive forecasts of hand-held communications devices, analysts predict a revenue surge as SDPs engage on data services as value-added consumables. A broadened concept of global and open Service Delivery Platform is proposed for the IoS (FP7 ICT Advisory Group, 2008). Service-oriented Architectures (SOA) and Web services have mainly served as technological solutions that enable enterprise functionality to be made available to users as shared and re-usable services on a network (Curbera, M. Duftler, R. Khalaf, et al, 2002). With the help of the IoT, the IoS gains more significance and possible solutions for personalization and customization of a service. Networks of smart things could transmit accurate and real-time information to the service provider thus enabling to secure fast, accurate and demand based service. Nevertheless, success of web based services also depends on the maturity of the definition of the business processes, business objectives and associated key performance indicators. According to Working Group on Web-based Service Industry (2008), the emergent Web-based service industry depends on symbiotic relationships with established Internet and telecommunications ecosystems to leverage their existing business lines and long-established trust. At the same time, a rich array of web-based content and social services will be used to enhance more traditional services into new channels such as the growing world of handheld devices. The IoT creates an opportunity to be available for the web-based services thus

enhancing the commercial and social potential for the IoS. The symbiosis between two conceptions (technologies) could increase service quality in healthcare, finance or trading sectors, where quick reactions to environment changes are needed. The technological and ethical factors of implementing IoS based on IoT are also an issue. By highlighting the weak links it is possible to facilitate the problem resolution and to see a broader spectrum of application models for the IoT in the context of the IoS.

4. Research challenges in the field of IoT

The possible research scale for the IoT is very broad, starting with "smart" domestic electric appliances, vehicles with sensor-based technologies, medical equipment, assembly line progress detection, efficient energy usage tools and many more. Developing the idea even further it is becoming clear that physical world is turning into an information system itself, there data entities flow from various devices thus enabling them to sense and interpret the ongoing process data. These changes have positive and negative aspects from the technological, legal and social approach. Optimism based predictions toward the huge economical and social potential for IoT reveal only small part of the picture. There is a lack of technological standards in some areas, while other sectors are divided and fragmented. This problem is common to all wide-used technological innovation and is real challenge for industrial and government bodies. RFID standardization may be considered as a case of a good practice and as success, mostly thanks to the efforts of former Auto-ID centre (now EPC Global), however, applying standards to the industry of robotics or nanotechnology is a complicated matter (ITU Internet Reports 2005). Technological standpoint is one of the few possible when discussing about problematic issues concerning IoT. The social and legal problems related to privacy and data protection create a new field for discussions. RFID implants can be used in collecting data about environment or a person who is bearing it. Technology can be widely applied in healthcare sector, with the possibility of using the cell phone with RFID-sensor capabilities as a platform for monitoring of medical parameters and drug delivery. The enormous advantages are to be seen firstly in prevention and easy monitoring and secondly in case of accidents and the need for ad hoc diagnosis (CERP-IoT cluster, 2010). Implants can track vital diagnosis data and serve as a passive information translator, or initiate actions which are necessary in particular situations. According to Directive 95/46/EC of the European Parliament and of the Council, data associated with human health are considered as sensitive. It means that usage of technologies create many more legal and ethical questions which need to be answered. In the International Telecommunication Union report for the IoT (2005) it is stated that protecting privacy must not be limited to technical solutions, but encompass regulatory, market-based and socio-ethical considerations. Unless there are concerted efforts involving all government, civil society and private sector players to protect these values, the development of the IoT will be hampered if not prevented. In the study Strategic Research Roadmap for IoT (2009) there are emphasized two

possible threats to privacy and data protection from physical person and juridical person standpoints. The control issues may become a serious concern due to a small scale of devices used as a backbone for IoT, their mobility and quantity. Study highlights that for confidentiality, established encryption technology exists, and one of the challenges is to make encryption algorithms faster and less energy-consuming. Moreover, any encryption scheme will be backed up by a key distribution mechanism. For small-scale systems, key distribution can happen in the factory or at deployment, but for ad-hoc networks, novel key distribution schemes have only been proposed in recent years.

In the EU policy framework for RFID (2007) it is stated that application of RFID must be socially and politically acceptable, ethically admissible and legally allowable. RFID will only be able to deliver its numerous economic and societal benefits if effective guarantees are in place on data protection, privacy and the associated ethical dimensions that lie at the heart of the debate on the public acceptance of RFID. It is also noted that databases in which private data are stored should comply with neutrality and neutrality requirements. The report, "Internet of Things—an action plan for Europe" (2009), proposes 14 action points, including work on the policy governance of RFID, continuous monitoring of the privacy and data security issues arising, action over the recycling of the potentially vast number of smart chips and cards, and pan-European standards work. The right to silence a RFID chip is one of the most intriguing in the document. While technologically it is complicated and loads additional burden to the industry, the idea is interesting and worth of discussion.

As for privacy and data protection, the technologies that could prevent third parties from retrieving or tampering with the data are at their infant stage and the regulation itself is at some points unclear and requires additional attention. Examples from healthcare related to privacy issues and sensitive data does not show the whole spectrum of possible threads. For each of these technologies, the privacy and security impact should be evaluated. On a consumer level, it remains to be investigated how much information can be extracted from consumer electronics with sensors, and to which extent this can be regulated by law. In any case, there's an enormous potential for enhancing the user experience, based on the "things" in his possession/surrounding (CERP-IoT, 2010). The situation concerning problematic issues related to privacy and data protection, standardization of the technologies and their presentation for consumers are going to be more complicated as the spread of IoT will increase. One of the most important challenges is to find a balance between legal regulations and technological progress. This also is great field for discussion, because society is fragmented when it is spoken about the usage of new powerful technologies, which true potential is hard to foresee.

5. Discussion and conclusions

Thus, the IoT has great promise, yet business, policy, and technical challenges must be tackled before such systems and solutions are widely embraced. Early adopters will need to prove that the new sensor-driven business models create superior value.

Industry groups and government regulators should study rules on data privacy and data security, particularly for uses that touch on sensitive consumer information. Legal liability frameworks for the bad decisions of automated systems will have to be established by governments, companies, and risk analysts, in consort with insurers. The spectrum of services which could be given by using the IoT could completely change the conception of some working models. The social aspect is none the less important, because the popularity and trust with the technology could give a synergic effect to all sectors, related to IoT. The privacy and data protection preservation methods should be discussed more in order to find the balance between technology development and business interests.

On the technology side, networking technologies and the standards that support them must evolve to the point where data can flow freely among sensors, computers, and actuators. Software to aggregate and analyze data, as well as graphic display techniques, must improve to the point where huge volumes of data can be absorbed by human decision makers or synthesized to guide automated systems more appropriately. The wider standardization in the field of IoT is necessary thus ensuring even technology development and minimizing the malfunction treat of the systems, based on different standards.

Within companies, big changes in information patterns will have implications for organizational structures, as well as for the way decisions are made, operations are managed, and processes are conceived. Optimizing business processes using IoT as a background could grant a competitive advantage, but risks should be considered seriously in order to achieve this goal. Scientists and researchers play crucial role in the development process for the IoT. The broader the discussion about IoT, the better chance of avoiding mistakes in the process of technology development.

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ATEITIES GALIMYBĖS DAIKTŲ INTERNETUI

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Santrauka. *Internetas, kaip tinklas, sudarytas iš tinklų, užtikrina efektyvų panašiais standartais grįstą informacijos perdavimą skirtingiems subjektams. Šiuo metu internetu naudojasi daugiau nei du milijardai žmonių visame pasaulyje. Interneto technologija sudaro sąlygas sudėtingų tinklinių sistemų atsiradimui, kurios evoliucionuoja, keičiasi bei leidžia nustatyti ryšius tarp skirtingų duomenų vienetų. Kita pakopa, leidžianti žengti dar vieną žingsnį interneto technologijos pritaikymo kontekste – daiktų internetas. Buitinių prietaisų, automobilių, energijos sąnaudų daviklių ar miesto transporto sistemų sujungimas į bendrą tinklą, skirtą vieningai prietaisų bei sistemų komunikacijai, leistų gerokai išplėsti funkcinę jų*

taikymo sritį. Daiktų interneto technologijų plėtojimas gali padėti spręsti nūidienai aktualius socialinius uždavinius, tokius kaip tvarus bei efektyvus energijos išteklių naudojimas, transporto srautų modeliavimas, sveikatos būklės stebėjimas, aplinkos pokyčių sekimas ir pan. Europos Komisijos komunikate, kuris apibrėžia Europos veiksmų planą daiktų interneto plėtros kontekste, išskiriamos prioritetinės gairės bei daiktų interneto technologijos vystymo kryptys. Šiame dokumente pabrėžiama, jog daiktų internetas tik iš dalies remiasi šiandienos internetu. Tai greičiau naujos atskiros sistemos, veikiančios savo infrastruktūroje, kūrimas. Daiktų internetas siejamas su naujų paslaugų atsiradimu bei prietaisų ir įrenginių ryšio užtikrinimu, kuris galėtų sieti 50–70 milijardų kompiuterių.

Straipsnio tikslas – apžvelgti bei išnagrinėti daiktų interneto vystymosi kryptis, panaudojimo būdus bei problematiką, susijusią su technologiniais, socialiniais bei teisiniais veiksniais. Daiktų internetas – technologija, siekianti sujungti fizinį ir virtualų pasaulius pasinaudojant sensoriniais įrenginiais bei sujungiant juos į tinklus, kurie komunikuoja tarpusavyje. Daiktų internetas, kai kurių autorių vadinamas kita interneto evoliucijos pakopa, glaudžiai siejasi su paslaugų internetu. Plintant nešiojamiems bei interneto prieigos galimybę turintiems įrenginiams, vystosi ir internetinių paslaugų sritis. Prognozuojama, jog daiktų interneto technologijų naudojimas stipriai paveiks paslaugų interneto plėtrą bei padidins internetu teikiamų paslaugų apimtis ir generuojamas pajamas. Žvelgiant iš technologinės pusės, daiktų interneto kūrimas apibūdinamas kaip kompleksiškas procesas, susiduriantis su standartizacijos bei teisinio reglamentavimo trūkumo problematika. Šiuo metu daiktų interneto kūrimui plačiai naudojama radijo dažnių atpažinimo (*RDA*) *technologija sukelia teisines ir etines problemas, susijusias su privatumo ir asmens duomenų apsauga. Daiktų interneto vystymasis keičia visuomenės įpročius, todėl šios technologijos naudotojai turėtų būti informuoti apie grėsmes bei galimybes. Šiai sričiai nagrinėti yra parengta nemažai studijų apie ateities interneto perspektyvas. Straipsnio autoriai siekia išskirti svarbiausias daiktų interneto vystymosi tendencijas bei suteikti medžiagos diskusijoms ir moksliniams tyrimams plėtojant daiktų interneto pritaikomumo idėją.*

Raktažodžiai: *daiktų internetas, paslaugų internetas, ateities internetas.*