Green Internet of Things (IoT): Go Green with IoT

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***Abstract*— Internet of Things helps integrating and connecting the physical devices to the Internet without any human intervention and human to human or human to computer interaction. It represents the future trend and the next biggest revolution unfolding in the IT world. The people and things are connected with anything and anyone, anytime, anyplace, using network or service. It also aims at how IoT can lead to a greener and cleaner environment through Green IoT. This paper gives overview of IoT and Green IoT. It also highlights various technologies and concerns regarding green IoT and how it can reduce energy consumption. This paper enlightens the concept of Internet of Things (IoT), its features, security issues, technology adoption trends.**

Keywords*— Environment, Internet of Things (IoT), Green IoT, network, revolution.

I. INTRODUCTION

The Internet is a continuously evolving entity where everyday radical changes are brought about. With the cheap and readily available Broadband connections and Internet devices data is easily available. There is increase in the number of Internet connected devices which helps the Internet of Things. The Internet of Things is driven by an expansion of the Internet through the inclusion of physical objects combined with an ability to provide smarter services to the environment as more data becomes available.

Here the ―things‖ refer to the embedded machines with sensors that can gather, store and analyze data. As they are linked to Internet, data can be uploaded for processing; updated software can be uploaded and can even be controlled from a long distance.

The term "Internet of Things" describes a number of technologies and research disciplines that enable global connectivity over the world-wide physical objects. Objects in IoT can sense the environment, transfer the data, and communicate with each other. They become powerful tools to understand physical world and to respond to emergent events and irregularities promptly. Thus, the IoT is seen by many as the ultimate solution for getting insights about real-world physical processes in real-time. [1]

Technologies like RFID(radio-frequency identification), sensor networks, biometrics, QR codes (Quick Response codes) and nanotechnologies will be the cornerstone of the upcoming IoT, in which information and communication systems are invisibly embedded in the environment around us, real implementations addressing varying applications, including smart grid, e-health, intelligent transportation, etc. [2]

IoT makes full use of things to offer services to all kinds of applications, while maintaining the required privacy.

According to the definition of IERC (IoT European Research Cluster) __A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual __things‘‘ have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.‘‘

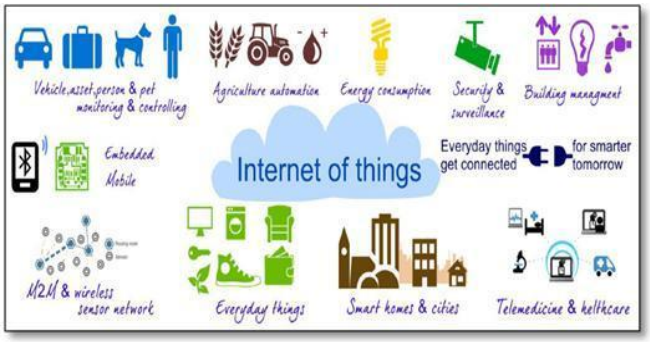

FIG. 1 Internet of Things

The basic idea of IoT is that everything (e.g., from small rooms to large buildings, from everyday appliances to sophisticated embedded systems, from man-made artifacts to natural objects) around us could be connected, sense and cooperatively communicate over the Internet.

Every device connected to IoT will be uniquely identified by its IP address. The brains of these objects will be sensors. These sensors are micro electromechanical systems (MEMS) that will respond to changes in temperature, sound, humidity, pressure, motion, light, time, weight, etc., and take the necessary action that it is programmed to. [3]

The Internet of Everything, it is a proposed setup in which existing, common day-to-day inanimate objects like machines and appliances and also people and animals will be connected in a network and will be able to exchange data.

Objects and machines will be able to send and receive messages to each other, eliminating the intervention of humans.

II. GREEN IOT

Environmental issues are acquiring more attention as the general public becomes more aware of the formidable consequences of the Environmental Degradation causes. Recent technological advances have led to an increase in the carbon footprint. The advancement in this field is paving the way for an emerging area known as **Green IoT**. Within a

few years it would provide green support for varied users in managing their tasks. The Green Internet of Things (G-IoT)

is predicted to introduce significant changes in our daily life and would help realizing the vision of ―green ambient intelligence‖ which interconnects our physical world through green networks. Green networks in IoT will contribute to reduce emissions and pollutions, make the most of environmental conservation and surveillance, and minimize operational costs and power consumption. [4]

Considering the energy efficiency as the key during the design and development of IoT, green IoT can be defined as follows. ―The energy efficient procedures (hardware or software) adopted by IoT either to facilitate reducing the greenhouse effect of existing applications and services or to reduce the impact of greenhouse effect of IoT itself. In the earlier case, the use of IoT will help reduce the greenhouse effect, whereas in the later case further optimization of IoT greenhouse footprint will be taken care. The entire life cycle of green IoT would focus on green design, green production, green utilization and finally green disposal/recycling to have no or very small impact on the environment.‘‘

According to global consultants Gartner, Inc. (world's leading information technology research and advisory company), ICT (Information and communications technology) presently account for approximately 0.86 metric gigatons of carbon emissions annually (about 2 percent of global carbon emissions).And with the same ICT including IoT technologies, have a direct effect on lowering CO2 emissions.[5]

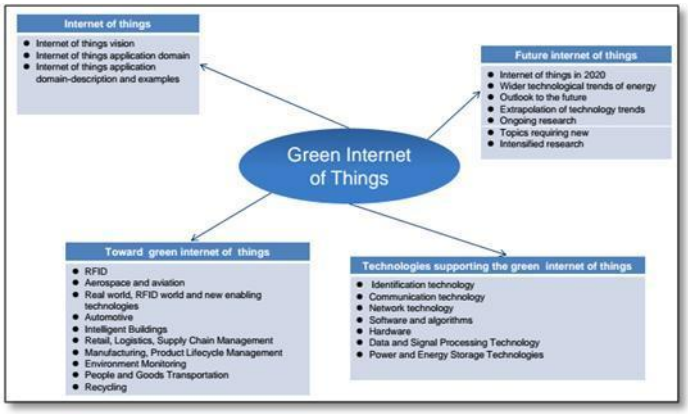

FIG. 2 Green Internet of Things

Green IoT not only indicates green environment but also saves time and energy. It provides a systematic solution that enables green and sustainable growth of the society. It supports innovations and applications for addressing societal challenges, such as smart transport, sustainable city, and efficient utilization of energy to make a green IoT environment.

IoT solutions have the capability to be monitored online. These devices send out data to an online dashboard and then users are able to see that data online.

III. TECHNOLOGIES SUPPORTING THE GREEN IOT

There are six elements in IoT, i.e., identification, sensing, communication technologies, computation, services and semantic.

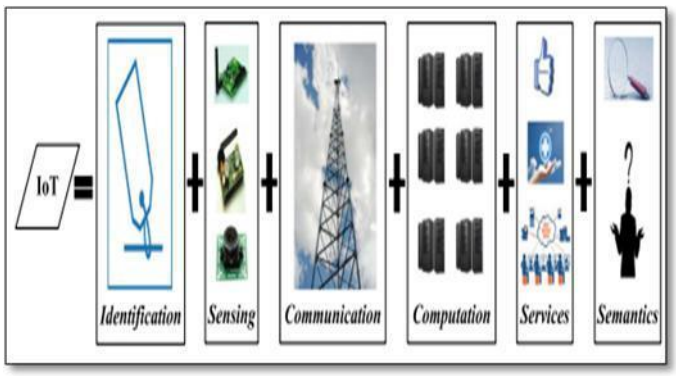

FIG. 3 Elements of IoT

1. ***Identification*** is naming and matching services with their demand i.e. gathering information at a ―point of activity.‖ This can be information captured by an appliance, a wearable device, a wall mounted control or any number of commonly found devices.

2. ***Sensing*** is for collecting various data from related objects and sending it to a database, data warehouse, data center, etc. The gathered data is further analyzed to perform specific actions based on required services. The sensors can be humidity sensors, temperature sensors, wearable sensing devices, mobile phones, etc. The sensing can be biometric, biological, environmental, visual or audible (or all the above). Sensing technology is purpose specific.

3. ***Communication*** technologies connect heterogeneous objects together to offer specific services. This requires either Wi-Fi (wireless LAN based communications) or WAN (wide area network) communications. The communication protocols available for the IoT are: Wi-Fi, Bluetooth, IEEE 802.15.4, Z-wave, LTE-Advanced, Near Field Communication (NFC), ultra-wide bandwidth (UWB), etc.

4. ***Computation***, the hardware processing units (e.g., microcontrollers, microprocessors, system on chips (SoCs), field programmable gate arrays (FPGAs)) and software applications perform this task. Many hardware platforms (e.g., Arduino, UDOO, FriendlyARM, Intel Galileo,Raspberry PI, Gadgeteer) are developed and various software platforms (e.g., TinyOS, LiteOS, Riot OS) are utilized. Cloud platform is a particular important computational part of IoT, since it is very powerful in processing various data in realtime and extracting all kinds of valuable information from the gathered data. Gathered data is transmitted to a cloud based service where the information coming in from the IoT device is aggregated with other cloud based data to provide useful information for the end user. The data being consolidated can be information from other internet sources as well as from others subscribing with similar IoT devices. Data processing is required to provide useful information.

5. ***Services*** in IoT can be categorized into four classes:
   - Identity-related services
   - Information aggregation services
   - Collaborative-aware services
   - Ubiquitous services

Identity-related services provide the base for other types of services, since every application mapping real world objects into the virtual world needs to identify the objects first.

Information aggregation services gather and summarize the raw information which needs to be processed and reported. The obtained data are further utilized by the collaborative aware services to make decisions and react accordingly.Ubiquitous services are for services to anyone on demand, anytime and anywhere.

6. ***Semantic*** means the ability to extract knowledge intelligently so as to provide the required services. This process usually includes: discovering resources, utilizing resources, modeling information, recognizing and analyzing data.

The commonly used semantic technologies are: resource description framework (RDF), web ontology language (OWL), efficient XML interchange (EXI), etc.

IV. APPLICATIONS

FIG. 4 Applications of IoT

1. *Industrial Automation[11]*

   a. Machine to machine communications: with the use of RFID tags automation is possible and RFID reader directly communicates with the robot without any human intervention.

   b. Plant Monitoring: Emerging technologies can efficiently monitor various parameters, such as temperature, air pollution, machine faults, etc., of an industrial plant to improve energy efficiency.

2. *Healthcare*

   a. Real-Time Tracking: tracks and monitors patients and medical equipment. In relation to assets, tracking assists with maintenance, availability, monitoring of use, and materials tracking to prevent any instrument from being inadvertently left behind in a patient's body in the course of surgery. [43]

   b. Identification: Energy efficiency can be achieved by having efficient tracking methods, efficient RFID-based tracking, prediction techniques, etc. It is valuable for quickly retrieving patient information and monitoring patient locations in the hospital. These technologies can support patient identification to reduce dangerous patient incidents (such as wrong drug, dose, etc.), electronic health records (in and out patient), and infant identification (to prevent mismatching).

   c. Smart Data Collection helps to reduce processing time, automated hospital admission processing, and automated care and procedure auditing, and reduces costs.

   d. Smart Sensing: Sensor devices provide patient conditions for diagnosis and real-time health indicators.

3. *Environment Monitoring*

It is used to identify spatial and temporal changes, physical changes in the environment, organism changes, and changes caused by human actions or natural events.

a. Agriculture: it can sense the water levels and accordingly the suitable crop can be grown. Aiding agriculture and helping prevent forest fires as well.

b. Pollution control: The Internet of Things Academy (IOTA) is leading the charge for improving air quality in London. The IOTA has been experimenting with sensors and other technology to try to improve the air quality in London. One solution that was proposed by the IOTA is the BuggyAir project. The IOTA wants to have sensors in buggies (strollers) that measure pollution at street levels and record the data. The GPS in the stroller would give the exact location of the pollution levels.

c. The use of IoT technology can make air pollution monitoring less complex and help in better understanding the environment

d. Waste management: Rapid increase in volume and types of solid and hazardous waste makes waste management a significant problem. Waste management is a vital issue, particularly in relation to the environment. The costs associated with waste disposal can also be significant, particularly in densely populated countries. Waste can be municipal waste, electronic waste, biomedical waste and industrial waste. To reduce the environmental impact of waste dumping, many municipal and corporate bodies are involved in the development of efficient waste management systems. Embedding RFID reader, antenna and scale on garbage truck can make them intelligent. When trash (with an RFID tag) is deposited into the bin, the reader and antenna communicates with the RFID tags, the bin can identify the type of trash to facilitate the recycling process. Furthermore, the waste bins can communicate with each other (by routing information across them) to better manipulate the waste. Such smart practices help promote a healthy environment.

e. Smart water: potable water monitoring tools to monitor the quality of tap water.

f. Smart environment: alarm and control of CO2 emissions of factories, pollution emitted by cars and toxic gases generated.

4. RESIDENTIAL SECTOR

a. Intelligent Buildings: Home owners can track all of their systems to see which are not performing properly. If given which devices waste the most energy, users can act accordingly to save both money and energy. The Internet of Things into technology such as solar panels. Many IoT solutions give feedback on energy usage and guide the user in the right direction to properly allocate energy without wasting money. There is a direct correlation with the time spent on analyzing the data an IoT solution provides and how much energy can be saved. With the proper IoT solution, entire cities can be run more efficiently and in a greener manner. With motion sensors, the lights would turn off when no one is in the room. This is only one small example of IoT and building automation.

b. Garbage collection: some cities are starting to implement smart trash cans that can send out notifications on when they need to be emptied. This can save a lot of time for garbage collectors and can also be helpful for the environment.

c. Water sensors: With these sensors, officials were able to gather information on which restaurants were illegally dumping waste into sewers or if any taps are left open without being used.

d. Smart Metering: A smart meter periodically records the consumption of electric energy and transmits that information to the utility company for monitoring and billing purposes. Smart meters enable two-way communication between the smart meter and the utility company. In contrast, traditional meters only measure total consumption, and provide no information regarding how the energy was consumed. On the other hand, smart meters provide site-specific information that can offer a number of potential benefits to householders. These include a) an end to estimated bills; and b) a tool to better manage their energy use that can help to reduce their energy bills and carbon emissions.

5. PEOPLE AND GOODS TRANSPORTATION

Recently, cars, trains, buses, bicycles, and roads have been equipped with tags, sensors, actuators, and the necessary processing power to send important information to traffic control sites. Such advanced transportation systems help to route traffic better, provide tourists with appropriate transportation information, and monitor the status of transported goods.

a. Smart Parking: helps finding vacant places to park the vehicles, particularly in major cities.

b. Smart Traffic Congestion Detection: With thegrowing worldwide population, traffic problems, such as traffic congestion, etc., are increasing daily. By using the technology of vehicular ad hoc networks (VANETs), it is possible to avoid traffic congestion allowing vehicles to communicate with each other and to share road information to better understand road conditions. This will reduce carbon emissions and help to build a green environment.

6. RETAIL, LOGISTICS, SUPPLY CHAIN MANAGEMENT

a. Smart Logistics/Shipment: Information collected through RFID, NFC, and sensors can enable real-time monitoring of the supply chain system. These technologies can also gather product-related information in real time to help enterprises to respond to changing markets in the shortest possible time. Enterprises using advanced technologies (such as Walmart and Metro) only need few days to fulfill customer demands in contrast to the traditional approaches.

b. Quality monitoring: perishable products such as fruits, meat, and dairy products travel thousands of miles from the production site to consumption sites and require constant monitoring to ensure quality standards. IoT enabled technologies offer great potential for improving the efficiency of the food supply chain and for helping to limit the carbon footprint.

7. RECYCLING

Public awareness about the changing paradigm of energy supplies, consumption, and infrastructure is increasing. Rather than being based on fossil resources or nuclear energy, the future energy supply needs to be based largely on various renewable resources. The future electrical grid must be flexible enough to react to power fluctuations by controlling energy sources and the consumption by the consumers. Such grid will be based on networked smart devices (appliances, generation equipment, infrastructure, and consumer products) based on IoT concepts.

Overall, IoT can dramatically increase the quality of life for citizens. There are countless examples of companies like this trying to make the world more green using IoT. IoT is something that everyone can get behind as it not only saves money, but it is good for the environment and the sustainability of the planet for future generations.[8]

V. GREEN IOT -RELATED PROJECTS AND STANDARDIZATION

Government and various organizations are taking initiatives and are playing a laudable role in up- liftment of the society with the inclusion of Governments across the world have put forth initiatives to force corporations to reduce carbon emissions, become more energy efficient, and use greener techniques.

The TREND project collects power consumption data, assesses the energy-saving potential of technologies, protocols, architectures, and experiments with new approaches. It also includes training programs to spread green network awareness, i.e., GreenNet.

Project EARTH investigates the energy efficiency of wireless communication systems. It focuses on the theoretical

and practical energy efficiency limitations of current networks to develop a new generation of energy efficient equipment, deployment strategies, and network management solutions to ensure quality of service (QoS).

The IEEE Communication Society has also established a Technical Subcommittee on Green Communications and Computing (TSCGCC). TSCGCC works to develop and standardize energy-efficient communications and computing. It also provides opportunities to interact and exchange technical ideas, to identify R&D challenges, and to collaborate on solutions for the development of energy-sustainable, resource-saving, and environmentally friendly green communications and computing technologies.

VI. CHALLENGES & OPPORTUNITIES FOR GREEN IOT

Green technologies will play an important role in enabling the energy-efficient IoT. There are many challenging issues that need to be addressed. Here, key issues have been summarized that need further consideration.[9]

A. Green IoT Architectures

For IoT, a standard architecture, such as the ISO OSI model or the TCP/IP model, is needed to enable communication across various applications and heterogeneous networks that have a wide variety of devices. Moreover, it is important to understand how to integrate energy efficiency across the whole architecture to make it energy efficient.

B. Green Infrastructure

Providing energy efficient infrastructure for IoT can be achieved through a redesign approach.

C. Green Spectrum Management

The cognitive radio approach brings many benefits to green mobile services which are currently restricted to RF systems.

D. Green Communication

The energy-efficient communication faces many challenges such as providing a continuous energy supply to objects in loop and supporting energy-efficient communication protocols that enable peers to communicate in a reliable manner, etc. Efficient adoption of new energy sources, such as wind, solar, thermal, and vibration to assist the current green IoT appear promising.

E. Green Security and QoS Provisioning

Security and privacy are major concerns for IoT deployment. Implementing of security algorithms requires a substantial amount of processing from devices.

VII. FUTURE OF GREEN IOT

Internet of Things (IoT) has transformed our ecosystem of information that has changed our lives a lot. From indoor to the outside world, the IoT has brought about digital revolution. It has helped a lot in decision making with the use of analytics and thereby improving transparency. This has led to huge investments in sensors and which is likely to increase in the years to come.

It is expected that the Internet of things will be omnipresent in the coming years; improving the quality of our lives, the way we live and work. In the years to come we foresee to have smart cars, smoke detectors, door locks, industrial robots, streetlights, heart monitors, trains and wind turbines connected to sensors.

VIII. CONCLUSION

Environmental issues are acquiring more attention as the general public becomes more aware of the consequences that the environment degradation causes. There are many things which need a great focus in the areas of standardization, security, and governance for the smooth functioning of Internet of Things that can benefit the society on the whole. This paper also emphasizes on various associated technologies and concerns regarding green IoT for a smarter world. IoT represents an important paradigm shift in ICT that will smooth the progress of smart cities around the world.

The Green Internet of Things (G-IoT) is expected to bring in noteworthy revolutions in our day to day life and would facilitate comprehend the vision of ―green ambient intelligence‖. Within a few years we will be surrounded by a massive amount of sensors, devices and ―things‖, which will be able to communicate via IP, act ―intelligently‖, and provide green support for users in managing their tasks.

Finally, future research directions and open problems regarding green IoT have been presented. In this paper, green viewpoint of the IoT have been reviewed. Recent developments in green IoT area have been identified and discussed along with the future scope for green IoT. A great deal of interesting research is expected to come out in this area.

REFERENCES

[1] Roberto Minerva, Abyi Biru, Domenico Rotondi"Towards a definition of the Internet of Things (IoT)"Issue 1 – Published 13 MAY 2015
[2] L. Atzori, A. Iera, and G. Morabito, __The Internet of Things: A survey,‘‘ Comput. Netw., vol. 54, no. 15, pp. 2787–2805, Oct. 2010.
[3] Pros and Cons of Internet of Things (IoT) [online] Available: online
[4] Chapter 14: Green Internet of Things (IoT)
[5] Green IT: One Answer to Global Warming? Preston Gralla, [online] Available: online
[6] L. Da Xu, W. He, and S. Li, __Internet of Things in industries: A survey,‘‘ IEEE Trans. Ind. Informat., vol. 10, no. 4, pp. 2233–2243, Nov. 2014.
[7] C. Perera, C. H. Liu, and S. Jayawardena, __The emerging Internet of Things marketplace from an industrial perspective: A survey,‘‘ IEEE Trans. Emerg. Topics Comput., to be published.
[8] ―Green Internet of Things for Smart World‖, Chunsheng Zhu, Victor C. M. Leung ; Lei Shu ; Edith C. -H. Ngai, Special Section in IEEE Access: Challenges for Smart Worlds
[9] The Internet of Things (IoT): An Overview, Understanding the issues of more connected world.Internet Society
[10] N. Gershenfeld, R. Krikorian, and D. Cohen, ―The Internet of Things,‖ Sci. Amer., vol. 291, no. 4, pp. 76–81, 2004.
[11] The IoT Generation [online] Available: online
[12] IoT-A: Architectural Ref. Model for the IoT. [Online]. Available: www. iot-a.eu/arm
[13] T. S. López et al., ―Adding sense to the IOT—An architecture framework for smart object systems,‖ Pers. Ubiquitous Comput., vol. 16, no. 3, pp. 291–308, Mar. 2012.
[14] Green Comm. & Comp. [Online]. Available: www.comsoc.org/about/committees/emerging#gcc
[15] GreenTouch, Accessed Feb. 20, 2014. [Online]. Available: www. greentouch.org/

[16] GREEN-T greent.av.it.pt Accessed Feb. 28, 2014.
[17] Green IT Initiatives in Japan, Accessed Feb. 28, 2014. [Online]. Available www.meti.go.jp/english/policy/
[18] H. S. Dunn, ―The carbon footprint of ICTS,‖ Global Inf. Soc. Watch, Univ. West Indies, Kingston, Jamaica, 2010.
[19] H. Nannan, ―Green ICT applications and development,‖ in Proc. ITU/ MIIT Seminar ICT Enabler Creative Green Economy, 2011, pp. 1–23.
[20] S. Murugesan, ―Harnessing green IT: Principles and practices,‖ IEEE IT Prof., vol. 10, no. 1, pp 24–33, Jan./Feb. 2008.
[21] N. Gershenfeld, R. Krikorian, and D. Cohen, ―The Internet of Things,‖ Sci. Amer., vol. 291, no. 4, pp. 76–81, 2004.
[22] Rwan Mahmoud,Tasneem Yousuf,Fadi Aloul,Imran Zualkernan,"Internet of things (IoT) security: Current status, challenges and prospective measures",IEEE CONFERENCE PUBLICATIONS
[23] Qian Xiaocong; Zhang Jidong "Study on the structure of ―Internet of Things(IOT)‖ business operation support platform" IEEE CONFERENCE PUBLICATIONS
[24] Salim Elbouanani; My Ahmed El Kiram; Omar Achbarou "Introduction to the Internet of Things security: Standardization and research challenges" IEEE CONFERENCE PUBLICATIONS
[25] Yen-Kuang Chen "Challenges and opportunities of internet of things" IEEE CONFERENCE PUBLICATIONS
[26] Gartner Says a Thirty-Fold Increase in Internet-Connected Physical Devices by 2020 Will Significantly Alter How the Supply Chain Operates, [online] Available: online
[27] "Internet of Things", IBM Connects, [online] Available: online
[28] IDC: 30 Billion Autonomous Devices By 2020, [online] Available: online
[29] Seize New Product and Revenue Opportunities with the Internet of Things, [online] Available: online
[30] Forecast: The Internet of Things, Worldwide, 2013, [online] Available: online
[31] Internet of Things: Six Key Characteristics, [online] Available: online
[32] THE CONNECTED-HOME: Forecasts And Growth Trends For The Leading _Internet Of Things' Market, [online] Available: online
[33] How the Internet of Things could dramatically change the workplace as we know it, [online] Available: online
[34] Researchers show that IoT devices are not designed with security in mind, [online] Available: online
[35] $117 Billion Market For Internet of Things In Healthcare By 2020, [online] Available: online
[36] Industrial Internet: Pushing the Boundaries of Minds and Machines, [online] Available: online
[37] A Wave or a Bubble: IIoT's Success or Doom?, [online] Available: online
[38] Virgin Atlantic to Integrate iBeacon Technology Into London's Heathrow Airport, [online] Available: online
[39] American Airlines undertakes industry's biggest deployment of iBeacons at DFW Airport, [online] Available: online
[40] Cisco Unveils IoT Framework, [online] Available: online
[41] The Internet of Things, 2014, [online] Available: online
[42] Gartner's Internet of Things predictions, [online] Available: online
[43] It's Official: The Internet Of Things Takes Over Big Data As The Most Hyped Technology, [online] Available: online
[44] Gartner's 2014 Hype Cycle for Emerging Technologies Maps the Journey to Digital Business, [online] Available: online
[45] Gartner's 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor, [online] Available: online
[46] Internet of Things market to hit $7.1 trillion by 2020: IDC, [online] Available: online
[47] Who's Winning The Internet Of Things Developer War? Apple And Google, [online] Available: online
[48] Eugène david ngangue ndih (member, IEEE) and soumaya cherkaoui (senior member, IEEE) ―on enhancing technology coexistence in the iot era: zigbee and 802.11 case‖
[49] David Niewolny ―How the Internet of Things Is Revolutionizing Healthcare‖