Internet of Things: Design of a New Layered Architecture and Study of Some Existing Issues

Indu Bala Thingom

(Department of Information Technology, N.E.H.U., India)

Abstract: *Internet of Things (IoT) creates the existence of smart objects and the interactions amongst them and between humans and these objects for the development of the environment as a whole. Objects become smart/intelligent by using new technologies and connecting them through the internet. Not only objects but also buildings, vehicles and even cities have become smart by being connected using this technology called IoT. In this paper a new architecture of IoT is proposed and a brief discussion of the features of each layer is provided. In the later part of the paper a brief discussion on the different issues of IoT will be given.*

Keywords: *Internet of Things (IoT), RFID tags, sensors, actuators, Human Computer Interaction (HCI), Machine-to-Machine (M2M) communications.*

I. INTRODUCTION

Internet of Things (IoT) traces back to the year 1990 when John Romkey created the first device, a toaster that could be turn on and off over the internet. Also in 1993, Quentin Stafford-Fraser and Paul Jardetzky created the Trojan Room Coffee Pot which was located in the Trojan Room within the Computer Laboratory of the University of Cambridge and was used to monitor the pot levels with an image being updated about 3 times a minute and sent to the buildings server. Then in 1998, a year before losing his battle to cancer, Mark Weiser continues his explorations into the topic and constructed a water fountain outside his office whose flow and height mimicked the volume and price trends of the stock market [1]. These are some of the inventions where we could see that things are becoming smarter.

The term Internet of Things (IoT) is coined in 1999 by Kevin Ashton, cofounder and executive director of the MIT Auto-ID centre. The Internet of Things was the title of a presentation he made at Procter & Gamble (P&G) [1].

Internet of Things is a network of physical objects linking to the Internet whereby the objects can provide information about their status, identities, locations, physical attributes and their capabilities, and the objects can also gather required information about their environment.

Before the emergence of IoT, people used to collect information about objects and store in the internet databases for widespread uses. But due to the limited availability of time and resources the data collection becomes a problem. Moreover, it is not guaranteed that everything that was collected is genuine as there was no direct communication between the objects and the person who did the survey. The information was gathered through some observations that the surveyor had done. What if, instead of collecting information, the objects provide information about themselves? Then only we can guarantee some genuineness about the information. So, physical objects are added senses so that they can think and act accordingly. For this purpose things are connected to internet by using embedded technologies such as Radio Frequency Identification (RFID) tags, sensors and actuators. Thus, they can identify and represent themselves in the physical world

Internet connected objects can provide and update data about themselves which makes data available easily to be used by human beings and other internet connected objects. Hence people can concentrate on other things as information is readily available and do not have to spend time and give effort on that data collection process. Meanwhile, these objects can interact with people and other internet connected objects in their environment and become active participants in business, social and private processes, thereby reducing loss, waste and cost effectively. Thus, Internet of Things enables person-to-object (Human Computer Interaction (HCI)) and object-to-object (Machine-to-Machine (M2M)) communications [2, 3].

In practical application, the Internet of Things will allow cars to self diagnose down the very component, or inform the owner when there is less petrol. It can allow our homes to alert us of potential problem areas, or automate our comforts, or help in preserving energy by switching off the lights, AC, TV etc. when we actually forget to do so.

II. ARCHITECTURE

After a study of various architectures [2-10] of IoT designed by researchers, here a six layered architecture is proposed and discussed below:

- Sensing layer
- MAC layer
- Networking layer
- Processing and storage layer
- Services layer
- Business layer

In the sensing layer we use embedded technologies such as RFID tags, sensors and actuators, which sense data from Things in the IoT system. The data collected can be physical meaning of each Thing, attributes, locations, status etc. This information is transformed into signals and passed to some connectivity, which then passed to the next layer through the internet. Most sensors require connectivity to the sensor aggregators (gateways), which can be in the form of a Local Area Network (LAN) such as Ethernet and WiFi connections or Personal Area Network (PAN) such as ZigBee, Bluetooth and Ultra-Wideband (UWB). For sensors that do not require connectivity to gateways, their connectivity to backend servers/applications can be provided using Wide Area Network (WAN) such as GSM, GPRS, and LTE. Sensors that use low power and low data rate connectivity use Wireless Sensor Networks (WSNs).

The MAC layer receives the information from the sensing layer and transmits to the next layer. It is responsible for device monitoring and control, Quality-of-Service (QoS) management and energy management. IoT is expected to be a low traffic application and many of the physical objects may have very limited energy storage. Therefore, the ideas of SMAC (Sensor MAC) and CSMA/CA are adopted. In SMAC things periodically listen and sleep which reduces the energy consumption. In CSMA/CA a node attempts to reserve the channel after it sees the medium idle for an Inter-Frame Space (IFS) amount of time. If the node fails to reserve the medium, it switches to sleep mode to save energy and waits for the next listening cycle. As a result the hybrid of SMAC and CSMA/CA medium access protocol can save the energy as well as reduce the interference among the things [11-13].

The networking layer is responsible for transmission, routing and addressing each thing in the system using IPv6. The communication standard 6LoWPAN (IPv6 over Low power Wireless Personal Area Networks) allows the low-power devices to communicate and exchange data via IPv6 which allows network auto-configuration, making devices easy to be managed and configured automatically once they are in the network. IPv6 can bring about efficient allocation and management of addresses by distributing addressing space in a hierarchical manner.

The processing and storage layer processes the query, analysis and storage of sensed data in the database. It also handles security controls and process modeling. Thus it is responsible for the database management, resource management and security management. Data gathered is huge so it uses some technologies like cloud computing, ubiquitous computing, etc.

The services layer uses the analyzed and processed data for the different services to be used in the IoT system. It develops the IoT applications to be more intelligent, authenticated and safe, considering that the industrial technologies used can be controlled to cover the human needs.

The business layer determines the service charge and management, cost estimation and distribution of the services provided by the services layer.
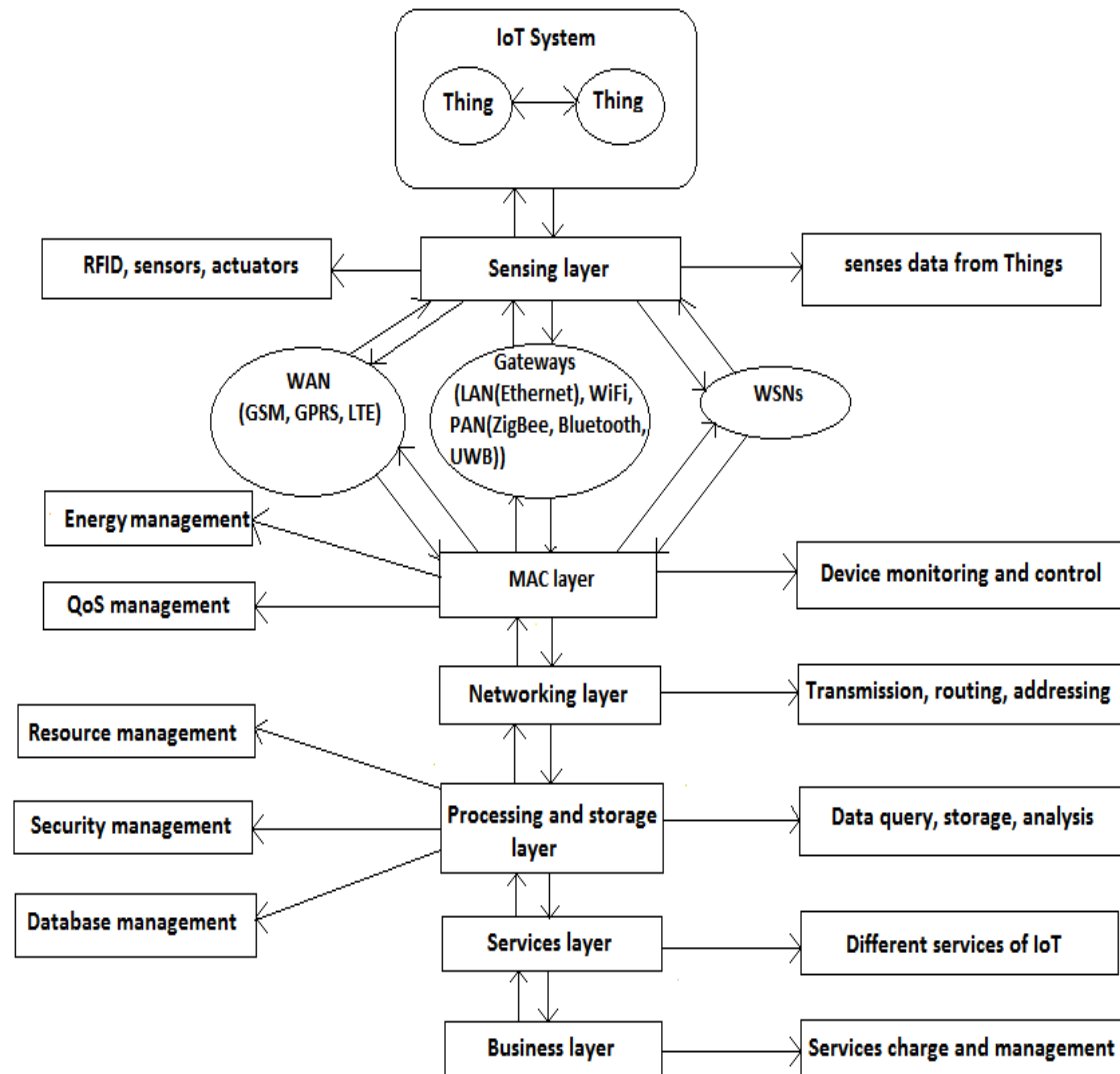
The architecture of IoT is shown in Fig. 1.

Figure 1: Architecture of IoT

III. MAIN ISSUES OF INTERNET OF THINGS

Some of the issues related to IoT that need to be considered and solved for overall effective performance are discussed as follows:

- **Data management issue**

With increasing use of IoT more and more objects become interconnected and these objects are constantly exchanging all types of information. Due to the massive availability of data, processes involving in handling these data like transmission, analyzing and storing become difficult [3].

Security, privacy and trust: In the Internet of Things, things communicate through wireless network. But wireless medium are prone to security problems. Things are often isolated in the IoT system and this makes an intruder hack the things physically and so important data are being hacked (physical attack) and also infiltrates the network (wireless information attack). And these things are not provided with defensive mechanisms so they have low self defense. Information that flow in the IoT are mainly personal and

sophisticated data and any unauthorized man-in-the-middle can extract all such data by imposing as the intended user, thereby disclosing privacy. And we cannot trust that the data came from the authorized user [3].

- **Networking issue**
Using of IPv6 creates unlimited IP addresses. So the internet infrastructure will face problem in coping with the highly heterogeneous IoT and global connection will become difficult [10].
1.) SMAC reduces power consumption but by decreasing the awake/sleep duty cycle, the chances for things to be connected decrease too and the link delay increases [14, 16].
2.) Mobile communication and WLAN are sharing the same spectrum, which may lead to severe interference. Exclusive frequency allocation is difficult and often not enough for application. Strategy like CSMA/CA is usually employed to cope with possible collision and hop to another frequency band. In the IoT context, the resources wasted in collision cannot be ignored. A non-collision solution is required to fulfill the frequency reuse [11-13, 15].
3.) WSN is highly limited on computing and power resources. Once the battery of a node is exhausted, it cannot be activated, and it is usually impractical to replace the battery [11-14].

- **Communication issue**
Communication between things gives rise to some problems regarding object identification and QoS. Object identification is done using technologies like RFID which has radiation, privacy, violation and inconvenience of information updating. In many researches QoS is considered only in wireless sensor networks but not in RFIDs, so it becomes a short term solution [8, 10].

- **Energy issue**
Communication is one process which makes devices consumes high energy, and things connected in the IoT may have different characteristics and capabilities. So, interoperability between things with less energy consumption is highly advisable. Moreover sensors need to be able to sustain longer battery lifespan to shorten hardware maintenance, prevent breakdown of communication and interact with each other. For this purpose the design and use of low-power chipsets will create a significant impact and consideration on power consumption for future sensors [4, 8, 10, 14].

- **Scalability**
The network of things consists of cooperation and coordination of many devices and adding sensors and actuators to all of them requires highly specialized field experts and is time consuming, costly, requires huge memory capacity and energy consuming and hence is not scalable. As devices become connected to IoT availability of information becomes unmanageable [2].

- **Heterogeneity**
Sensors and actuators (chips) are embedded in different types of devices which have different characteristics. So the chips will have different operational characteristics. The heterogeneity increases in devices which use these chips and increases tremendously when they are globally connected to IoT [2].

IV. CONCLUSION

In this paper the origin of Internet of Things is discussed and defined briefly its meaning and purpose. After studying the architectures of IoT designed by many researchers, a new six layered architecture is proposed and a brief explanation of each layer is given. IoT has contributed a lot in the development of our environment and the living style, but also it comes with some drawbacks. Therefore a study on some of its main issues is done regarding its management, communication, energy consumption, networking, security etc.

REFERENCES
[1]. Postscapes.com/internet-of-things-history. < Accessed on 9th April 2014 >
[2]. S. Hachem, T. Teixeira, and V. Issarny, Ontologies for the Internet of Things, Proc. 8th Middleware Doctoral Symposium, ser. MDS '11, New York, NY, USA: ACM, 2011, 3:1–3:6.
[3]. O. Said, M. Masud, Towards Internet of Things: Survey and Future Vision, International Journal of Computer Networks (IJCN), 5(1), 2013, 1-17.

[4]. A. Bassi, R. Giaffreda and P. Vlacheas, A Common Architectural Approach for IoT Empowerment, Internet of Things- Converging Technologies for Smart Environments and Integrated Ecosystems (Denmark, River Publishers, 2013).

[5]. J. An, X. Lin Gui, X. He, Study on the Architecture and Key Technologies for Internet of Things, Proc. International Conference on Electrical and Computer Engineering, Advances in Biomedical Engineering, 11, 2012, 329-335.

[6]. C. Han, J.M. Jornet, E. Fadel, I.F. Akyildiz, A cross-layer communication module for the Internet of Things, Computer Networks 57 (2013), 2012, 622-633.

[7]. http://www.ida.gov.sg/~/media/Files/Infocomm%20Landscape/Technology/TechnologyRoadmap/InternetOfThings.pdf. <Accessed on 9th April 2014 >

[8]. L. Zheng, H. Zhang, W. Han, X. Zhou, J. He, Z. Zhang, Y. Gu, and J. Wang, Technologies, Applications, and Governance in the Internet of Things, Internet of Things - Global Technological and Societal Trends (Denmark, River Publishers, 2011).

[9]. R. Khan, S. U. Khan, R. Zaheer and S. Khan, Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges, Proc., 10th IEEE International Conference on Frontiers of Information Technology (FIT) , Islamabad, 2012, 257-260.

[10]. J. Jin, J. Gubbi, T. Luo and M. Palaniswami, Network Architecture and QoS Issues in the Internet of Things for a Smart City, Proc. International Symposium on Communications and Information Technologies (ISCIT), Gold Coast, QLD , 2012, 974-979.

[11]. A. Aijaz and A. H. Aghvami, A PRMA based MAC Protocol for Cognitive Machine-to-Machine Communications, Proc. IEEE ICC 2013 - Cognitive Radio and Networks Symposium, Budapest, 2013, 2753-2758.

[12]. Y. Liu, C. Yuen, J. Chen, and X. Cao, A Scalable Hybrid MAC Protocol for Massive M2M Networks, Proc. IEEE Wireless Communications and Networking Conference (WCNC): MAC, Shamghai, China, 2013, 250-255.

[13]. D. Tarchi, R. Fantacci and D. Marabissi, Proposal of a Cognitive Based MAC Protocol for M2M Environments, Proc. IEEE 24th International Symposium on Personal, Indoor and Mobile Radio Communications: MAC and Cross-Layer Design Track, London, United Kingdom, 2013, 1609-1613.

[14]. S. Siddiqui and S. Ghani, ES-MAC: Energy Efficient Sensor-MAC Protocol for Wireless Sensor Networks, Proc. 10th IEEE International Conference on Networking, Sensing and Control (ICNSC), Evry, 2013, 28-33.

[15]. C. Tang, L. Song, J. Balasubramani, S. Wu, S. Biaz, Q. Yang and H. Wang, Comparative Investigation on CSMA/CA-Based Opportunistic Random Access for Internet of Things, Internet of Things Journal, IEEE, 1(2), 2014, 171-179.

[16]. W. Ye, W. Ye, J. Heidemann, and D. Estrin, An Energy-Efficient MAC Protocol for Wireless Sensor Networks, Proc. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Socities, INFOCOM, 3, 2002, 1567-1576.